Policy Brief

Silicon Twist

Managing the Chinese Military's Access to AI Chips

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June 2022

Executive Summary

Over the last five years, the Chinese People's Liberation Army (PLA) has made significant progress adopting artificial intelligence for combat and support functions. Chinese leaders broadly expect AI to usher in the "intelligentization" (智能化) of military affairs, characterized by ubiquitous sensor networks, more frequent machine-on-machine engagements, and a faster tempo of operations.[1]

But the PLA's progress in AI and related technologies largely depends on continued access to a special class of semiconductors—AI chips—which are used to train advanced machine learning systems. By analyzing 24 public contracts awarded by PLA units and state-owned defense enterprises in 2020, this policy brief offers a limited but detailed look at how the Chinese military comes to access these devices.

Despite more aggressive efforts by the Trump and Biden administrations to limit technology exports to the Chinese military, the PLA is placing orders for AI chips designed by U.S. companies and manufactured in Taiwan and South Korea. The authors of this policy brief consider alternative approaches that the United States could take to curtail Chinese military access to AI chips—such as a limited crackdown on Chinese military suppliers, or an embargo on AI chips exported to China. However, both of these options have serious limitations, and could prove counterproductive to U.S. national and economic security interests. Instead, the authors propose that the United States expand its collection of open-source intelligence and adopt new export control measures based on high-end chip features. Key findings include:

1. The PLA is placing orders for AI chips designed by U.S. companies and manufactured in Taiwan and South Korea.

- Of the 97 individual AI chips we could identify in public PLA purchase records, nearly all of them were designed by Nvidia, Xilinx (now AMD), Intel, or Microsemi.
- By comparison, we could not find any public records of PLA units or state-owned defense enterprises placing orders for high-end AI chips designed by Chinese companies, such as HiSilicon (Huawei), Sugon, Sunway, Hygon, or Phytium.

2. The U.S. government is limited in its ability to meaningfully constrain the sale of AI chips to specific end-users in China. A strategy based on end-user export controls is likely insufficient to limit Chinese military access to AI chips or broader progress in AI-related technologies.

- Difficulties associated with tracking AI chips and the variety of potential vendors would make it challenging for U.S. regulators to wage a targeted crackdown on the PLA's intermediary chip suppliers.
- The PLA often buys commercial off-the-shelf AI systems from Chinese academic institutions and private companies, which also buy U.S.-designed chips, and are not easily captured by U.S. restrictions on *military* end-users.

3. Effectively managing the PLA's access to AI chips will require a deeper understanding of China's defense industry and new forms of export control for technologies related to AI. For example, such controls could be based on the physical and technical characteristics of chips exported to China, rather than on their intended applications or end-users—but this regime would require buy-in from U.S. allies and partners to be effective.

- Abandoning end-user controls in favor of a more extreme policy, such as an embargo on chip exports to China, would alienate regional partners and jeopardize the long-term viability of the U.S. semiconductor industry.
- The United States could gain a better understanding of China's AI defense industry by expanding its collection and analysis of open-source information.

Ultimately, how the United States should best manage PLA chip access—or whether it should even attempt to do so—is a contentious issue that touches competing interests across U.S. industry and government. These questions involve too many unknown variables to answer confidently. But by carefully studying what limited information the Chinese military chooses to publish about its chip purchases, this report illuminates some of the barriers the United States faces in regulating this practice—and opportunities for reform.

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Introduction

Integrated circuits are found in every smartphone and personal computer on earth. They are systems comprising billions of transistors printed on silicon chips, capable of performing advanced calculations at impressive speeds. But not all microprocessors are made alike. The number of calculations that a chip is capable of computing is constrained by the number of its transistors—"basic computational devices that can be switched between on (1) and off (0) states."[2] Modern computer chip designs achieve remarkable density by placing transistors nanometers apart on the surface of a wafer—a distance smaller than most bacteria.[3]

"AI chips" are integrated circuits capable of processing computationally demanding artificial intelligence systems.[4] Generally speaking, there are three kinds of AI chips: graphics processing units (GPUs), field-programmable gate arrays (FPGAs), and certain application-specific integrated circuits (ASICs).[5] Different kinds of AI chips have advantages and disadvantages when it comes to either *training* a machine learning system, or using that system to make an *inference* about the world. But as prior CSET research indicates, only cutting-edge chips—generally considered today to be chips at the 12 nm node and below—are suitable to train and run cutting-edge neural networks. Older computer chips take too much time, sometimes months, and cost orders of magnitude more in electric bills.[6]

In light of the Chinese military's ambitious AI goals, AI chips are particularly important. They are discrete inputs to AI development, whose purchase bears directly on training and fielding AI systems, and which are theoretically controllable commodities. However, as this policy brief demonstrates, regulating the People's Liberation Army's (PLA) access to AI chips is easier said than done—especially since these processors are all-purpose commodities found in consumer goods and business solutions worldwide.[7]

Key Segments of the AI Chip Supply Chain

The AI chip supply chain is among the world's most complex and tightly integrated. In addition to the United States, allies and partners including Japan, the Netherlands, South Korea, and Taiwan house crucial steps in semiconductor design, fabrication, and testing processes.[8] With annual sales exceeding $600 billion, the global semiconductor market is highly competitive.[9] Key segments of the industry include basic research, followed by the production of electronic design automation (EDA) software and intellectual property (IP) that will be used to design a chip, as well as the production of semiconductor manufacturing equipment, procurement of materials, manufacturing of the chip itself (fabrication), assembly and testing of the chip, and finally distribution.[10]

For more than 30 years, China's leaders have aspired to wean the country off of its dependence on foreign-designed, foreign-produced chips.[11] The central Chinese government has poured tens of billions of dollars into all segments of the country's semiconductor industry, leading to an unprecedented 30 percent annual growth in sales since 2020.[12] Still, U.S. firms like Nvidia, Xilinx, and Intel dominate the international AI chip design market, while South Korea's Samsung and the Taiwan Semiconductor Manufacturing Company (TSMC) remain the titans of global semiconductor fabrication. High barriers to entry, including a reliance on intrinsic knowledge and highly specialized equipment, have so far prevented Chinese companies from catching up.

Current U.S. Efforts to Restrict PLA Access to AI Chips

In their efforts to limit Chinese military progress in AI, U.S. policymakers must balance absolute gains from trade and continued innovation in the semiconductor industry against relative gains in Chinese military power afforded by its AI chip purchases.[13] To achieve this balance, the U.S. government has attempted to limit Chinese military access to certain types of technology while leaving intact most sales between U.S. and Chinese businesses.

This tension between economic and security interests is reflected in the U.S. export control system, which encompasses but extends well beyond semiconductors destined for China. A plethora of statutes, rules, and regulations authorize the U.S. government to manage the export, re-export, or transfer of physical items, information, software, or services abroad—including AI chips. A more detailed summary of semiconductor-related export controls can be found in Appendix B. In short, the U.S. Department of Commerce may screen and approve or deny exports on the basis of:

- **The item itself** (list-based controls)—most notably, those goods and commodities listed on the Commerce Control List. Whereas FPGAs and certain AI ASICs are listed on the CCL and subject to export review, GPUs—the most common type of AI chip—are not.[14]

- **The intended use** (end-use-based controls)—such as terrorism, military and intelligence activities, and the development of weapons of mass destruction.

- **The intended user** (end-user-based controls)—most notably, those institutions listed in the U.S. Bureau of Industry and Security's (BIS) Entity List and Military End User List.

For chips manufactured in the United States, the federal government can directly restrict exports to foreign militaries and malign actors by invoking end-user-based controls, namely through the Entity List and denial orders placed on individual companies. Alternatively, if the chip is made abroad but contains a U.S. origin component, BIS may invoke the "foreign direct product rule" (FDPR) to prevent its export.[15] In practice, the United States has used the FDPR to restrict Taiwanese companies from exporting chips to China that were made using U.S.-origin manufacturing equipment or EDA tools. Moreover, in the interest of effectively limiting China's indigenous chip design industry, the United States and its allies can also place controls on the direct export of design IP to Chinese fabrication centers. For examples of additional regulatory actions taken against Huawei and other Chinese companies, see Appendix B.

While AI chip components, EDA tools, and manufacturing equipment play a crucial role in the earlier stages of designing and manufacturing an advanced chip, this brief focuses on regulating the supply of completed AI chips to the Chinese military and state-owned defense companies, and considers the role of list-based controls, end-user-based controls, and the FDPR in that effort.

Methodology and Scope

This policy brief examines Chinese military access to AI chips by analyzing purchasing information published by the PLA. CSET's corpus of Chinese military procurement tenders spans 66,321 records published between March 30 and December 1, 2020. These tender notices run the gamut from PLA requirements and requests for proposals to announcements of equipment or software contracts that were actually awarded to Chinese companies.[16] Of the 66,321 tenders in our dataset, 21,088 announce public contracts awarded to firms to supply the PLA with equipment, including software and electronic components.[17]

Several limitations constrain our analysis of PLA AI chip procurement:

First, our analysis is limited to unclassified PLA purchase records published between March 30 and December 1, 2020. By comparison, public metadata indicates that the PLA awarded at least two thousand confidential (秘密) or secret (机密) equipment contracts during this period of time, about which we know little. Any number of these contracts could be related to AI chips, and they are not captured in our analysis.

Second, each of these records represents a contract to purchase a certain piece of equipment. We could not verify that each chip was actually delivered to the PLA unit or Chinese defense company who ordered it. However, some of the vendors listed in our dataset are officially licensed partners and distributors of U.S. semiconductor companies in China, and would likely be able to fulfill these contracts.

Third, there is no consensus on the definition of an "AI chip." The very phrase is an imprecise term of art, and the specific chip models required to train advanced machine learning algorithms change constantly as technology improves. Moreover, while many GPUs, FPGAs, and ASICs are useful for training AI systems, these chips have other applications, such as gaming, complex simulation, modeling, and image processing programs.

Finally, only some PLA contract award notices specify the make and model of chips to be purchased; others merely indicate that PLA units are buying "microprocessors" or "computer chips" without offering any additional information. Our analysis takes a conservative approach, only considering contracts for clearly identified GPUs, FPGAs, and AI ASICs—and therefore represents only a portion of the PLA's public purchasing activity that may be related to AI chips.

Identifying AI Chip Purchases Made by the Chinese Military

This study attempts to classify PLA procurement projects related to AI chips by using keyword searches and manual disambiguation. We first searched for contracts with names that included any of 16 broad keywords: integrated circuit (集成电路), graphics card (显卡), graphics processing unit (图形处理单元 or 图形处理器), microchip (微芯片 or 芯片), microprocessor (微处理器), field-programmable gate array (现场可编程门阵列 or 现场可编程逻辑门阵列 or 现场可编程逻辑阵列), semiconductor (半导体), system on a chip (片上系统), core (芯), and the English-language abbreviations “GPU,” “FPGA,” “ASIC,” and “SOC.” Of the 21,088 publicly available contract awards in our dataset, 323 contained one or more of these phrases.

We then manually inspected each of these 323 chip-related contracts to determine whether the contract included GPUs, FPGAs, or ASICs which could be considered AI chips. Of the 323 chip-related contracts in our dataset, at least 24 (7 percent) were specifically for these three kinds of processors—that is, very high-end chips that might be used to train AI systems. By comparison, 141 contracts refer to “chips” or “integrated circuits” but do not offer any indication of a chip type, or whether it may be relevant to AI training or processing. It is possible that some of these contracts are for AI chips, but we have no way of knowing for certain.[18] The remaining 158 contracts are not for *AI chips*, but include other kinds of microprocessors, like central processing units (CPUs), or electronic components such as diodes and analog-to-digital converters.

Table 1: Number of Contracts Considered at Each Step of CSET Analysis

Type of Information	Number of Contracts
All public contracts in CSET’s corpus of PLA purchasing information.	21,088
Contracts containing chip-related keywords.	323
Contracts for GPUs, FPGAs, or AI ASICS (“AI chips”).	24
Contracts that specify a type or number of AI chips to purchase.	11

Source: CSET corpus of PLA purchasing activity.

Just 11 of the 24 AI chip contracts in our dataset specified a type or number of units to be purchased, accounting for a total of 97 individual chips. This is an extremely small sample, as high-end machine learning systems are typically trained on arrays spanning hundreds or thousands of AI chips.[19]

Any number of hypotheses could explain the exceedingly low volume of AI chips reflected in our dataset (0.1 percent of 21,088 public contracts specifically mention AI chips). One explanation could be that the PLA is not actually procuring that many AI chips to train machine learning systems itself, but prefers to buy "pretrained," commercial off-the-shelf systems from the private sector.[20] Indeed, like the U.S. military, the PLA tends to buy complete capabilities, not individual components required to assemble or train them. During the same period of time, for example, 343 public PLA contracts mentioned AI and related systems.[21] Previous CSET research has found these technologies rely intensively on U.S.-origin chips. Another explanation may be that the PLA is buying a large volume of AI chips for use in-house, but the largest orders are reflected in the 141 ambiguous "chip" contracts in our dataset, or articulated in the classified contracts, and are therefore not captured in our analysis.

As a whole, it is difficult to determine whether the low purchasing volume is an accurate reflection of PLA's behavior, or simply an artifact of our dataset and analytic approach. That said, given public reporting about the Chinese military's extensive surveillance programs and growing interest in AI, we assume that the PLA is purchasing many more AI chips—either directly or indirectly by buying systems that contain such chips—to sustain its advances in surveillance systems and smart weaponry.[22] The sample of 97 chips included in this study should be viewed as the proverbial tip of an iceberg.

Although we are able to identify only 97 chips, it is likely that other AI chips purchased by the PLA would be similar in origin and technical specification.[23] This is because, as previously noted, there are only a handful of companies in the world that specialize in designing these high-end AI chips, and the PLA has limited options of where to buy them: Chinese companies such as HiSilicon, Sugon, Hygon, Sunway, Phytium, and Jingjia Microelectronics currently occupy less than 1 percent of global market share in high-end CPU, GPU, FPGA, and ASIC design, where U.S. companies like Nvidia, Xilinx, and Intel dominate.[24]

Finding 1: The PLA Places Orders for U.S.-Designed AI Chips

The Chinese military enjoys access to high-end AI chips designed by U.S. companies and manufactured in Taiwan and South Korea. Of the 97 individual AI chips identified in our dataset, nearly all of them were designed by U.S.-based companies Nvidia, Xilinx, Intel, and Microsemi (see Table 2). In each case, PLA units and state-owned defense companies awarded contracts for U.S.-designed chips to Chinese intermediary companies.

Table 2: AI Chip Models Specified in Public PLA Contracts, April to November 2020

Device Type	Chip Model	Chip-Design Firm	Country of Chip-Design Firm	Quantity
GPU	Quadro RTX8000	Nvidia	United States	Not Specified
GPU	Tesla V100	Nvidia	United States	Not Specified
GPU	Titan V	Nvidia	United States	10
GPU	Jetson TX1	Nvidia	United States	4
FPGA	Kintex-7	Xilinx	United States	Not Specified
FPGA	Virtex-7	Xilinx	United States	2
FPGA	Not Specified	Xilinx	United States	24
FPGA	A3P400-PQG208I	Microsemi	United States	50
CPU[25]	Xeon Platinum 8260	Intel	United States	4
FPGA	JFM7K325T (clone of XC7K325T, Kintex-7)	Fudan Microelectronics / Xilinx	China/United States	1
FPGA	Not Specified	Not Specified	Not Specified	2

Source: CSET corpus of PLA purchasing activity (11 contracts specify a model of AI chip to purchase).

We searched for, but could not find, any records of PLA units or defense state-owned enterprises (SOEs) awarding contracts for Chinese-designed AI chips—such as those sold by HiSilicon (海思), Phytium (飞腾), Hygon (海光), Sugon (曙光), Sunway (双威), or Jingjia Microelectronics (景嘉微).[26] Of the 21,088 contracts in our dataset, 62 mention any of these six companies by name—either as vendors or as designers of equipment to be purchased from another company. Indeed, while most of the contracts mentioning these firms were for CPUs and other processors, none were for AI chips.[27]

That the Chinese military is placing orders for U.S.-designed AI chips is not necessarily surprising. Prior CSET research has highlighted that, nationwide, Chinese consumers import the overwhelming majority of AI chips from the United States, Taiwan, Japan, and South Korea.[28]

Finding 2: The PLA's Intermediary Suppliers are Rarely Named in U.S. Export Control Lists

Our analysis reveals 11 cases where intermediary companies based in China offered to sell U.S.-designed AI chips to Chinese military units or defense SOEs. Some of these intermediaries are officially licensed distributors for global semiconductor companies headquartered in the United States. Table 3 shows the seven intermediary suppliers identified in 11 of the most detailed AI chip contracts in our dataset.[29]

Table 3: Intermediary Suppliers of U.S.-Designed AI Chips Identified in Public PLA Contracts

Supplier Name (EN)	Supplier Name (CN)	AI Chip to be Supplied to PLA Unit or Defense Company	PLA Unit or Defense Company	Date of Contract Award
Beijing Lanyun Qifu Technology Co., Ltd.	北京蓝耘企服科技有限公司	Nvidia Quadro RTX8000	Chinese Academy of Military Sciences	09/25/2020
Beijing Hengsheng Technology Co., Ltd.	北京衡声科技有限公司	Nvidia TX1 and Xilinx Virtex7	China Aerospace Science and Technology Corporation	08/21/2020
SITONHOLY (Tianjin) Co., Ltd.	思腾合力（天津）有限公司	Nvidia Titan V	Academy of Military Sciences	04/23/2020
Xi'an Like Innovative Information Technology Co., Ltd.	西安丽科创新信息技术有限公司	Nvidia Tesla V100	PLA Strategic Support Force	10/29/2020

Hangzhou Changhui Electronic Technology Co., Ltd.	杭州昶晖电子科技有限公司	Xilinx Unspecified	China Aerospace Science and Technology Corporation	07/03/2020
Zhengzhou Hong'an Communications Technology Co., Ltd.	郑州宏安通讯科技有限公司	Xilinx Kintex-7	AVIC Optoelectronics Technology Co., Ltd.	10/19/2020
LINKZOL (Beijing) Technology Co., Ltd.	联众集群(北京)科技有限公司	Nvidia Unspecified	PLA Strategic Support Force	04/13/2020

Source: CSET corpus of PLA purchasing activity (seven vendors of U.S.-designed AI chips).

Some of the PLA's chip suppliers are officially licensed distributors of U.S. goods. For example, in April 2020, SITONHOLY won a contract to supply Nvidia-designed Titan V GPUs to the PLA Academy of Military Science.[30] On its website, SITONHOLY claims to be an "elite-level partner of Nvidia" and "officially authorized distributor of Nvidia products" in China—and the company is listed as a partner on Nvidia's website.[31] In addition to the PLA, SITONHOLY's clients apparently include 80 percent of universities in China working on AI.[32]

Some evidence indicates that the Chinese government and military are also using front companies to purchase AI chips from U.S. firms. For example, in August 2020, Beijing Hengsheng Technology Co., Ltd. won a contract to supply Nvidia TX1 and Xilinx Virtex7 processors to TSINGETECH (北京青翼凌云科技有限公司), a subsidiary of the China Aerospace Science and Technology Corporation that specializes in smart processors and high-performance computing.[33] The two email addresses listed as points of contact for Beijing Hengsheng Technology Co., Ltd. in public financial records are registered for dozens of other technology consulting companies based in Beijing.[34]

In some cases, U.S. semiconductor companies may not be aware that their products are ultimately destined for use by the Chinese military. Regardless, under the current U.S. export control system, it is likely that none of the AI chips sold to PLA units or defense companies would have required a license for export from the United States or any other government. Among the seven Chinese companies in our dataset selected to supply U.S.-designed AI chips to the PLA, none are named in the U.S. Commerce Department's Entity List or Military End User List. Moreover, most of the AI chip purchases in our dataset are for GPUs, which are not a controlled commodity. Finally, the U.S. "military end use" rule does not apply to foreign-made semiconductors shipped from outside the United States, even if they were designed in the United States. Except for some types of FPGAs covered by multilateral export control regimes, no other country specifically regulates semiconductor exports to China.

What to Do About It: Three Ways to Play a Dangerous Game

As the techno-security competition between the United States and China continues to evolve, three broad schools of thought describe how the United States should best govern Chinese military access to AI chips. Experts variously favor engaging in a targeted but protracted crackdown on intermediary suppliers (whack-a-mole); imposing extensive, blunt-force limitations on U.S.-China chip sales (pull the trigger); or continuing with the current, ad hoc approach to chip exports (stay the course). Each of these approaches carries distinct risks for U.S. national security and long-term economic competitiveness.

Whack-a-Mole

Faced with the reality that the Chinese military often finds ways to access U.S.-designed AI chips, U.S. policymakers may be tempted to play a very demanding game of "whack-a-mole" to crack down on its intermediary chip suppliers. By adopting a more aggressive—but still targeted—approach to export control, the United States could attempt to limit chip sales to the PLA and important military end-users while leaving intact joint civil and commercial AI research and the bulk of AI chip trade between the United States and China.

To be sure, the Trump administration created, and the Biden administration has maintained, new controls designed to curtail technology exports to military end-users in China.[35] In particular, the Trump administration expanded the China-specific "military end use" rule so that it applied to basic semiconductors, semiconductor production equipment, consumer electronics, civil aircraft parts, and other items unilaterally controlled for "anti-terrorism" reasons only.[36] One implication of the change was that items that previously did not require a license to be exported to China (or any other country other than Cuba, Iran, North Korea, or Syria) now need one if there "is knowledge" that it is destined for military applications or for a particular military end-user. The new military end-user rules, however, do not apply to items made outside the United States—even if they were created or designed using U.S.-origin technology or software—as is the case for most AI chips.

The last three U.S. presidential administrations have each placed restrictions on Chinese companies that have acted contrary to U.S. national security and foreign policy interests by placing them on the Department of Commerce's Entity List. The list now includes more than five hundred institutions based in mainland China.[37] But considering the size of the Chinese defense industrial base and the volume of cross-border trade with the United States, the U.S. approach to managing technology exports has been relatively limited. Prior CSET research found that a fraction of the PLA's AI vendors are named in key U.S. export control and sanctions regimes.[38] It bears repeating that none of the seven PLA AI chip suppliers identified in this study are named in either the U.S. Entity List or Military End User List.

In theory, the United States could make greater use of existing controls to prevent the PLA from purchasing U.S.-designed chips. For example, the Department of Commerce could add GPUs to the Commerce Control List, requiring a license to export the millions of GPUs sold from U.S. companies to China each year—but this would increase the number of license applications under its remit by several orders of magnitude, creating substantial workforce demands on top of existing logistical and resource constraints.[39] It could also expand the use of the National Security Foreign Direct Product Rule, prohibiting chips produced by TSMC or Samsung from being exported to Chinese military end-users; and endeavor to update its lists of Chinese military companies at considerable speed. To execute these objectives, Congress would need to drastically scale up resources for regulatory and enforcement agencies and bring the Department of Commerce into lockstep with the U.S. intelligence community.

Beyond the aforementioned logistical and political constraints, however, three issues make playing "whack-a-mole" with the PLA's AI chip distributors a challenging prospect:

First, chips themselves are hard to track. Although they are technically sophisticated, physical inputs to AI development, chips in transit do not carry an easily observable signature.[40] Even amid the global chip shortage, high-end GPUs are easily found on third-party websites like Alibaba, Amazon, and eBay, which account for tens of millions of dollars in aftermarket sales.[41] The "AI chips" described in this paper are widely available worldwide and predominately used in exclusively commercial applications.

*Second, the PLA can make use of a variety of intermediary suppliers to source AI chips***.** The 11 detailed contracts in our dataset were awarded to seven different companies, some of which are officially authorized U.S. chip resellers. So long as U.S. chip-design companies continue to rely on Chinese partners for licensing and distribution, they will continue to have little visibility into, or leverage over, the final destinations or end-uses of their products in China.

Finally, focusing narrowly on chip sales to the PLA misses the largest source of China's strength in AI—algorithms developed, trained, and sold by private industry. As previously noted, the PLA likely prefers to contract companies that offer completed or easily customizable off-the-shelf AI systems rather than the individual components required to assemble them in-house. Due, in part, to the Chinese Communist Party's military-civil fusion (军民融合) strategy, U.S. regulators have struggled to distinguish between military and nonmilitary end-users in China.[42] A policy framework that focuses narrowly on limiting chip sales to the PLA and major defense SOEs risks leaving China's burgeoning AI defense industry intact, and would minimally affect the quality of systems and services sold to the PLA.[43]

Given the difficulty in tracking chips, the variety of potential intermediaries, and the murky line between civil and military end-users in China, there are reasons to doubt that even an optimally executed "targeted approach" would meaningfully constrain the PLA's access to AI chips or progress in AI-related technologies.

Pull the Trigger

Given the challenges associated with limiting chip sales to specific end-users, U.S. policymakers may be tempted to adopt drastic measures to restrict AI chip sales to China. So far, the United States has coordinated with the Taiwanese and South Korean governments to prevent Chinese chip-design companies from licensing fabrication through TSMC and Samsung.[44] In an extreme scenario, the Department of Commerce could invoke the foreign direct product rule on all *U.S.-designed* AI chips (defined as the 12 nm-node generation or better) fabricated overseas and bound for mainland China—irrespective of their intended application or end-user. Throughout January 2022, the Biden administration publicly signaled that it was considering an expansive use of the FDPR to deter Russia's invasion of Ukraine.[45] Then, on February 25, 2022, President Biden authorized an outright embargo on U.S.-designed chip exports to Russia.[46]

Experts hold mixed opinions about the prospect of banning AI chip sales to China. Given China's whole-of-government push to build an indigenous chip manufacturing industry, some experts question whether the United States would be capable of maintaining Chinese dependence on U.S. chips in the medium- to long-term future. Others view U.S.-Chinese economic interdependence as a vulnerability, and contend that the Chinese government could hold undue influence over U.S. semiconductor companies.

In theory, an AI chip embargo could temporarily disrupt the Chinese military's development of AI for combat and support applications. But to make an impact, it would have to be invoked well in advance—while China's indigenous chip production capacity is still limited—rather than in response to a crisis.

Moreover, such a move risks alienating U.S. partners in Taiwan and South Korea. Indeed, it would be extremely difficult to persuade leaders in Taipei and Seoul to sign onto such a drastic step—especially since the latter already struggles to navigate the contentious relationship between Washington and Beijing.[47] It is difficult to overstate the significance of TSMC and Samsung as strategic assets for Taiwan and South Korea, respectively, and their political leaders would likely resist U.S. efforts to impose an embargo that may harm their economic and political standing.[48]

Looking domestically, suddenly adopting an embargo on AI chip exports could have severe and potentially catastrophic consequences for the U.S. semiconductor industry and long-term technological innovation. The Chinese market accounts for 25 percent of global AI chip consumption, with AI chips sold to China in 2021 amounting to an estimated value between $2.5 billion and $5 billion.[49] Annual U.S. Securities and Exchange Commission filings imply that an all-out embargo would equate to billions of dollars in annual losses for U.S. chip-design firms (see Table 4).[50]

Table 4: Select U.S. Semiconductor Company Revenues from China (billions of USD)

Company	2018	2019	2020	2021	Percent of Net Revenue Derived from China (last year of data)
Xilinx[51]	N/A	$0.9B	$0.9B	$1.0B*	32%
Nvidia[52]	N/A	$2.8B	$2.7B	$7.1B	26%
AMD[53]	$1.3B	$1.7B	$2.3B	$4.1B	25%
Intel[54]	$18.8B	$20.0B	$20.3B	$21.1B	27%

Source: Companies' annual 10-K filings to the U.S. Securities and Exchange Commission—see endnotes in column 1. * Xilinx 2021 revenues are projected.

One solution could be to provide U.S. companies with viable alternatives to the Chinese market. The CHIPS for America Act of 2022 offers significant incentives for semiconductor companies to construct fabrication facilities in the United States.[55] But the real challenge would be whether, or how, to compensate for the loss of Chinese market access. Even with carefully calibrated incentives and a more robust industrial policy, some experts warn that eliminating this source of revenue could have dire consequences for U.S. innovation and economic competitiveness.[56]

Beyond the political and economic costs of enforcement, there is a question about optimal timing, beyond which "pulling the trigger" would prove ineffective or counterproductive to U.S. security interests. An embargo enacted too early would allow the Chinese military to find alternative ways to source advanced semiconductors, and likely elevate its national push for chip indigenization.[57] Enacted too late, an embargo would do little to blunt the PLA's most relevant technological advances—especially as China progresses with indigenous chip design and fabrication.[58]

Stay the Course

Given the logistical problems with waging a targeted crackdown on intermediaries, and the political and economic costs of enforcing an embargo, the United States is more likely to "stay the course" in its approach to Chinese military AI chip access than to embark on a substantively different policy path.

Though counterintuitive, there are also some reasons why the U.S. government may want to continue allowing the Chinese military to purchase advanced AI chips. One argument is that the United States should pursue a "leaky-faucet strategy" when it comes to AI chip exports. By permitting the Chinese military to access *enough* AI chips to function and modernize, U.S. policymakers can undermine proposals to pour even more money into China's indigenous chip industry, while gaining some marginal insight into the structure of the Chinese defense industry. But expert opinion on this issue is mixed. In discussions with this report's authors, some experts found it difficult to believe that China's push for semiconductor indigenization has left any stone unturned. One former U.S. official argued that "gaining marginal insight" into how the Chinese military procures AI chips is a poor rationale for allowing their continued access.

Second, semiconductors remain one of the United States' few sources of leverage amid the deteriorating U.S.-China relationship. For example, in a truly dire crisis, U.S. senior leaders could threaten to prohibit AI chip sales to China in the hopes of heading off a military engagement in the South China Sea or similarly destructive activity. Expert opinion on this issue is also mixed. While some believe that threatening chip supplies could pressure Chinese decisionmakers to walk back from the brink of crisis, others argue that Chinese political leaders would likely have already priced in the loss of semiconductor imports, were they to stage an attack against Taiwan or another U.S. partner. Notably, threatening chip supplies to Russia in early 2022 failed to deter its invasion of Ukraine. Chinese political leaders are acutely aware of their dependency on the United States for AI chips and a bevy of other chokepoint (卡脖子) technologies—but actually "pulling the trigger" would irrevocably sacrifice this deterrent, and would have to be executed at the right time—which is difficult to predict—to materially impact the PLA's warfighting capability.[59]

Another Path?

Each of the three approaches outlined above carries distinct risks, and is unlikely to meaningfully inhibit Chinese military progress in AI. The bottom line is that, if U.S. policymakers want to more effectively manage PLA access to AI chips, then they will need to fundamentally rethink the legal authorities and attitudes that underpin U.S. export control and intelligence collection.

First, restricting Chinese military access to AI chips will require new and creative approaches to export control. One path forward could include a tailored set of new, technology-based export controls that are applied plurilaterally.[60] The U.S. Export Control Reform Act of 2018 requires that the Department of Commerce identify and control "emerging and foundational technologies" essential to U.S. national security, which are not already covered by existing multilateral export control regimes. Under ECRA, the Department of Commerce could identify specific types of chips (including high-end GPUs), which are relevant to training AI systems, and coordinate with partners to screen intended end-users and prevent their export. The Department of Commerce could likewise expand the U.S. "military end user" rules and apply them to exports of otherwise uncontrolled chips, if they are being used for AI-related research or other applications within China.

Second, to better understand and track commercial connections to China's defense-industrial base, the U.S. government can expand its collection and analysis of open-source, Chinese-language information. This brief identified seven Chinese military vendors which are not listed in U.S. end-user export control regimes. There is room for open-source analysis to address other security challenges. A previous CSET memo outlined that "the Intelligence Community (IC) has not emphasized open-source intelligence (OSINT), and other potential 'sponsors' (e.g., DoD, DoE) have failed to develop robust open-source capabilities."[61] This is due in part to restrictions imposed by Title 50 authorities, which inhibit the intelligence community from sharing information with both governmental and nongovernmental actors.[62] One solution could be to establish an Open Translation and Analysis Center, which would be located outside of the intelligence community and dedicated, in part, to studying China's defense industry and broader innovation base.[63]

Conclusion

Despite efforts by the Trump and Biden administrations to limit the Chinese military's access to U.S.-origin technology, the PLA is placing orders for U.S.-designed AI chips, which are crucial for its progress in AI and broader military modernization. Public equipment contracts indicate that the Chinese military purchases U.S.-origin equipment through intermediaries, including both officially licensed distributors and shell companies, not directly from U.S. semiconductor vendors.

This policy brief also assessed two potential alternatives to restrict PLA chip access, pursuant to the existing U.S. export control system: a targeted crackdown on the PLA's intermediary suppliers, and an embargo of AI chips. We assess that each of these alternatives would be less viable than the United States' current approach to managing PLA chip access, and could prove counterproductive to U.S. economic and national security interests.

The problem with a targeted crackdown is that PLA purchasing habits fundamentally challenge core tenets of the U.S. export control framework, which are predicated on limiting sales to known military end-users or for intended use in military and intelligence activities. By comparison, a country-wide AI chip embargo could overcome some of the mechanisms by which the PLA gains access to AI chips, and could temporarily limit its progress in AI and related technologies. However, actually enforcing such an embargo would come with steep political and economic costs, and may cause ricochet effects that damage the U.S. semiconductor industry, alienate U.S. partners in the region, and backfire against long-term U.S. innovation and technological competitiveness.

Ultimately, effectively limiting Chinese military progress in AI and other cutting-edge technologies will require the U.S. government to adopt novel forms of export control, which extend well beyond the current focus on visible end-uses and end-users. At the same time, the U.S. government should seek to improve its own situational awareness by better harnessing open-source information and sharing relevant export information with allies and partners.

Disclaimer

The mention of any individual, company, organization, or other entity in this report should not be construed to imply the violation of any law or international agreement.

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Acknowledgments

This report would not have been possible without the input of Will Hunt, who aided in U.S. semiconductor industry analysis and revised multiple drafts, as well as Jennifer Melot, who facilitated data collection, and Ben Murphy, who provided translation support. The authors are especially grateful to Caolionn O'Connell, Matt Turpin, John VerWey, and Kevin Wolf for their comprehensive reviews. The authors thank Alex Stephenson for research support.

The authors would also like to thank Catherine Aiken, Shelton Fitch, Igor Mikolic-Torreira, Margarita Konaev, Drew Lohn, Matt Mahoney, Dewey Murdick, Lynne Weil, and Emily S. Weinstein for their suggestions on style and content.

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Document Identifier: doi: 10.51593/20210068

Appendix A: Chinese Military Purchasers of AI Chips

Unsurprisingly, the PLA Strategic Support Force—the military branch dedicated to cyber, space, and electronic warfare—is the largest purchaser of AI chips in our dataset, followed by the Academy of Military Sciences, which conducts military-related AI research.

Table 5: Public AI Chip Contracts Awarded by PLA Units and Defense SOEs or Their Subsidiaries, April–November 2020

Entity (EN)	Entity (CH)	Total No. AI Chip Contracts
Strategic Support Force	战略支援部队	11
Academy of Military Sciences	军事科学院	6
CASC	中国航天科技集团有限公司	4
AVIC Jonhon Optronic Technology Co., Ltd.	中航光电科技股份有限公司	2
Navy	海军	1
Total		24

Source: CSET corpus of PLA purchasing information (24 contracts for AI chips).

Appendix B: Summary of Export Controls Pertaining to Semiconductors

Several layers of U.S. export control apply to certain types of semiconductor devices bound for China. Broadly speaking, these include controls on certain *end uses* of chips (i.e., for military activities or the development of weapons of mass destruction), *end users* of chips (i.e., institutions known to be involved in military activities or human rights abuses), and *types* of chips (i.e., chips that meet certain technical specifications, like radiation-hardened chips or microwave power amplifiers). The United States has also adopted varying degrees of *extraterritorial* controls (i.e., chips made or designed using U.S.-origin components or software). In addition to U.S.-imposed controls, *multilateral* export control frameworks apply varying degrees of control based on intended end-use. The following paragraphs summarize these controls as they apply to semiconductors.

All U.S.-origin semiconductors of any type or capability that are designed or in any way modified for any type of military, intelligence, or space application, sensitive or otherwise, are subject to worldwide controls. Such chips are embargoed for export from the United States or reexport from third countries to China, directly or indirectly, regardless of end use or end user.

Allied countries that are members of the Wassenaar Arrangement control for export from their countries such chips, regardless of the chip's country of origin. The license policies on exports of non-U.S.-made chips are inconsistent. Nonetheless, most nations generally prohibit the export of bespoke chips to China that are used for overt military applications. Taiwan is not a member of the Wassenaar Arrangement, but it is an adherent, meaning that it imposes the same controls. South Korea is also a member of the Wassenaar Arrangement.

Extraterritorial Controls

Any foreign-produced chip of any sort or capability that is designed or modified for any type of military, intelligence, or space application that is produced or designed, in whole or in part, from U.S.-origin technology or software is subject to U.S. extraterritorial controls. The export or reexport of such chips to China, directly or indirectly, is prohibited, regardless of end use or end user.

A foreign-produced item of any type anywhere outside the U.S. that incorporates any amount or percentage of such chips is subject to U.S. extraterritorial controls and completely embargoed for shipment to China regardless of end use or end user. This is known as the "see-through" rule (in the ITAR) or the "zero de minimis" rule (in the

EAR). Such chips, whether U.S.- or foreign-produced, “taint” any foreign-produced item of any sort into which they are incorporated.

The installation onto any type of chip, regardless of origin or type, of U.S.-origin software or software produced from U.S.-origin technology or software that is directly related to or required for a military or intelligence item of any nationality causes the chip to become subject to U.S. export controls. The export and reexport of such chips (because of the software installed on them) is embargoed for export to China.

U.S. persons and U.S. companies are prohibited from providing services from the United States or from a third country to anyone in China or any Chinese national regardless of location. This is true in cases where the services would in any way assist in the development, production, or use of a chip designed or modified for any type of military or intelligence application. This is also true even if all of the technology, software, and underlying commodities are of foreign origin, and otherwise commercial and uncontrolled.

U.S. persons and U.S. companies are also prohibited from providing services involving any type of semiconductor (or other item) if in support of the creation of weapons of mass destruction or military-intelligence efforts in China.

Chips that are in any way designed or modified for missile, chemical/biological, or nuclear applications are generally subject to equally broad controls by the United States and the members of the other three multilateral export control regimes.

All U.S.-origin “dual-use” chips controlled for “national security” reasons are controlled for export from the United States, or reexport from third countries, to China, regardless of end use or end user. Such chips are those that are not designed or modified for military applications, but the Wassenaar Arrangement allies have decided nonetheless have material utility for military applications. Such chips are summarized below. They have Export Control Classification Numbers (ECCNs) with a “0” in the middle. The United States and Wassenaar allies endeavor to update this list each year.

The United States and the Wassenaar allies deny such exports if, after reviewing the application, they determine there is a risk the chip will be diverted to a military application. The United States is generally more risk averse than its allies with respect to such assessments, which results in an unlevel playing field between U.S. companies and their competitors in Wassenaar countries. The United States also applies a broader “national security” standard for civil applications that could support China’s military modernization efforts, even if indirectly.

All extreme ultraviolet (EUV) lithography tools and their parts and components are controlled for “national security” reasons. EUV tools are specific to advanced node chips. Many types of advanced etch and deposition tools are also specific to advanced node chips for the same reason, although most are not because they are node agnostic.

Most EDA tools are not specific to advanced node chips because they are agnostic as to the type of chip designed. (The control is on the technology that is the design for the chip.) The Wassenaar allies, however, agreed in December 2021 to control as “national security” items EDA software that specially design for the development of chips with a Gate All Around Field Effect Transistor infrastructure. Such software is unique to design advanced node semiconductors, but there are questions about how much such software actually exists (since it tends to be node agnostic or not specific to GAAFET).

Foreign-produced dual-use chips that are controlled for such “national security” reasons are subject to U.S. extraterritorial export controls if they are produced directly for U.S.-origin technology or software that is also subject to “national security” controls. This is the original foreign direct product rule, and is now called the “National Security FDP rule.”

Foreign-produced chips that are not controlled for “national security” reasons are subject to the Export Administration Regulations (EAR) if produced from U.S. software, technology, or equipment and destined to anyone if a Huawei company is involved.

With few exceptions, commercial chips that are (i) basic and not designed or modified for military applications and (ii) not controlled for “national security” or other regime-based reasons are prohibited without a license (which is rarely granted) for export from the United States or reexport from third countries if U.S.-origin if:

- The end user is on the Entity List, Denied Persons List, Military End User List, Military-Intelligence End User List, or the Specially Designated Nationals and Blocked Persons List; or
- The exporter or reexporter has “knowledge” (which is broader than actual knowledge) that the:
    - end user in China, even if unlisted, is a “military end user,” which is defined broadly to include situations even when the company provides any support of any amount for military activities, even if all its other activities are purely civil;
    - end use in China would be for a “military end use,” which is to support military items even if the item was not originally designed for military applications;

- the end use in China is a “military-intelligence end use;” or
- the end user in China is a “military-intelligence end user.”

Such chips are referred to in the EAR as being controlled for “anti-terrorism reasons” only. These controls were created over basic chips decades ago. The list of such chips––which are generally in ECCN 3A991 on the Commerce Control List (and restated, in part, in Supp. No. 2 to Part 744)—has been repurposed to attach the end use and end user controls described above.

- Until the allied response to Russia’s invasion of Ukraine, these end-use and end-user controls were completely unilateral, meaning no other country had such controls. A growing group of more than 30 countries have adopted their own controls on exports to Russia of basic semiconductor and other items that have historically been unilaterally controlled only by the United States.
- Whether the allies have the authority and political will to create such controls against other countries, such as China, is a current topic of debate.[64]

The military end-use/end-user controls also apply to the export of virtually all types of semiconductor design (e.g., EDA) and production tools (e.g., etch, deposition, inspection, and metrology). These end-use/end-user controls are also completely unilateral.

The “dual-use” chips controlled for “national security” reasons (i.e., Wassenaar items) are in Category 3 of the Department of Commerce’s Control List. Relevant chips include the following characteristics:

- radiation-hardened (3A001.a.1)
- temperature-hardened (3A001.a.2)
- compound semiconductors that operate at a clock frequency exceeding 40 MHz (3A001.a.3)
- analog to digital converters with specific capabilities (3A001.a.5)
- electro-optical chips designed for signal processing (3A001.a.6)
- FPGAs that have a maximum number of single-ended digital inputs/outputs of greater than 700 or an aggregate one-way peak serial transfer data rate of greater than 500 5G/s or greater (3A001.a.7) (This standard catches most modern FPGAs.)
- “neural network integrated circuits,” which is an undefined term (3A001.a.9)
- 4A004 controls “neural computers,” which are defined as “computational devices designed or modified to mimic the behavior of a neuron or collection of neurons. . . ”

- Custom integrated circuits for which the function is unknown and the chip as basic characteristics (3A001.a.10)
- Digital integrated circuits based on compound semiconductors with certain capabilities (3A001.a.11)
- Fast fourier transform processors with specific capabilities (3A001.a.12)
- Direct digital ICs with specific capabilities (3A001.a.13)
- Chips that perform analog-to-digital conversions that have particular capabilities (3A001.a.14)
- Vacuum electronic devices with specific characteristics (3A001.b.1)
- Monolithic Microwave Integrated Circuits with specific characteristics (3A001.b.2)
- Discrete microwave transistors with specific characteristics (3A001.b.3)
- Microwave sold state amplifiers with specific characteristics (3A001.b.4)
- Electronically or magnetically tunable band-pass filters with specific characteristics (3A001.b.5)
- Converters and harmonic mixers (3A001.b.6)
- Microwave power amplifiers and modules with specific characteristics (3A001.b.7, b.8, b.9)
- Oscillators with specific characteristics (3A001.b.10)
- Frequency synthesizer electronic assemblies with specific characteristics (3A001.b.11)
- Transmit/receive modules of various types (3A001.b.12)
- Acoustic wave devices with specific characteristics (3A001.c)
- Chips made from superconductive materials with specific characteristics (3A001.d)

Until the allied response to Russia's invasion of Ukraine was set into effect, the United States had for decades unilaterally controlled the types of semiconductors listed below. They are among the types of items covered by the Military End Use rule, which means that if the exporter of such items from the United States has knowledge that they will be for a military end use or a military end user in China (and a few other countries), then a license would be required. In essence, they are the following:

- Integrated circuits that have performance speed of 5 GFLOPS or more and an arithmetic logic unit with an access width of 32 bit or more (3A991.a.1); a clock frequency rate exceeding 25 MHz (3A991.a.2); or more than one data or instruction bus or serial communication port that provides a direct external interconnection between parallel "microprocessor microcircuits" with a transfer rate of 2.5 Mbyte/s (3A991.a.3).
- Storage integrated circuits, that:

    - Are electrical erasable programmable read-only memories (EEPROMs) with a storage capacity (3A991.b.1);
    - Exceed 16 Mbits per package for flash memory types (3A991.b.1.a); or
    - Exceed 1 Mbit per package; or exceed 256 kbit per package and a maximum access time of less than 80 ns. (3A991.b.1.b)
- Static random access memories with a storage capacity exceeding 1 Mbit per package or exceeding 256 kbit per package and a maximum access time of less than 25 ns. (3A991.b.2)
- Analog-to-digital converters having a resolution of 8 bit or more, but less than 12 bit, with an output rate greater than 200 million words per second (3A991.c.1); a resolution of 12 bit with an output rate greater than 105 million words per second (3A991.c.2); a resolution of more than 12 bit but equal to or less than 14 bit with an output rate greater than 10 million words per second (3A991.c.3); or a resolution of more than 14 bit with an output rate greater than 2.5 million words per second (3A991.c.4)
- Field programmable logic devices having a maximum number of single-ended digital input/outputs between 200 and 700 (3A991.d)
- Fast Fourier Transform processors having a rated execution time for a 1,024 point complex FFT of less than 1 ms (3A991.e)
- Custom integrated circuits for which either the function is unknown, or the control status of the equipment in which the integrated circuits will be used is unknown to the manufacturer, having more than 144 terminals; or a typical "basic propagation delay time" of less than 0.4 ns. (3A991.f)

Endnotes

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[10] To learn more about individual semiconductor components and U.S. policies governing their export, please refer to Khan, "Securing Semiconductor Supply Chains."

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[13] This balance is exhibited in friction in the U.S. policy process, which extends well beyond AI chips: In her speech outlining a "New Approach to the U.S.-China Trade Relationship," U.S. Trade Representative Katherine Tai underscored that "Our objective is not to inflame trade tensions with China. Durable coexistence requires accountability and respect for the enormous consequences of our actions," https://ustr.gov/about-us/policy-offices/press-office/speeches-and-remarks/2021/october/remarks-

prepared-delivery-ambassador-katherine-tai-outlining-biden-harris-administrations-new. By comparison, National Security Advisor Jake Sullivan has argued that "we have to work closely and especially closely with our partners on our export control and investment screening regimes to make sure they are postured for intense technology competition," https://www.whitehouse.gov/nsc/briefing-room/2021/07/13/remarks-by-national-security-advisor-jake-sullivan-at-the-national-security-commission-on-artificial-intelligence-global-emerging-technology-summit/. Popular reporting has outlined some of the Biden administration's competing equities on China policy. See Bob Davis, "Biden Promised to Confront China. First He Has to Confront America's Bizarre Trade Politics," *POLITICO*, January 31, 2022, https://www.politico.com/news/magazine/2022/01/31/biden-china-trade-politics-00003379; and Hans Nichols, "Scoop: Inside Biden aides' China fight," *Axios*, January 30, 2022, https://www.axios.com/biden-aides-china-spat-85a34544-36d7-4b8e-b564-3da14dddabc2.html. This is to say nothing about security-minded pressure from Capitol Hill. "Cotton, Colleagues Call on Department of Commerce to Implement Export Control Laws or Risk Losing Export Control Authority," Office of U.S. Senator Tom Cotton, June 15, 2021, https://www.cotton.senate.gov/news/press-releases/cotton-colleagues-call-on-department-of-commerce-to-implement-export-control-laws-or-risk-losing-export-control-authority.

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[15] Khan, "Securing-Semiconductor Supply Chains."

[16] For a more detailed explanation of procurement in the Chinese military and the contents of this dataset, see Ryan Fedasiuk, Jennifer Melot, and Ben Murphy, "Harnessed Lightning: How the Chinese Military is Adopting Artificial Intelligence," Center for Security and Emerging Technology, October 2021, https://cset.georgetown.edu/publication/harnessed-lightning/.

[17] These include winning bid announcements (中标公告) and single-source procurement awards (单一来源公示 or 单一来源公告).

[18] While we believe many of these contracts are likely for CPUs and distinctly non-AI chips, it is possible that some of them actually do account for AI chips, which would not be detected in our analysis.

[19] The applied research lab OpenAI trained GPT-3, the world's most sophisticated language transformer at that time, on a supercomputer that featured 285,000 CPU cores, ten thousand GPUs, and four hundred gigabits per second of network connectivity. Jennifer Langston, "Microsoft announces new supercomputer, lays out vision for future AI work," Microsoft, May 19, 2020, https://blogs.microsoft.com/ai/openai-azure-supercomputer/.

[20] Fedasiuk, Melot, and Murphy, "Harnessed Lightning."

[21] Fedasiuk, Melot, and Murphy, "Harnessed Lightning."

[22] In 2021, Huawei trained Pangu-Alpha, its GPT-3 competitor, on more than 2,000 of its own Ascend 910 AI chips. Wei Zeng et al, "PanGu-α: Large-scale Autoregressive Pretrained Chinese Language Models with Auto-parallel Computation," arXiv:2104.12369 [cs.CL].

[23] Khan, "Securing Semiconductor Supply Chains."

[24] Saif M. Khan, Alexander Mann, and Dahlia Peterson, "The Semiconductor Supply Chain: Assessing National Competitiveness," Center for Security and Emerging Technology, January 2021, https://cset.georgetown.edu/wp-content/uploads/The-Semiconductor-Supply-Chain-Issue-Brief.pdf.

[25] Intel's Xeon 8260 is an extraordinarily sophisticated 24-core CPU designed to run data-intensive tasks, and is considered an AI chip.

[26] "AI chips" are defined here as GPUs, FPGAs, and ASICs designed for AI training or inference. Typically these logic chips are manufactured using a 12 nm node process or better.

[27] For example, Jingjia Microelectronics won contracts to supply 240 MWG122 GPUs to the Aviation Industry Corporation of China, and an unknown number of G6112 GPUs to the China Aerospace Science and Technology Corporation. Both of these are low-end processors not suitable for training machine learning applications.

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[30] Information available upon request.

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[32] "About Us," SITONHOLY.

[33] Information available upon request.

[34] "Beijing Hengsheng Technology Co., Ltd.," financial records and registry information made available by Kanzhun, accessed January 2022, https://perma.cc/NW6A-WJSX. The company is registered to the Modern Manufacturing Technology Industrial Park of Beijing Academy of Science and Technology (北京市科学技术研究院现代制造技术产业园部分企业). According to public financial records, the company's legal representative and sole shareholder is Tian Haitao (田海涛). This may be the same Tian Haitao who is the deputy director of Henan Province's Department of Industry and Information Technology. Tian leads inspections of semiconductor companies in Henan Province, and makes frequent visits to Beijing: "Tian Haitao, deputy director of the Henan Provincial Department of Industry and Information Technology, led a team to investigate and guide the Provincial Electronic Quality Inspection Institute" [河南省工业和信息化厅副厅长田海涛带队调研指导省电子质检院], Sohu post, November 10, 2021, https://perma.cc/3PY9-YS5K.

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[36] 85 Fed. Reg. 23459 (Apr. 20, 2020), https://www.bis.doc.gov/index.php/documents/regulations-docs/federal-register-notices/federal-register-2020/2545-85-fr-23459/file.

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[38] Fedasiuk, Melot, and Murphy, "Harnessed Lightning."

[39] The U.S. Bureau of Industry and Security currently processes about forty thousand export license applications each year. By comparison, millions of GPUs are sold to Chinese customers. "Annual Report to Congress for Fiscal Year 2020," U.S. Department of Commerce Bureau of Industry and Security (BIS), https://www.bis.doc.gov/index.php/documents/pdfs/2711-2020-bis-annual-report-final/file.

[40] Paul Mozur and Don Clark, "China's Surveillance State Sucks Up Data. U.S. Tech Is Key to Sorting It," *New York Times*, January 20, 2021, https://www.nytimes.com/2020/11/22/technology/china-intel-nvidia-xinjiang.html.

[41] Michael Kan, "Scalpers Have Sold 50,000 Nvidia RTX 3000 GPUs Through eBay, StockX," *PCMag*, January 27, 2021, https://www.pcmag.com/news/scalpers-have-sold-50000-nvidia-rtx-3000-gpus-through-ebay-stockx.

[42] William Alan Reinsch, "Unpacking Expanding Export Controls and Military-Civil Fusion," Center for Strategic and International Studies, May 14, 2020, https://www.csis.org/analysis/unpacking-expanding-export-controls-and-military-civil-fusion; and Alex Stone and Peter W. Singer, "China's Military-Civil Fusion Strategy: What to Expect in the Next Five Years," *Defense One*, February 18, 2021, https://www.defenseone.com/ideas/2021/02/china-military-civil-fusion-strategy-next-five-years/172143/.

[43] For one example, the PLA Ground Force has awarded contracts to one of China's largest enterprise AI companies, 4Paradigm. See Ellen Nakashima and Jeanne Whalen, "Biden administration concerned about U.S. investments in Chinese tech companies with military or surveillance ties," *Washington Post*, December 16, 2021, https://www.washingtonpost.com/national-security/us-investments-china-biden/2021/12/15/835876a0-5772-11ec-a808-3197a22b19fa_story.html.

[44] In April 2021, U.S. Senators Tom Cotton and Michael McCaul called on the Commerce Department to expand this practice: https://www.cotton.senate.gov/imo/media/doc/edaletter.pdf.

[45] Ellen Nakashima and Jeanne Whalen, "U.S. threatens use of novel export control to damage Russia's strategic industries if Moscow invades Ukraine," *Washington Post*, January 23, 2022, https://www.washingtonpost.com/national-security/2022/01/23/russia-ukraine-sanctions-export-controls/; and Jeffrey J. Schott, "Will tough U.S. sanctions deter Russian aggression in Ukraine?," Peterson Institute for International Economics, February 1, 2022, https://www.piie.com/blogs/realtime-economic-issues-watch/will-tough-us-sanctions-deter-russian-aggression-ukraine.

[46] This embargo not only applies to exports of 3A991 and other "anti-terrorism" items destined to Russia (or Belarus), but it also applies to foreign-produced semiconductors produced from U.S. technology, software, or tools. All such items are prohibited for export to Russia, with few exceptions. Foreign-made semiconductors and other items not identified on the U.S. Department of Commerce's Control List are prohibited for shipment from outside the United States to Russia if there would be a military end use or military end user involved. Unlike China-specific unilateral controls imposed by the United States, more than 30 allies agreed to impose controls on exports to Russia from their countries of semiconductors and other items that had previously only been controlled for export by the United States. See Eamon Barrett, "Russia buys 70% of its chips from China, but the U.S.'s blockade of American semiconductors will still hit Putin hard," Fortune, February 25, 2022, https://fortune.com/2022/02/25/biden-ban-chip-semiconductors-exports-russia-ukraine/.

[47] Tobias Harris, Abigail Bard, and Haneul Lee, "The China Difference in the U.S.-South Korea Alliance," Center for American Progress, December 14, 2021, https://www.americanprogress.org/article/the-china-difference-in-the-u-s-south-korea-alliance/; and Ryan Fedasiuk, "Strengthening the U.S.-ROK Technology Alliance," Sejong Institute, December 3, 2021, https://koreaonpoint.org/view.php?page=3&idx=61.

[48] Some reviewers were more optimistic that Taiwan and South Korea could be persuaded to adopt an embargo, "particularly if other electronics manufacturing opportunities open up." One reviewer pointed out that "the market for these chips is very liquid," and argued that "chips wouldn't go unsold since demand exceeds supply."

[49] We thank Will Hunt and John VerWey for their contributions to this analysis. This number is also expected to increase quickly over time as the market for AI chips grows. By comparison, Russian consumption accounts for a much smaller share of the global AI chip market.

[50] Some experts are skeptical of this claim, noting the magnitude of the global chip shortage. One reviewer commented that "these chips will not go unsold."

[51] Xilinx 10-K filing, https://investor.xilinx.com/static-files/3f77caaa-e0e9-4e8a-a2ee-3f40d4536bd9. Accessed April 1, 2022.

[52] NVIDIA 10-K filing, https://www.sec.gov/ix?doc=/Archives/edgar/data/0001045810/000104581022000036/nvda-20220130.htm. Accessed April 1, 2022.

[53] AMD 10-K filing, https://www.sec.gov/ix?doc=/Archives/edgar/data/2488/000000248822000016/amd-20211225.htm. Accessed April 1, 2022.

[54] Intel 10-K filing, https://www.intc.com/filings-reports/all-sec-filings?form_type=10-K&year=#document-5130-0000050863-22-000007-2. Accessed April 1, 2022.

[55] Will Hunt, "Sustaining U.S. Competitiveness in Semiconductor Manufacturing: Priorities for CHIPS Act Incentives," Center for Security and Emerging Technology, January 2022, https://cset.georgetown.edu/publication/sustaining-u-s-competitiveness-in-semiconductor-manufacturing/.

[56] For example, see the statement from the Semiconductor Industry Association quoted in Nakashima and Whalen, "U.S. threatens use of novel export control."

[57] Lorand Laskai, "Why Blacklisting Huawei Could Backfire: The History of Chinese Indigenous Innovation," *Foreign Affairs*, June 19, 2019, https://www.foreignaffairs.com/articles/china/2019-06-19/why-blacklisting-huawei-could-backfire.

[58] "White Paper on China's Computing Power Development Index" [中国算力发展指数白皮书], original CSET translation by Ben Murphy, November 19, 2021, https://cset.georgetown.edu/publication/white-paper-on-chinas-computing-power-development-index/.

[59] Semiconductors are not China's only technology import dependency. See 34 other "chokepoint" technologies identified in Ben Murphy, "Chokepoints: China's Self-Identified Strategic Technology Import Dependencies," Center for Security and Emerging Technology, May 2022, https://doi.org/10.51593/20210070.

[60] See a related proposal by Kevin Wolf and Emily S. Weinstein, "COCOM's daughter?," *World Export Control Review* 109 (May 2022): https://cset.georgetown.edu/article/cocoms-daughter/.

[61] Tarun Chhabra, William Hannas, Dewey Murdick, and Anna Puglisi, "Open-Source Intelligence for S&T Analysis," Center for Security and Emerging Technology, September 2020, https://cset.georgetown.edu/publication/open-source-intelligence-for-st-analysis/.

[62] Chhabra, Hannas, Murdick, and Puglisi, "Open-Source Intelligence for S&T Analysis."

[63] "Congressman Castro Introduces Bipartisan Bill to Create China and Russian Translation and Analysis Center," Office of Joaquin Castro, July 28, 2021, https://castro.house.gov/media-center/press-releases/congressman-castro-introduces-bipartisan-bill-to-create-china-and-russian-translation-and-analysis-center.

[64] For example, see "Public Comments of Kevin Wolf, Emily Kilcrease, and Jasper Helder Regarding Areas and Priorities for US and EU Export Control Cooperation under the US-EU Trade and Technology Council," January 14, 2022, https://s3.us-east-1.amazonaws.com/files.cnas.org/documents/011422.US-EU.TTC.Wolf.Kilcrease.Helder.FINAL.pdf?mtime=20220118112213&focal=none; and "US, Allies Should Establish New Multilateral Export Control Regime, Experts Say," *Export Compliance Daily*, May 25, 2022, https://exportcompliancedaily.com/article/view?search_id=552196&id=1261400&BC=bc_628e33fec5933.