



Harnessed Lightning

HOW THE CHINESE MILITARY IS ADOPTING ARTIFICIAL INTELLIGENCE

AUTHORS Ryan Fedasiuk Jennifer Melot Ben Murphy OCTOBER 2021



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Executive Summary

rtificial intelligence (AI) is progressing at lightning speed. What 10 years ago would have been considered science fiction self-adapting computer algorithms with billions of parameters is now a central focus of military and intelligence services worldwide.¹

Owing in part to Al's fast-paced development, most analyses of its military promise tend to focus more on states' future aspirations than present-day capabilities. This is particularly true for the Chinese People's Liberation Army (PLA), which has routinely made clear its desire to harness Al for military advantage, and which prefers to keep a close hold over its actual, technical capabilities.² But as tensions mount between the United States and China, and some experts warn of an impending crisis over Taiwan, it is crucial that U.S. policymakers and defense planners understand the commercial off-the-shelf (COTS) Al technologies already available to the Chinese military.³

This report offers a detailed look at the PLA's adoption of AI by analyzing 343 AI-related equipment contracts, part of a broader sample of more than 66,000 procurement records published by PLA units and stateowned defense enterprises in 2020. The report identifies key AI defense industry suppliers, highlights gaps in U.S. export control policies, and contextualizes the PLA's AI investments within China's broader strategy to compete with the United States. Key findings include:

 Chinese military leaders are already procuring AI-related systems and equipment to prepare for "intelligentized" warfare, but AI so far represents a small fraction of overall purchasing activity.⁴

- Approximately 1.9 percent of public PLA contracts awarded between April 2020 and November 2020 are related to AI or autonomy.
- While we can only estimate a floor for Chinese military AI spending, it is likely that the PLA spends more than \$1.6 billion each year on AI-related systems and equipment.
- The PLA seems most focused on procuring AI for intelligence analysis, predictive maintenance, information warfare, and navigation and target recognition in autonomous vehicles.
- Whereas some PLA officers have expressed serious reservations about developing lethal autonomous weapons systems (LAWS), laboratories affiliated with the Chinese military are actively pursuing AI-based target recognition and fire control research, which may be used in LAWS.
- 2. Chinese leaders view AI as the key to transforming the PLA into a "worldclass," globally competitive military force. PLA advances in AI and autonomy will create new vulnerabilities for the United States and allied forces operating in the Indo-Pacific.
 - The PLA hopes to use AI to generate asymmetric advantages vis-à-vis the United States, which it regards as a "strong enemy" (强敌), but also a role model for AI development.
 - PLA units and military laboratories are focused on developing autonomous vehicles and surveillance systems in the undersea domain, where the United States has traditionally had a significant advantage.
 - The PLA is stepping up investment in information operations and adaptive radar systems to jam and blind U.S. sensor and information networks, which PLA leaders judge to be particularly vulnerable.
 - To compensate for vulnerabilities in its own networks, the PLA may adopt edge applications of AI (directly proximate to, or embedded within a platform) that can operate semi- or fully autonomously.
- 3. China's military-civil fusion (军民融合) development strategy is helping the PLA acquire COTS technologies, both from private Chinese technology companies and sources outside of China.
 - Most of the PLA's AI equipment suppliers are not state-owned defense enterprises, but private Chinese tech companies founded after 2010.

- Although most suppliers are not state-owned, many have benefited from equipment, personnel, information, or capital provided directly or indirectly by the state.
- Of the 273 PLA AI equipment suppliers identified in this study, just 8 percent are named in U.S. export control and sanctions regimes.
- Some Chinese suppliers make a business out of sourcing foreign data or components and reselling them to sanctioned Chinese defense companies and PLA units.
- Lapses in due diligence and situational awareness may permit the Chinese military and defense industry to access capital and technology originating in the United States and partner nations, including advanced computer chips.

Supported by a burgeoning AI defense industry, the Chinese military has made extraordinary progress in procuring AI systems for combat and support functions. Within the next five to 10 years, the PLA will likely continue investing in AI to disrupt U.S. military information systems and erode the U.S. advantage in undersea warfare.

Although PLA investment in the technology appears substantial—roughly equivalent to that of the U.S. military—it remains to be seen how exactly AI might alter the balance of military power in the Indo-Pacific. In addition to renewed interest in counter-autonomy research, U.S. and allied efforts to regulate access to semiconductor devices may hinder the utility and availability of AI systems for the Chinese military.

Introduction

n the early pages of Liu Cixin's science fiction novel Ball Lightning, when asked what, exactly, goes on at System Review Department No. 2, Dr. Lin Yun replies that she develops "new concept weapons" (新概念武器)—fantastical ideas with the potential to change warfare itself. As the mastermind behind the Chinese military's eventually catastrophic "lightning weapons" program, Lin is remembered for her ends-justify-means personality and willingness to develop dangerous weapons in the service of the state.⁵

Seventeen years after it was first published in Chinese, Liu's novel has been eclipsed by his more successful series, *Remembrance of Earth's Past*. A Hugo Award winner, he publicly decries any comparison between his imagined universe and modern geopolitics.⁶ But there can be no denying that Liu's fictional depiction of a Chinese People's Liberation Army bent on mastering "lightning weapons" bears striking similarities to its quest for artificial intelligence today. Chinese military leaders expect AI to fundamentally change warfare, and are leaning on the technology to transform the PLA into a "world-class military" by 2050.⁷ AI's revolutionary potential and general-purpose application even led Andrew Ng, former chief scientist at the Chinese internet company Baidu, to label it "the new electricity" in 2017.⁸

Despite some anxiety within the PLA about developing intelligent or automated weapons systems, concerns about technology misuse seem to take a back seat to the needs of the state.⁹ The PLA's rapid embrace of AI raises questions about strategic stability and the future of warfare. While analysts generally agree that AI forms the basis of the PLA's modernization strategy, questions linger about how far it may be willing to go in developing lethal autonomous weapons systems (LAWS), and which of its new concept weapons will eventually mature into programs of record.¹⁰

By examining 343 AI-related equipment contracts awarded by PLA units and state-owned defense enterprises in 2020, this study offers a detailed view of how the Chinese military is beginning to wield AI—and to what end. The report begins by reviewing the budgetary constraints and modernization goals that have shaped the PLA's transition to "intelligentized" warfare, followed by a discussion of the study's methodology and limitations.

It then identifies seven primary application areas for which the Chinese military is awarding AI-related equipment contracts: autonomous vehicles, intelligence analysis, information warfare, logistics, training, command and control, and target recognition. The bulk of the report discusses common trends and significant AI purchases made within each of these fields.

A fourth section profiles 273 of the PLA's known AI equipment suppliers, highlighting gaps in U.S. export control policy and prevailing technology transfer risks.

Finally, the report discusses how AI fits into the PLA's broader concepts of operations, before concluding with a discussion of the policy tensions that will shape its military competition with the United States.

Preparing for Intelligentized Warfare

A t \$209 billion, China's official 2021 defense budget is second only to that of the United States, and has grown more than 6 percent annually over the past decade.¹¹ The largest portion of PLA defense expenditure is not for personnel, training, or maintenance, but equipment—which accounted for more than 41 percent of the PLA's budget in 2017, the last year detailed data was made available.¹² Equipment was not always the dominant focus of Chinese military spending (in the 1960s, it comprised just 20 percent of the annual defense budget), but it has ascended slowly over the past six decades to become the cornerstone of China's military modernization.¹³ Moreover, the PLA's reported equipment spending is likely an understatement, as "the PRC's published military budget omits several major categories of expenditures and its actual military-related spending is higher than what it states in its official budget."¹⁴

Different periods in recent Chinese history have necessitated that PLA planners procure different kinds of equipment. These priorities are reflected in three interlinked and at times overlapping modernization phases mechanization (机械化), informatization (信息化), and intelligentization (智 能化—which are clarified in China's periodic defense white papers:

 After being made a priority in the 1980s, mechanization sought to equip PLA units with modern platforms, including electronic warfare systems, as well as motorized, armored personnel carriers and infantry fighting vehicles. Mechanization emphasized fixed boundaries and armor operations, primarily for troops stationed along China's land borders, at the expense of naval and air operations.¹⁵ In 2020, the PLA announced it had "basically achieved" mechanization.¹⁶

- Since the 1990s, the PLA's dominant push has been informatization, in which wars are won through information dominance, and the space and cyber domains are the "commanding heights of strategic competition."¹⁷
 PLA operational concepts today emphasize the need to win "informatized local wars" by using long-range, precision, smart, and unmanned weapons and equipment.¹⁸ In 2020, the PLA announced its goal to become a "fully mechanized and informatized" force by its centenary, the year 2027.¹⁹
- First mentioned in China's 2015 Defense White Paper, intelligentization
 represents "a new round of military revolution" characterized by networked,
 intelligent, and autonomous systems and equipment. It endeavors to build
 on mechanized and informatized systems, creating "ubiquitous networks" in
 which "'human-on-human' warfare will be replaced by 'machine-on-human'
 or 'machine-on-machine warfare.'"²¹ In particular, AI forms the basis of the
 PLA's push toward intelligentization, and tops the list of emerging technologies
 prioritized in recent Chinese strategy documents and development plans.²²

Although these modernization goals represent "phases" of development, there is significant overlap between them: "While some units of the PLA employ data links, network-centric sensor-to-shooter system-of-systems, and field a variety of UAVs, electronic warfare platforms, and advanced combat capabilities," writes Dean Cheng, "other units are still in the midst of simply shifting from towed artillery to self-propelled guns, improving their main battle tanks and becoming fully motorized."²³ Since 2013, however, the PLA has placed significantly less emphasis on mechanization and informatization, and is starting to phase in intelligentization as a guiding concept, as evidenced in the 2015 and 2019 defense white papers (Figure 1).²⁴



FIGURE 1 Equipment Modernization Phases Mentioned in China's Defense White Papers

At the same time, numerous reforms to China's military and defense industry have sought to streamline the PLA's promotion of science and technology and acquisition of intelligent equipment. Some of the most significant have included the creation of an Equipment Development Department alongside an entirely new service branch, the PLA Strategic Support Force (PLASSF).²⁵ Renewed emphasis on military-civil fusion (MCF; 军民融合), too, has expanded the PLA's access to private-sector innovation and enabled it to draw on the work of internet giants like Baidu, Alibaba, and Tencent, and telecom giants like Huawei and ZTE.²⁶ But even with reforms, contemporary scholars have questioned whether China's historically bloated and inefficient defense industry can sufficiently adapt to the information age.²⁷

Source: CSET keyword analysis of all nine Chinese defense white papers published between 2000 and 2019.

² Methodology and Scope

P rocurement information holds distinct advantages for those looking to understand the Chinese military and its immediate capabilities. First, defense contracts offer strong signals of both intent and capability, as militaries willing to spend limited resources on commercial off-the-shelf (COTS) solutions clearly deem them useful. Second, as it does in the United States, the public procurement process shapes China's ability to acquire and harness AI for military advantage.²⁸

To assess how China is adopting AI, this report analyzes a sample of purchasing information published directly by the Chinese military in 2020. In addition to capabilities identified in procurement contracts, the authors draw on theoretical writings and research papers by PLA officers and defense industry engineers to assess how the PLA may use the AI systems it is purchasing, and how these systems fit into its concepts of operations.

CSET's corpus of PLA procurement tenders spans 66,207 records published between March 30 and December 1, 2020. These tender notices run the gamut from technology requirements and requests for proposals (RFPs) to announcements of equipment or software contracts that were awarded to Chinese companies. Different types of procurement information reflect different steps in the PLA's technology acquisition process:

- Requirements, inquiries, and bid solicitations signal demand. They
 reflect the PLA's technological priorities and perceived gaps that
 research institutions and service branches are trying to fill.²⁹
- Contract awards signal supply and, ultimately, capability. They
 represent weapon systems or components the PLA sought to acquire and ostensibly received. In most cases, several companies
 compete to win a contract through a competitive bidding pro-

cess.³⁰ More rarely, the PLA selects a single vendor as a contract recipient without considering alternative suppliers ("sole source" procurement).

Of the 66,207 tenders in the CSET dataset, 21,086 announce contracts to supply the PLA with equipment, including software and electronic components.³¹ Information about many of these purchases is limited. While 49,493 tenders in the dataset are publicly available (公开), the rest are classified as confidential (秘密; 14,024 tenders) or secret (机密; 2,270 tenders).³²

TABLE 1

Types of Procurement Information Published by the PLA, April-November 2020

ANNOUNCEMENT TYPE	PUBLIC (公开)	CONFIDENTIAL (秘密)	SECRET (机密)	TOTAL
Award (Bid)	15,028	1,855	356	17,239
Award (Sole Source)	3,545	272	30	3,847
Bid Solicitation	7,508	2,767	416	10,691
Inquiry	12,268	659	4	12,931
Requirement	2,705	2,509	406	5,620
Modification or Annulment	2,143	600	102	2,845
Other	6,716	5,362	956	13,034
Total	49,913	14,024	2,270	66,207

Source: CSET corpus of PLA procurement activity.

UNDERSTANDING PROCUREMENT IN THE PLA

This study primarily considers contract awards, but also makes use of RFPs and bid solicitations filed by PLA service branches, scientific papers published by research institutions, advertisements from Chinese defense companies, and theoretical articles published in outlets like *People's Liberation Army Daily* (解放军报). Of the 21,086 contract awards included in the CSET dataset, 18,354 are "public" and include information such as the requesting unit, intended end user, project budget, tendering agency, and contract winner. A full list of variables can be found in Appendix I. Most of these contracts were not awarded by PLA units, but by defense state-owned enterprises including the Aviation Industry Corporation of China (AVIC), China Aerospace Science and Technology Corporation (CASC), and hundreds of their subsidiaries.³³ Just 3,726 of the 18,354 public equipment contracts in the dataset were awarded by PLA service branches, while the remain-

ing 14,628 contracts were awarded by defense SOEs; theater commands; and research institutes and academic institutions under the control of the Central Military Commission, including the Academy of Military Sciences and the National University of Defense Technology (NUDT).

The 18,354 public contracts in our dataset include all manner of supplies and equipment ranging from toilet seats and ball bearings to completed, off-the-shelf CH-4 Rainbow (彩虹) combat UAVs. We do not claim to have a complete history of the PLA's purchase records for this period of time. However, by examining trends among a sample of public contracts awarded in 2020, this paper aims to illuminate the specific types of AI-related equipment the PLA is purchasing, and to explore their potential application.

IDENTIFYING AI AND "INTELLIGENT" EQUIPMENT PURCHASES

Several limitations constrain our assessment of the Chinese military's AI-related procurement activity. First, definitions of "AI" are not consistent even within the U.S. defense enterprise. The U.S. Department of Defense's (DOD) 2020 AI strategy defines AI as "the ability of machines to perform tasks that normally require human intelligence"—a description that includes "decades-old DoD AI" such as autopilot and signal processing systems, but also modern deep learning techniques.³⁴ Second, Chinese defense engineers frequently conflate terminology surrounding *unmanned* and *autonomous* systems, making it difficult to distinctly analyze the latter. Finally, some project titles are ambiguous and difficult to categorize. The PLA's contract notices offer very little information about each product's technical specifications or envisioned use, though manufacturers sometimes advertise this information.³⁵ This study therefore adopts a broad definition of AI, including most contracts that describe "intelligent" systems and equipment.

Despite these constraints, we identify PLA procurement projects related to AI and autonomy by using keyword searches and an AI assistant, "Elicit."³⁶ We first searched for contracts with names that included any of 14 broad keywords: algorithm (算法), automatic (自动), autonomous (自主), autonomy (自治), intelligent (智 能), human-machine (人机), unmanned (无人), prediction (预测), artificial intelligence (人工智能), computer vision (计算机视觉), robot (机器人), intelligence (智慧), learning (学习), and the English-language abbreviation "AI." Of the 18,354 public equipment contracts in the dataset, 523 contained one or more of these phrases.³⁷

However, some of these keywords are excessively broad, and upon closer examination, many of the projects that mention them are not strictly related to AI development. For example, "learning" (学习) returned contracts related to machine learning (机器学习), but also military education. "Automatic" (自动) and "robot" (机 器人) likewise returned contracts about automated manufacturing, machinery, tools, and robotic projects that likely do not feature AI or autonomy. We therefore eliminated 180 extraneous "intelligent" equipment contracts, for a total of 343 contracts related to AI and autonomy. These AI-related contracts represent 1.9 percent of PLA-wide public contract awards from April–November 2020. For a full explanation of the coding and labeling process, see Appendix I.

PRICING CHINESE MILITARY AI DEVELOPMENT

Of the 343 AI contract notices in the dataset, 205 (60 percent) listed the monetary value of the contract. Public AI contracts in the dataset were typically awarded through a competitive bidding process, as opposed to sole-source procurement. They ranged in value from \$1,300 (RMB 9,000, for an intelligent sound-and-light alarm detection system) to \$3 million (RMB 21 million, for an intelligent UAV data access and management platform), with the average contract amounting to \$240,000 (RMB 1.7 million). These contracts are noticeably small, even when adjusted for purchasing power parity.³⁸ It is likely that the PLA's equivalent of major defense acquisition programs are classified or otherwise not captured in this dataset.³⁹

Approximately 2 percent of all public equipment contracts in the dataset appear related to AI, broadly defined. The PLA's five main service branches—as opposed to theater commands, research institutes, or defense SOEs—award the majority of public AI contracts. As in the United States, these service branches are tasked with procuring equipment used in military operations. Among the PLA Air Force, Ground Force, Navy, Rocket Force, and Strategic Support Force, approximately one in 20 public equipment contracts appear related to AI.

The PLA spends more than 41 percent (approximately \$86 billion) of its official \$209 billion budget on equipment, and provides no additional information about how that funding is distributed.⁴⁰ If public contracts reflect how the PLA prioritizes different emerging technologies, then it is likely the PLA spends more than \$1.6 billion each year on AI-enabled systems.⁴¹ However, because it is still an emerging technology, the PLA's true spending on AI likely exceeds this number, as more funding is captured in research and development rather than off-the-shelf technology procurement. Moreover, the most resource-intensive AI projects are likely classified. For these reasons, we can only approximate a floor for Chinese military AI spending. Using a different methodology and set of source documents, past CSET analysis estimated a ceiling for Chinese defense-related AI research at "no more than about 19 billion RMB (\$2.7 billion)" in 2018, "and possibly much less."⁴² Our analysis supports the conclusion that annual Chinese military spending on AI is in the low billions of U.S. dollars.

Comparisons between Chinese and U.S. military spending are inherently complicated, as both countries define AI differently, discuss intelligent and autono-

mous systems in different ways, publish different degrees of information about their equipment spending, count that spending differently, and use currencies with different degrees of purchasing power. However, if the PLA does spend between \$1.6 billion and \$2.7 billion on AI-related technologies each year, then its AI spending is likely on par with that of the U.S. military. Various analyses of DOD budgets for procurement and research indicate that it spent between \$800 million and \$1.3 billion on AI in 2020, with an additional \$1.7 billion to \$3.5 billion for unmanned and autonomous systems.⁴³

³ AI Purchases by Application

Prior analysis has highlighted the PLA's plan to use AI in a variety of military applications, including intelligent and autonomous unmanned systems; intelligence analysis; simulation, war-gaming, and training; information warfare; and decision support.⁴⁴ Yet there are many ways to taxonomize AI applications for military use. CSET's 2020 study Chinese Perspectives on AI and Future Military Capabilities identified 12 specific AI applications of interest to Chinese military and defense industry researchers, including cybersecurity and intelligent munitions.⁴⁵ The DOD's Communities of Interest on autonomy include four AI application areas: machine perception, reasoning, and intelligence; human-machine collaboration; scalable autonomous system teaming; and test, evaluation, validation, and verification.⁴⁶

This study builds on prior taxonomies of AI applications, consolidating some fields while adding others. After reviewing the 343 AI-related contracts in our dataset, we arrived at seven discrete application areas for which the PLA is adopting AI:

- 1. Intelligent and Autonomous Vehicles
- 2. Intelligence, Surveillance, and Reconnaissance (ISR)
- 3. Predictive Maintenance and Logistics
- 4. Information and Electronic Warfare
- 5. Simulation and Training
- 6. Command and Control (C2)
- 7. Automated Target Recognition

The resulting taxonomy is imprecise. Working with limited information, we adopted an iterative labeling process to characterize each contract, which is described in more detail in Appendix I. Contracts that did not clearly fit in any of these seven categories were marked "Other." Despite some labeling uncertainty, this report finds that autonomous vehicles, ISR, predictive maintenance, and information warfare are priorities within the PLA's intelligentization strategy. To a lesser extent, PLA units also appear interested in using AI for simulation, target recognition, and command and control systems. Appendix II includes more detailed information about how each of the PLA's service branches are adopting AI, while the remainder of this section discusses each application in detail.



Number of PLA AI Contracts by Application Area

FIGURE 2

Source: CSET corpus of PLA procurement activity (343 AI contracts).

INTELLIGENT AND AUTONOMOUS VEHICLES

Since it first unveiled the Wing Loong-1 combat UAV in 2009, the PLA has made significant progress in developing intelligent and autonomous systems in the air and maritime domains. Of the 343 AI equipment contracts considered in this study, 35 percent (121) are related to intelligent or autonomous vehicles. Market research firms estimate that military and security services today account for more than 40 percent of the Chinese UAV market, and procurement records confirm that several PLA units and defense SOEs purchase COTS autonomous vehicles through a public purchasing platform called the Drone Network (无人机网).⁴⁷

Most of the unmanned and autonomous vehicle contracts in our dataset are for airborne systems. While it is difficult to distinguish between contracts for remotely piloted or truly autonomous aircraft, some PLA units have funded research into autonomous flight, and others have purchased "intelligentized" microwave interference, reconnaissance, and data processing modules, which may be attached to remotely piloted or self-flying aircraft.⁴⁸ Myriad Chinese suppliers advertise unmanned or autonomous aerial vehicles for combat or surveillance, including private enterprises, SOEs, and state-run research and design centers. Examples of such systems include the ASN-301—a reverse-engineered copy of the IAI Harpy loitering munition⁴⁹— and the GJ-11 "Sharp Sword" combat UAV.⁵⁰ The Chinese Academy of Sciences (CAS) Shenyang Institute of Automation (SIA) is at the forefront of state-backed autonomous vehicle research.⁵¹ In 2020, it was awarded contracts to supply a "3D intelligent collision avoidance system" for CASC, and "intelligent self-flying machinery" for the PLA Air Force (PLAAF).⁵²

The Chinese defense industry is also developing coordinated swarms of fixedwing UAVs and rotorcraft.⁵³ Whereas scholars in the late 2010s speculated about hypothetical swarm applications, the technology has progressed significantly, and some limited swarm applications now appear operational.⁵⁴ In 2020, multiple PLA units and CASC institutes awarded contracts for air-launched drone clusters and subsystems used in swarms, including self-organizing UAV communications systems, group node management and control software, AI-based radar coincidence imaging, and collision avoidance sensors.⁵⁵ In October 2020, the PLA Ground Force (PLAGF) placed a \$900,000 order to construct "drone swarm targets."⁵⁶ It is not clear from the contract what such a swarm engagement would look like in practice. The Drone Network also advertises COTS software and hardware for use in UAV group operations, such as "SwarmLink"—a network gateway that can support more than three hundred vehicles.⁵⁷ Beyond COTS systems, several Chinese universities have conducted swarm-related research, including Beihang University, Nanjing University of Aeronautics and Astronautics, and Zhejiang University's Institute of UAV Systems and Control.⁵⁸ Notably, multiple lines of research focus on contesting and jamming U.S. military swarm projects such as LOCUST and Gremlins.⁵⁹

Although most information about such systems is likely to be classified, some public procurement records also indicate that the PLA is purchasing unmanned and autonomous underwater vehicles (UUVs and AUVs). Five contracts in our dataset were for AUV platforms, and another contract was for an intelligent ship integration system.⁶⁰ In the summer of 2020, for example, the PLASSF placed orders for AUVs from Tianhe Defense, a company which seems to be emerging as China's national champion in A/UUVs.⁶¹ Tianhe advertises a "shadowless AUV solution," which it claims is capable of autonomously diving below 200 meters.⁶² In addition to contract awards, advertisements from Chinese industry suppliers indicate that they are developing small- and medium-sized, fully autonomous underwater vehiclespossibly for sale abroad. Today, none of the top 10 companies selling AUVs in the international market are Chinese.⁶³ Yet several COTS AUV models are advertised on the Drone Network, and some PLA units may purchase them for undersea detection and reconnaissance. Examples include the ZF-01 AUV, which can apparently dive to 100 meters with a towed sonar array⁶⁴; and Kawasaki's SPICE AUV, which comes equipped with a robotic arm for underwater fiber-optic cable and pipeline inspection.65

FIGURE 3



AUV Likely Ordered by the Strategic Support Force in 2020

Source: Phoenix New Media and Tianhe Defense.66

Finally, at least four public contracts in our dataset were related to developing "intelligent satellites" that can autonomously adjust their orbit or engage in rendezvous and proximity operations with other space assets. For example, in August 2020, the PLA Academy of Military Sciences awarded an "intelligent satellite simulation software" contract to Hunan Gaozhi Technology Co., Ltd. (湖南高至科技有 限公司).⁶⁷ The company sells high-resolution cameras and intelligent video analysis servers, and holds several patents related to intelligent or automatic servo control in satellite systems.⁶⁸ In August 2020, the CASC Shanghai Academy of Space Technology likewise awarded a contract for an "on-orbit satellite data acquisition and prediction subsystem"; while other CASC institutes awarded contracts for intelligent or automatic inclination adjustment, high-precision attitude determination, and small satellite positioning systems.⁶⁹

Although nearly all of the vehicle contracts reviewed in this study are described as "intelligent" (智能), the true nature of this intelligence—and the machine learning methods that may or may not be involved in their operation—is unclear. The PLA has long procured unmanned, remotely-piloted vehicles for reconnaissance and strike missions. But in the 2020s, Chinese leaders hope that improvements in autonomous navigation and online, real-time learning will cement unmanned vehicles as the backbone of intelligentized, machine-on-machine warfare.⁷⁰

INTELLIGENCE, SURVEILLANCE, AND RECONNAISSANCE

Al promises to revolutionize military ISR, perhaps more than any other application area. That potential is reflected in the PLA's procurement activity, as nearly one in five AI contracts canvassed in this study (63) appear related to ISR. U.S. military and intelligence services recognize the importance of using AI in foreign media and geospatial imagery analysis, and PLA units are adopting AI toward similar ends. According to Liu Linshan, a researcher at the PLA Academy of Military Sciences, "battlefield situational awareness . . . includes not only the results of one's own reconnaissance, surveillance, and intelligence activities, but also massive amounts of geographic information data, human social and cultural data, and social media data" that can be fused to improve situational awareness at all levels of operation.⁷¹

A significant number of the PLA's AI-based ISR contracts concern remote sensing and geospatial imagery analysis, consistent with U.S. intelligence community assessments of China's space strategy.⁷² Throughout 2020, CASC institutes and PLASSF units placed orders for polarized surface detection, imagery analysis, distance measurement, and multisource data fusion systems to be embedded in satellites.⁷³ In August, for example, the PLASSF awarded a "geospatial information perception and intelligent analysis subsystem" contract to Beijing Uxsino Software Co., Ltd. ("Uxsino," 北京优炫软件股份有限公司).⁷⁴ The company produces data processing systems analogous to those made by Oracle in the United States.⁷⁵ CASC institutes are also developing microsatellites with edge AI information processing applications. One CASC subsidiary, Shenzhen Aerospace Dongfanghong HIT Satellite Ltd. (深圳航天东方红海特卫星有限公司), advertises a constellation of 80 "intelligent autonomous operation and management" MV-1 microsatellites capable of "full color, multi-spectral, and hyperspectral imaging" at resolutions of 1 to 5 meters.⁷⁶

In the maritime domain, the PLA is interested in using AI for underwater inspection and deep-sea sensing. State-run research institutes in this study awarded contracts for intelligent pipeline detection and identification, multisource information processing and scene analysis, and automated coordinate measuring units for underwater vehicles. In July 2020, the PLA Navy (PLAN) awarded an ocean mapping contract to Startest Marine (星天海洋), which offers several products related to undersea surveying and mapping.⁷⁷ One of its products, GeoSide1400, is a side-scanning UUV that "uses the backscattered echoes of seabed targets for detection."⁷⁸ A video on Startest Marine's website depicts GeoSide1400 being towed by a fishing boat and patrolling the subsurface coastline, an application that could be used to detect U.S. undersea forces in a crisis.⁷⁹ The company also advertises services for undersea mapping and hydrological data collection depicted in Figure 4.⁸⁰

FIGURE 4 Undersea Sensor Systems Offered by a PLA Contractor



Source: Startest Marine.81

Finally, the PLA is using AI in multisource data fusion for foreign military analysis, including textual analysis of foreign-language documents.⁸² In the fall of 2020, the PLAGF awarded two contracts for "foreign military equipment intelligent document data resources"; and in November, an unspecified PLASSF unit ordered a "mul-tilingual intelligent text processing system" from Nanjing Glaucus-Tech Co., Ltd. (Glaucus-Tech; 南京国业科技有限公司). On its website, Glaucus-Tech advertises the "GL-AI Speech Recognition System 001," which can apparently translate foreign languages into Chinese with 80 percent accuracy, at a rate of 20 words every 150 milliseconds.⁸³ The company's products rely on NVIDIA processors as components, including the Tesla P40 GPU.⁸⁴

On balance, Chinese military AI contracts for ISR applications exhibit priorities similar to those stated by the U.S. intelligence community, such as network management, image classification, and transcription of foreign languages.⁸⁵ However, in part because of its lack of operational experience, the PLA has struggled to access certain types of data required for some weapons systems, such as radar signature-based target recognition.⁸⁶

PREDICTIVE MAINTENANCE AND LOGISTICS

As in the United States, the Chinese military is using AI for equipment maintenance and logistics. Of the 343 AI contracts in our dataset, 11 percent (38) were related to maintenance, repair, logistics, or sustainment. Newly established PLA contractors have developed AI-based applications for leak detection, fault diagnosis, and "smart warehouses" intended to predict and fill orders for materiel.⁸⁷ In March 2020, for example, the Academy of Military Sciences awarded Anwise Global Technology (安怀信科技) a contract for an automated code testing platform.⁸⁸ Established in 2016, Anwise is one of China's largest intelligent equipment manufacturers, and primarily services the military aerospace and electronics industries.⁸⁹ Its products include AI-based software for soldering fault diagnosis and a virtual prototype library for testing and evaluation of aerospace weaponry.⁹⁰ In November 2020, the PLAGF and PLASSF awarded predictive maintenance contracts to Wego (威高), which produces medical devices and fault diagnosis equipment; and Sucheon Technologies (硕橙科技), which focuses on using AI in mechanical noise recognition.⁹¹

FIGURE 5 Intelligent Maintenance Systems Offered by a PLA Contractor



Source: Anwise Global Technology Co., Ltd.92

Predictive maintenance is also emerging as an edge application for otherwise inaccessible, remotely piloted, or autonomous platforms. In 2020, multiple PLA research institutes fielded orders for automatic test equipment on satellites and underwater vehicles that cannot easily be reached for diagnostic testing and repair.⁹³ CASC, for example, awarded two \$800,000 contracts for ATE systems on unspecified constellations of Earth observation satellites in geosynchronous and low earth orbit.

PLA officers predict drastic decreases in equipment and materials stockpile requirements as a result of intelligentized maintenance and logistics systems. "With the development of information technology such as big data and cloud computing," write two PLA logistics officers, "it is not necessary to establish a large-scale resource reserve . . . all materials need only be supplied to the required place at the required time."⁹⁴ Consistent with this thinking, CASC and the PLA Ground Force placed orders for intelligent procurement systems for bullets and Internet of Things (IoT) devices throughout 2020.⁹⁵

INFORMATION OPERATIONS AND ELECTRONIC WARFARE

The U.S. military considers electronic warfare to be a component of information operations, and designates information, data, knowledge, and influence as "information-related capabilities."⁹⁶ Approximately 8 percent of public PLA AI contracts in this study (29) are related to IO, broadly defined. However, AI stands to affect each of these capabilities in different ways. Some AI projects support the PLA's public opinion warfare (舆论战) and psychological warfare (心理战) strategies, whereas others focus on electromagnetic spectrum dominance or defense and intrusion in cyberspace.⁹⁷

Public opinion manipulation is a longstanding focus of the PLA and the Chinese Communist Party (CCP) more broadly.⁹⁸ CSET's report Truth, Lies, and Automation found that, with breakthroughs in AI, "humans now have able help in mixing truth and lies in the service of disinformation."99 Procurement records and research papers indicate that the Chinese military is actively exploring this capability.¹⁰⁰ In November 2020, for example, the PLASSF's Information Engineering University awarded a contract for an "internet public opinion AI clustering system" to Zhengzhou Meicheng Electronic Technology Co. (郑州美诚电子科技有限公司), an electronics wholesaler. It showcases three products related to "online behavior management" that range in price from \$6,000 to \$56,000.¹⁰¹ Each is a computer processor produced by Ruijie Networks (锐捷网络), advertised as being able to "intelligently" track source and destination IP addresses, website URL visits, and search history; and perform "real-name online behavior auditing."¹⁰² AI-based sentiment analysis software is also common among PLA units and defense SOEs. KnowleSys (乐思网 络), one of China's largest public opinion management software companies, claims Dalian Naval Academy as a customer.¹⁰³ Its products can apparently analyze trends and predict "hotspots" on both Chinese and foreign social media platforms. Al-enabled sentiment analysis systems like these will grow in importance as the CCP continues to expand its overseas information operations.¹⁰⁴ "In the era of artificial intelligence," writes a professor at NUDT, "audience information can be intelligently collected and analyzed by machines, various data about public opinion warfare opponents can also be obtained through network detection and deep data analysis; and public opinion warfare happens in real-time."¹⁰⁵

In addition to psychological operations and social media manipulation, the PLA is purchasing AI-related systems for use in electronic warfare. The PLA Navy Submarine Academy, for example, has awarded several contracts related to adaptive beamforming techniques, using AI to produce a dynamic filter that will cancel the effect of interfering signals.¹⁰⁶ Other PLA units awarded contracts for automatic frequency modulation, microwave jamming, broadband automatic gain control, and multisource signal separation.¹⁰⁷ Chinese experts broadly believe AI will revolutionize electronic warfare by replacing today's passive, adaptive technology with systems defined by more active, cognitive algorithm development.¹⁰⁸ Research papers published in 2020 by PLASSF Units 91404, 63610, and 93175¹⁰⁹ discuss using adaptive, self-correcting systems to conduct operations related to "battlefield situational awareness, electromagnetic target reconnaissance, electronic counter-measures, electronic defense, and electromagnetic spectrum management."¹¹⁰

Cybersecurity and network exploitation are also focal points in the PLA's adoption of AI, and are key elements of information warfare. Prior CSET research has found that "machine learning has the potential to increase both the scale and success rate of spearphishing and social engineering attacks,"¹¹¹ and several Chinese universities are cooperating with the PLA to advance related research.¹¹² Throughout 2020, PLA units and state-owned research institutes in our dataset awarded contracts for intelligent terminal inspection systems; autonomous, self-configuring software; and software control management systems.¹¹³ In November, for example, the PLASSF awarded a contract for an AI-based "cyber threat intelligent sensing and early warning platform" to EverSec (恒安嘉新 (北京) 科技股份公司). The company serves as a national-level "Cybersecurity Emergency Service Support Unit" (网络 安全应急服务支撑单位) for the Chinese government's National Computer Network Emergency Response Technical Team/Coordination Center.¹¹⁴ In this capacity, EverSec's role seems analogous to that of FireEye or CrowdStrike's support for the Cybersecurity and Infrastructure Security Agency in the United States.¹¹⁵ Beyond its adaptive cybersecurity products, the company also advertises services for petabyte-scale data storage and processing, Al-based open source data mining, and internet blocking and censorship protocols.¹¹⁶ EverSec claims that its products are used in all 31 Chinese provinces, autonomous regions, and provincial-level municipalities, and evidently PLASSF units also purchase some of these services.¹¹⁷ The U.S.-based venture capital firm Seguoia Capital is an investor in EverSec.¹¹⁸

SIMULATION AND TRAINING

The PLA has long had a problem with training its enlisted service members and officers. A lack of suitable aircraft, friction when conducting joint operations, rigid organizational culture, and seasonal tides in recruitment each affect its force posture and readiness.¹¹⁹ While improvements in technology can remedy only some of these issues, AI nonetheless stands to save precious time and training costs. Of the 343 PLA contracts considered in this study, 6 percent (22) concerned using AI for simulation and training.

Among the PLA officer corps, war-gaming is a well-established tradition, and is growing in importance given China's relative lack of real-world combat experience. It is no surprise that the PLA has awarded contracts for proprietary, AI-based war-gaming software for use in professional military education programs. DataExa (渊亭科技), for example, advertises an AI-based war-gaming simulator called "AlphaWar," inspired by DeepMind's Starcraft-playing AI system, AlphaStar.¹²⁰ The PLA's preoccupation with war-gaming grew out of the Information Operations and Command Training Department of NUDT, which created "computer-based, warzone level, intranet-based campaign exercises" throughout the 2000s.¹²¹ According to Chen Hangui, a researcher at the PLA Army Command College, one of the principal uses of AI will be in "war-game systems" to "more effectively test and optimize combat plans."¹²²

FIGURE 6 "War Game in Taiwan Strait 2019" Using CMO



Source: Chinese Institute of Command and Control.¹²³ CICC generated this simulation by using "Command: Modern Operations (CMO)," an \$80 computer game available on Steam.

PLA units are also using AI in virtual and augmented reality systems to train fighter pilots and drone operators. In August 2020, for example, Naval Aviation University awarded a contract to eDong AI (翼动智能) for a "human-machine integrated control algorithm model and simulation service."¹²⁴ The company primarily designs and builds VR/AR simulation centers, and also advertises stand-alone training software.¹²⁵ A similar contract was awarded to AOSSCI (傲势科技), which produces an "X-Matrix" UAV flight simulator for PLA pilots.¹²⁶ In June 2021, Chinese media reported that an AI system had defeated a top PLA pilot in a simulated dogfight similar to the Defense Advanced Research Projects Agency's Air Combat Evolution program.¹²⁷ Public contract awards indicate that AI-based simulation systems are becoming more common within the PLA.

While AI for simulation and training promises to save military services time and resources, deep learning systems rely heavily on data, are incapable of learning common sense, and lack interpretability—limitations acknowledged by Chinese defense contractors.¹²⁸ Still, even with these limitations, it is likely that advances in AI will continue to supplement or stand in for the PLA's often cited experience gap.

COMMAND AND CONTROL

Chinese military scholars and strategists expect the speed, efficiency, and flexibility afforded by AI to revolutionize battlefield decision-making.¹²⁹ Despite the PLA's emphasis on C2, however, public procurement data does not indicate that it is a priority: Just 4 percent (15) of the contracts in our dataset appear related to C2, and most included only limited information alongside nebulous names such as "intelligent control equipment," "smart management systems," and "autonomous mission planning." The few projects for which we could find adequate details seem primarily designed to support human decision-making processes, not replace them outright.

It is likely that the PLA's most significant AI-enabled C2 projects are classified, and therefore not included in our dataset. In the following paragraphs, we supplement analysis of public procurement records with outside information, such as defense industry advertisements, to better understand the scope of China's AI-enabled C2 capabilities. Several Chinese enterprises outside of our dataset advertise AI systems capable of automating some elements of command and control—including knowledge mapping, decision support, weapon target assignment, and combat tasking. While we could not use procurement records to confirm that PLA units have purchased each of the systems specified below, each of the following companies publicly claims the Chinese military as a partner or client.

Knowledge mapping is a visual representation of information designed to aid decision-making. DataExa, for example, advertises several services for AI-based knowledge mapping and combat decision support, such as encyclopedic information and real-time prediction about the movement of foreign weapons platforms.¹³⁰ In July 2020, the company's knowledge mapping software passed licensing review from the China Academy of Information and Communications Technology, and DataExa today lists the PLASSF and the Science and Technology Commission of the PLA Central Military Commission among its clients.¹³¹ One of its products, the DataExa-Sati Knowledge Map, provides "information about U.S. aircraft carrier equipment, such as submarines, destroyers, cruisers, and frigates accompanying aircraft carrier strike groups, and infrastructure such as overseas bases, satellite communications, logistics, and support equipment" to the PLA Navy.¹³² The company compares itself to the U.S. data management company Palantir Technologies.¹³³

Decision support systems streamline portions of the military decision-making process by helping identify courses of action for commanders.¹³⁴ One of China's most well-known military AI companies, StarSee (摄星智能), specializes in computer vision and decision support software. In 2020, the company won a commendation from China's Central Military Commission for its work on combatting COVID-19.¹³⁵ Among other products, StarSee advertises a "Real-time Combat Intelligence Guidance System" designed to "combine the massive parameter model of a knowledge graph and the dynamic information of the battlefield in real-time."¹³⁶ StarSee's product is designed to create a common operational picture across different PLA units.¹³⁷ By "relying on image, video, and audio language extraction and analysis technology," the company claims to be able to identify foreign weapons platforms, "give various performance parameters of the weapon, and calculate its sustainability, firepower, maneuverability, command and control capabilities, intelligence capabilities, and other threat level parameters."¹³⁸ A product demonstration from June 7, 2020, appears to track Chinese aircraft flying near a U.S. Arleigh Burke-class destroyer off the coast of California.¹³⁹ Members of the StarSee research team previously worked for Baidu, Alibaba, Tencent, and Microsoft Research Asia.¹⁴⁰

FIGURE 7



Real-Time Combat Intelligence System Offered by a PLA Contractor

Source: StarSee and Haixun News.¹⁴¹ StarSee's "Real-time Combat Intelligence Guidance System" appears to identify and track U.S. Navy assets near California in June 2020.

Weapon target assignment software selects an optimal combination of weapons systems to engage one or more targets, assuming different success rates for each.¹⁴² In addition to AI-based predictive maintenance and logistics software, the PLA contractor Anwise Global advertises a "SIMBAT Weapon Effectiveness Evaluation System," which can reportedly use "test data from multiple sources such as simulation, internal and external field tests, and exercises, among others, to evaluate effectiveness throughout the entire life cycle of weapons and equipment."¹⁴³ It is not clear whether the PLA has purchased access to SIMBAT specifically, but PLA units have awarded Anwise Global other AI contracts, and the PLA regularly publishes AI-based weapon target assignment research of its own.¹⁴⁴

Combat tasking, whereby a commander selects a course of action and directs a unit to complete some activity, represents one of the final steps in the military decision-making process.¹⁴⁵ Public procurement data indicates that PLA units and defense SOEs have awarded contracts for AI-based command and control software to support unit-level decision-making and combat tasking. One such project, awarded by the China Ship Research and Design Center of the China Shipbuilding Industry Corporation (CSIC), is for an "intelligent loss management system" to help commanding officers operate with fewer personnel after sustaining casualties. In another case, the PLA Ground Force awarded a contract to 4Paradigm, one of the largest enterprise AI companies in China, for a "battalion and company command decision-making model and human-machine teaming software."¹⁴⁶ 4Paradigm advertises a wide array of products and services, including software-defined computing platforms and an "automatic decision-making machine learning platform" called Sage HyperCycle.¹⁴⁷ As of January 2021, the company was cooperating on Very Large Database research with Intel and the National University of Singapore.¹⁴⁸ 4Paradigm's angel investor, Sequoia Capital, remains its largest outside shareholder.¹⁴⁹

Taken collectively, these examples illustrate the kinds of public, AI-based decision support applications being developed by the Chinese defense industry. While it is too early to say whether the PLA may attempt to automate other segments of its C2 infrastructure, it is clear that some units have already begun acquiring COTS technologies for combat decision support and contingency operations. China's private AI sector is also starting to mature, with a few specialized companies like Anwise Global, DataExa, and StarSee carving out a niche to support different segments of the PLA's decision-making process.

AUTOMATED TARGET RECOGNITION

Target recognition and fire control are critical components of modern weapons systems, but applying AI to these tasks is a fairly new area of research. Although much of the PLA's research into AI-based automated target recognition is still aspirational, some units are purchasing relevant systems and equipment, and 4
percent (14) of PLA AI contracts in our dataset appear related to ATR. Throughout 2020, PLA units and defense SOEs awarded contracts for feature extraction and recognition algorithms, target recognition algorithms for unmanned vehicles, brain-inspired multi-target fusion, and target detection based on synthetic aperture radar imagery.¹⁵⁰

Most notably, the Chinese military appears to be following in the footsteps of the DOD in developing AI-based ATR software for aerial vehicles.¹⁵¹ Today, private Chinese companies, including Shandong Hie-Tech Co., Ltd. (山东航创电子科技有限 公司), advertise AI-based ATR systems for use in UAVs. The company won a contract to supply the PLAN with "UAVs and supporting equipment" in June 2020.¹⁵² Research papers from PLA and state-sponsored laboratories also discuss developing AI-based ATR software. For example, the Shenyang Institute of Automation's first target recognition research forum in 2017 focused on using deep learning to recognize targets in still-frame images, and several SIA researchers have conducted research along similar lines.¹⁵³ SIA's Robotic Vision Group (机器人视觉组) lists a "UAV airborne visual automated target tracking system" as one of its achievements, but public information about the system is limited.¹⁵⁴

FIGURE 8



AI-Based UAV Target Lock Software Advertised by a PLA Contractor

Source: Shandong Hie-Tech.155

Note: The caption reads "Vehicle Recognition: Moving target frame selection locking and tracking capability based on AI chip computing power; autonomous recovery of targets temporarily lost due to cover."

The PLA also aspires to use AI-based ATR software in undersea vehicles. In 2020, various PLA units awarded ATR contracts to universities and state-run research institutes that were still in the early stages of developing the technology.¹⁵⁶ Notable examples include "USV target recognition algorithm and software development," "deep learning-based, automatic detection of targets at sea," and a contract to construct a "typical marine target database and target recognition module based on deep learning."¹⁵⁷ Multiple PLA units and defense SOEs awarded undersea target recognition contracts to Harbin Engineering University, one of seven universities administered by China's Ministry of Industry and Information Technology.¹⁵⁸ HEU researchers have developed a series of "Smart Water" (智水) AUVs for underwater ATR and path-planning missions, and are suspected of developing the HSU-001 large UUV first unveiled in China's 2019 National Day military parade.¹⁵⁹

Although AI-enabled ATR research is still in early development, it is maturing rapidly. Recent research papers by PLA units and defense industry engineers have used machine learning algorithms such as Single Shot Detector 300 (SSD300) and "You Only Look Once" (YOLO) to recognize targets with more than 80 percent accuracy.¹⁶⁰ While many of these algorithms are trained to recognize stationary targets in long-distance, overhead images, it remains to be seen whether or how the PLA may adopt AI-based ATR systems for ground-based weapons systems.

⁴ Supply and Demand for Intelligent Equipment in the PLA

B eyond the Chinese military's intended application of AI, it is important for U.S. policymakers and defense planners to understand the sources of the technology that is being purchased by the PLA. Based on trends in public PLA contracts, we offer three observations about the overall structure and efficiency of China's emerging military AI industry.

First, among the contract award notices in our dataset, defense SOEs are both buyers and suppliers of AI-related equipment. Research institutes and subsidiaries belonging to CASC, AVIC, the Aero Engine Corporation of China (AECC), and CSIC are included in the PLA's official procurement records (referred to as "PLA contracts"), and each placed orders for AI-related equipment in 2020.¹⁶¹ Along with other defense SOEs, these companies and their subsidiaries also *received* contracts to supply AI-related equipment to PLA units and other state-owned research institutions. This two-way transfer of technology could indicate that SOEs are specializing in certain subfields of AI development, rather than crowding out private-sector investment.

TABLE 2 The PLA's Top Buyers of AI-Related Equipment, April-November 2020

INSTITUTION	INSTITUTION (CHINESE)	NO. OF CONTRACTS
China Aerospace Science and Technology Corporation (CASC)	中国航天科技集团公司	82
Strategic Support Force	中国人民解放军战略支援部队	65
Ground Force	中国人民解放军陆军	58
Νανγ	中国人民解放军海军	51
Academy of Military Sciences	军事科学院	34
Air Force	中国人民解放军空军	10
Aero Engine Corporation of China (AECC)	中国航空发动机集团有限公司	8
Overall Design Institute of Hubei Aerospace Technology Research	湖北航天技术研究院总体设计所	5
Academy (CASIC 9th Overall Design Department)	(中国航天科工集团第九总体设计部)	
Rocket Force	中国人民解放军火箭军	4
China Ship Research and Design Center	中国舰船研究设计中心	3
National Defense University	中国人民解放军国防科学技术大学	3
People's Armed Police	中国人民武装警察部队	3

Source: CSET corpus of PLA purchasing activity (343 contracts specify purchasing units). Note: Values for state-owned enterprises such as CASC and AECC include multiple subsidiaries.

Second, whereas the organizations responsible for buying AI equipment are fairly concentrated, the PLA's AI equipment suppliers are diffuse. Of the 343 public AI contracts in this study, 331 contracts named 273 unique suppliers. Most companies were awarded just one public AI contract, and the single most active private-sector supplier, Langfang Rongxiang Electromechanical Equipment Co., Ltd. (廊坊市荣祥机电设备有限公司), was awarded just four contracts during our period of inquiry.

Moreover, China's MCF development strategy is improving the PLA's access to private-sector advances in AI. Since the 1980s, the Chinese government has attempted to integrate the technical achievements of the civilian and military industries to strengthen China's comprehensive national power. In more recent policy documents, the CCP has called for deepening MCF and "encouraging the twoway transfer and transformation of military-civil technology," as evidenced by the

TABLE 3 The PLA's Top Suppliers of AI-Related Equipment, April-November 2020

INSTITUTION	INSTITUTION (CHINESE)	NO. OF CONTRACTS
China Electronics Technology Group Corporation	中国电子科技集团公司	4
Langfang City Rongxiang Electrical and Mechanical Equipment Co., Ltd.	廊坊市荣祥机电设备有限公司	4
Harbin Engineering University	哈尔滨工程大学	4
Hebei Xintu Technology Co., Ltd.	河北新途科技有限公司	4
Shanghai Jiaotong University	上海交通大学	3
Beijing Institute of Technology	北京理工大学	3
University of Science and Technology Beijing	北京科技大学	3
Beihang University	北京航空航天大学	3
Shenzhen City Kehai Technology Co., Ltd.	深圳市中科海信科技有限公司	3
Northwestern Polytechnical University	西北工业大学	3
Inno Aviation Technology Co., Ltd.	西安因诺航空科技有限公司	3

Source: CSET corpus of PLA purchasing activity (331 contracts specify suppliers).

Internet+ Action Plan (2015), innovation-driven development strategy (2016), and New Generation Artificial Intelligence Development Plan (2017).¹⁶² CSET research has highlighted the role of new policy levers in achieving this goal, such as government guidance funds, technology brokers, and a formal Chinese AI Industry Alliance—of which 24 (9 percent) of the 273 suppliers in this study are members.¹⁶³ It should come as no surprise that a large number of private companies supply the PLA with AI-related equipment, and that some of these companies have benefited from equipment, personnel, information, and capital provided directly or indirectly by the state.

THE PRIVATIZATION OF INTELLIGENTIZATION

A robust military AI industry is emerging in China, spanning Chinese Academy of Sciences (CAS) research institutes, military factories, universities, private enterprises, state-owned enterprises, and their subsidiaries. To categorize each Al equipment supplier in our dataset, we searched for background information on each company's "About Us" web page, vacancies they advertised on job posting websites, and ownership information on Chinese financial service and due diligence platforms. We recorded the date each institution was established and any indication that it may be a subsidiary of a defense SOE or state-owned holding company. If a company publicly claimed to be a subsidiary or appeared to be majority-owned by an SOE, university, or CAS institute, we labeled it as such.

Among the 273 unique PLA suppliers identified in this study, we find that private Chinese technology companies—not SOEs or their subsidiaries—are the PLA's most common suppliers of AI-related equipment. Generally speaking, these are recently established, high-technology companies for whom intelligent software or sensors are a dominant focus.¹⁶⁴ The PLA awarded 61 percent of the public AI contracts in our dataset to 166 private enterprises. Of them, two-thirds (108) were founded since 2010, and more than one-third (63) were founded since 2015. Most have fewer than 50 employees and registered capital of less than \$1 million.¹⁶⁵

FIGURE 9





Source: CSET corpus of PLA procurement activity (273 known AI equipment suppliers).

As previously noted, China's MCF strategy is accelerating the PLA's access to, and adoption of, AI. Many of the non-state-owned companies that supply the PLA with AI equipment are supported directly or indirectly by the state, and some self-identify as "military-civil fusion enterprises" (军民融合企业). But even non-stateowned companies tend to jointly develop products with legacy defense SOEs, or base their business model around supplying them with software and equipment. The typical modern, private Chinese military AI company is:

- Founded by STEM graduates from elite universities in coastal provinces;
- Headquartered in a commercialization enclave or innovation park run by a university or the local CCP Science and Technology Commission;
- Engaged with researchers at defense-affiliated universities and research laboratories; and
- Sustained by contracts from public security bureaus, PLA units, and major defense SOEs.

LIMITATIONS OF U.S. EXPORT CONTROLS

U.S. policymakers regularly voice concerns that technology produced in the United States may be exfiltrated and deliberately or inadvertently accelerate Chinese military modernization. The U.S. government has adopted several policies designed to curtail the Chinese defense industry's access to equipment, personnel, information, and capital, especially where AI is concerned.¹⁶⁶ Since 1989, the United States has prohibited arms sales to China, and today the U.S. government presumes denial for license applications of items relevant to national security (NS items) to known military end-users in China.¹⁶⁷ Additional statutes place restrictions on specific companies:

- The Entity List (EL) published by the U.S. Department of Commerce's Bureau of Industry and Security restricts the ability of U.S. firms to sell or supply technology or intellectual property to specific institutions abroad, including some individuals and institutions based in China.¹⁶⁸
- The Chinese Military-Industrial Complex Companies List (NS-CMIC List) published by the Department of the Treasury's Office of Foreign Assets Control restricts the ability of U.S. persons to make securities investments or own stock in certain Chinese military companies, pursuant to Executive Order 13959.¹⁶⁹

 The List of Chinese Military Companies (NDAA Sec. 1260H List) published by the Department of Defense is mandated by the FY2021 National Defense Authorization Act, and exists to inform Americans of companies that may be connected to the Chinese military.¹⁷⁰ Subsequent Executive Orders have extended OFAC investment restrictions to include companies on the Sec. 1260H List.¹⁷¹

Although tens of thousands of Chinese companies are licensed to supply the PLA with equipment, very few are found on any of these three U.S. export control or sanctions lists. Of the 273 known AI equipment suppliers in our dataset, just 8 percent (22) face specific limitations set by the U.S. Departments of Commerce, Treasury, or Defense. At times, lapses in due diligence and situational awareness may permit the Chinese military and defense industry to access U.S. technology and capital.¹⁷²

FIGURE 10



Portion of Known PLA AI Equipment Suppliers Named in U.S. Export Control or Sanctions Lists

Source: CSET corpus of PLA procurement activity (273 known AI equipment suppliers).

Because most institutions that supply AI-related equipment are new and not subject to end-use controls, the Chinese military is frequently able to access or acquire technology from abroad, including from the United States. Some Chinese suppliers make a business out of sourcing foreign data or components and reselling them to sanctioned Chinese defense companies or PLA units. Beijing Zhongtian Yonghua Technology Development Co., Ltd. (Zhongtian Yonghua; 北京中天永华科技发展有 限公司), for example, is not currently listed in any U.S. sanctions regime. In August 2020, it was awarded a contract to supply intelligent sensor equipment to CASC, which the DOD designates as a Chinese military company.¹⁷³ A Chinese online business directory entry for Zhongtian Yonghua says that it is "mainly engaged in the agency and sales of various imported instruments and meters," and specifies that it is primarily a distributor of instrumentation equipment produced by companies in the United States (Agilent, Fluke Corporation, and Testo Inc.) and Japan (Hioki Corporation and Kyoritsu Electrical Instruments Works, Ltd.).¹⁷⁴ Multiple companies engage in similar activity, and some examples are included throughout this report.¹⁷⁵

5 What the PLA's Buying Habits Say About Its Battle Plans

P rocurement data offers a detailed, if incomplete, picture of how the PLA may use AI in future warfare. By comparing trends in purchasing records to long-standing themes observed in theoretical writings, research papers, and news reporting, we conclude that the PLA is interested in using AI to erode the U.S. advantage in undersea warfare and to jam U.S. sensor and communication networks. These aspirations are particularly relevant for U.S. policymakers and defense planners as they respond to mounting Chinese threats to Taiwan and other partners in the Indo-Pacific.¹⁷⁶

ERODING THE U.S. ADVANTAGE IN UNDERSEA WARFARE

The PLA's adoption of AI appears focused in part on overcoming its significant disadvantages in undersea warfare. Ten years ago, the PLAN had "very limited ASW [anti-submarine warfare] capabilities and [appeared] not to be making major investments to improve them"; and more recent assessments have concluded that floating mines and active sonar would likely prove ineffective against U.S. submarine forces operating in or near the Taiwan Strait.¹⁷⁷ To compensate, the PLAN commissioned the construction of an "Underwater Great Wall" (水下长城) acoustic sensor network in 2017, and has since rapidly expanded its diesel submarine force.¹⁷⁸ Today the PLA appears to be making significant investments in AI-enabled systems, such as A/UUVs, A/USVs, and undersea ISR systems, which could challenge U.S. and allied submarine forces in a crisis. In addition to the contract data presented earlier in this report, research published in 2021 by Jiangsu University of Science and Technology claims that "a full spectrum of unmanned submersibles has been initially

established in China," listing nearly a dozen AUV and UUV models of varying sizes.¹⁷⁹ Based on contract data and recent technology demonstrations, we assess that over the next five to 10 years, the PLAN will likely continue expanding its network of autonomous surface and undersea vehicles in an attempt to limit U.S. Navy access to the undersea space between the first and second island chains.¹⁸⁰

Public A/UUV contracts in our dataset are primarily for small- and medium-sized vehicles used for ISR, but English-language reporting has also shed light on some of the PLA's larger vessels, which are proliferating in number and growing in capability.¹⁸¹ Chinese AUVs have also set navigation records for depth and distance. In June 2020, the SIA's Haidou 1 (海斗一号) AUV successfully dove below 10,000 meters in the Mariana Trench; and in November, SIA's Sea-Whale 2000 (海鲸2000) AUV finished a 37-day continuous test, crossing 1,250 miles of the South China Sea.¹⁸² Despite the PLA's apparent progress in *testing*, however, prior CSET analysis has shown that "the state of the current technology, the complexity of antisubmarine warfare, and the sheer scale and physics-based challenges of undersea sensing and communications all suggest these systems have a long way to go."¹⁸³ Given limitations in battery life and the robustness of computer vision systems, it remains to be seen whether the PLA's expanding AUV force will materially change the undersea balance of power.

JAMMING AND BLINDING U.S. INFORMATION SYSTEMS

In conjunction with modernizing equipment, the PLA is developing new concepts of operations oriented around systems confrontation and systems destruction warfare, in which "warfare is no longer centered on the annihilation of enemy forces on the battlefield," but "won by the belligerent that can disrupt, paralyze, or destroy the operational capability of the enemy's operational system."¹⁸⁴ For example, an electronic warfare textbook published by NUDT emphasizes that "the U.S. military's combat command, military deployment, and joint operations are extremely dependent on battlefield information network systems," and prescribes that, "once the battlefield communication network is broken . . . the entire battlefield information network system (C4ISR system) will be severely damaged, destroyed, or even paralyzed."¹⁸⁵ Approximately 8 percent of public procurement projects in our dataset (29) are related to information and electronic warfare, many of which focus on jamming or blinding enemy sensor networks and using AI for cognitive electronic warfare. Examples of such equipment contracts are outlined in Table 4.

TABLE 4 Select AI-Related Electronic Warfare Contracts Awarded by PLA Units in 2020

TRANSLATED PROJECT NAME	MUCD	PROBABLE AFFILIATION WITHIN THE PLA
Autonomous and controllable transformation of software configuration	Unit 63796	PLASSF Xichang Space Launch Center
management system		
Optical fiber line automatic switching protection devices and optical	Unit 66389	PLASSF (Central Theater Command)
amplifier equipment		Information and Communications Brigade
Power amplifier and smart pressurizer	Unit 63751	PLASSF Base 26 Tracking and
		Communications Office
Enclosed space automatic frequency modulation device	Unit 63672	PLASSF Northwest Academy of Nuclear
		Research
Research on key test technology for microwave reconnaissance jamming	Unit 63871	Huayin Conventional Munitions Test and
UAV		Training Base
Environmental noise intelligent collection terminal	Unit 63811	PLASSF Wenchang Space Launch Center
Algorithm demonstration software for cooperative sensing of radar	Unit 93209	PLAAF Research Academy
targets; credible detection and dynamic evolution of electromagnetic		
environment		

Source: CSET corpus of PLA procurement activity (seven EW contracts awarded by identifiable PLA units).

Cyberattacks, data manipulation, and electromagnetic spectrum interference are key components of the PLA's systems confrontation strategy. In 2020, several PLA units and state-backed research institutions awarded contracts for "microwave reconnaissance jamming drones" and "electromagnetic weapon" payloads that can be attached to swarms of small UAVs and flown into enemy airspace.¹⁸⁶ PLA thinkers also emphasize the need to "disrupt or block the enemy's command and decision-making to ensure one's own decision-making advantage," and point to the U.S. Joint Enterprise Defense Infrastructure (JEDI; now the Joint Warfighting Cloud Capability) as a likely locus of systems confrontation.¹⁸⁷ "In the 'combat cloud' system," write PLA National Defense University professors Zhang Xiaotian and Luo Fengqi, "information and algorithms are key strategic resources, and the opposing parties will inevitably engage in information confrontation and algorithmic warfare in the 'cloud.'"¹⁸⁸

Fundamental Tensions in Chinese Military Modernization

espite the PLA's demonstrable progress in adopting AI, three points of tension will define its continued push toward intelligentization in the 2020s and beyond. These include the vulnerability of C4ISR networks; dependence on foreign computer chips; and disagreements over the development of lethal autonomous weapon systems.

BREAKING THE COMBAT CLOUD IT STRIVES TO EMULATE

The first tension concerns the PLA's plan to exploit U.S. battle networks while developing its own. Having watched and learned from the U.S. experience in Afghanistan, Iraq, Kosovo, and Libya, the PLA is investing heavily in its own networked C4ISR systems, many of which feature elements of AI.¹⁸⁹ The PLA's vision for an intelligentized force is based in large part on U.S. military concepts like network-centric warfare, Mosaic Warfare, and the notion of a "combat cloud."¹⁹⁰ In particular, PLA thinkers cite the need to "cloudify" (云化) their combat systems to speed up the observe-orient-decide-act (OODA) feedback loop first coined by U.S. Air Force Colonel John Boyd.¹⁹¹ By emulating U.S. integration of sensor arrays and weapons platforms, the PLA aims to develop "'ubiquitous networks' (泛在网络) that will shorten the distance between perception, judgement, decision-making, and action," and brace itself for the guickened tempo of modern warfare.¹⁹² "As the pace of war accelerates," write PLA science and technology analysts Shi Chunmin and Tan Xueping, "combat time will be calculated in seconds."¹⁹³ They go on to note that Link 16, the communications and tactical data transmission system used by the United States, NATO, and coalition forces, allows a delay of just seven milliseconds.¹⁹⁴

But ubiquitously connecting sensors and shooters has created new vulnerabilities for the United States, which PLA leaders recognize and plan to exploit. U.S. defense planners often lament that exquisite ISR and communication systems make for "big, fat, juicy targets,"¹⁹⁵ and worry that in a crisis, adversaries will jam, blind, and hack the networks that bind U.S. assets together.¹⁹⁶ As previously outlined, PLA leaders are forging a new array of operational concepts predicated on "systems confrontation" and "systems destruction," which are specifically designed to take advantage of U.S. vulnerabilities.¹⁹⁷ But it is not clear how the PLA plans to make its own networks resilient to the kinds of exploits it envisions deploying against the United States. One solution may be to develop edge applications—such as predictive maintenance systems for satellites or target recognition systems for autonomous underwater vehicles—can be found among the PLA's public AI contracts.¹⁹⁹

ENSURING ACCESS TO FOREIGN SEMICONDUCTORS

The second tension concerns the supply of advanced computing products at the heart of China's intelligentization strategy. Chinese leaders are acutely aware of the PLA's wholesale dependence on AI chips designed by U.S. companies and produced in Taiwan and South Korea. Although computing hardware was not the original focus of our procurement analysis, further investigation reveals that the PLA has awarded myriad contracts for U.S.-designed computer chips useful for training machine learning systems.²⁰⁰ One paper by researchers from China's Ministry of Industry and Information Technology estimates that "more than 90% of China's high-end chips rely on imports," including "100% of DRAM memory, 99% of CPUs, and 93% of MEMS sensors."²⁰¹ The Chinese government has constructed multibillion-dollar guidance funds to promote the country's domestic semiconductor manufacturing industry, but these initiatives are rife with corruption, and it is not yet clear whether they will succeed.²⁰²

In the meantime, U.S. policymakers have crafted a variety of export controls and sanctions designed to limit the Chinese military's access to leading-edge AI chips.²⁰³ Large Chinese corporations such as Huawei have had to cease production of some product lines and have seen large shortfalls in revenue as a result of U.S. sanctions.²⁰⁴ However, this study finds that few of the PLA's AI equipment suppliers just 8 percent of the companies in our dataset—face specific barriers to acquiring U.S. equipment, information, and capital. PLA units and defense SOEs continue to procure systems that use leading-edge NVIDIA and Xilinx processors, and sometimes purchase these processors, themselves, through intermediary companies. Moreover, in 2021, U.S. companies have cooperated on AI-related research projects with Chinese businesses that supply the PLA with AI systems and equipment.²⁰⁵ The PLA's continued access to U.S. and other foreign technology is not guaranteed. The United States and its allies may yet take additional steps to impede Chinese military access to the data, hardware, and personnel required to build an intelligentized force. If such policies were to create a significant shortage in advanced semiconductors, and if China continues to struggle with indigenizing segments of its own chip industry, it would likely slow or impair the PLA's intelligentization strategy. But U.S. experts warn that a decision to effectively cut off Chinese military access to foreign advanced semiconductors could inadvertently fuel China's homegrown chipmaking industry, and should not be taken lightly.²⁰⁶

DECIDING THE ROLE OF LETHAL AUTONOMOUS WEAPONS

The third tension concerns the development of LAWS. The Chinese government has famously shown a Janus face to LAWS, publicly calling for a ban on such weapons while privately carving out a legal defense for their development.²⁰⁷ As in the United States, different factions within the Chinese military and defense industry harbor different attitudes toward LAWS.²⁰⁸ A 2020 CSET study found that PLA officers and defense industry engineers are worried AI may undermine strategic stability by reducing the capability of Chinese air defenses, increasing the vulnerability of Chinese command and control systems, or degrading the PLA's available time to respond to an attack.²⁰⁹ Some PLA officers appear legitimately disturbed by LAWS, and caution against a future characterized by smart weapons. In 2021, for example, three PLA researchers responded to reports that a Turkish "Kargu-2" quadcopter had autonomously attacked a human target in Libya, writing that fully-autonomous weapon systems present "not only a lack of moral responsibility, but also a serious challenge to international humanitarian law and international peace and security."²¹⁰ This perspective is not uncommon, and PLA officers often voice similar concerns in research papers and think pieces.

Others in the PLA are more sanguine about Al's utility on the battlefield, and believe that technology will inevitably increase the operational tempo of war such that, unaided by fully automated systems, humans will be incapable of responding to imminent attack.²¹¹ Liu Peng, a member of China's Cloud Computing Expert Committee and professor at the PLA University of Science and Technology, wrote in 2020 that "at present, most intelligent combat decision-making systems are semi-autonomous systems with humans in the loop," but that the PLA should "introduce learning into the combat decision-making process to achieve mutual error correction, complementarity and efficiency."²¹² Defense officials in the United States have advanced similar arguments.²¹³ Among other issues, the fast pace of technology development, lack of appetite for safety measures, and general lack of trust between the United States and China are giving rise to a security dilemma around Al development.²¹⁴

Despite the Chinese government's stated position against LAWS, it is clear that developing AI-based target recognition and fire control systems is an objective of some PLA and government-backed research centers.²¹⁵ Computer vision is by far the most active subfield of the PLA's public AI research portfolio, and the share of PLA-sponsored research papers dedicated to "military target recognition" (军事目 标识别) increases each year.²¹⁶ By itself, AI-based ATR does not constitute a lethal autonomous weapon system. Yet target recognition remains an integral step in the detect-to-engage sequence, and AI-based ATR is inseparable from "AI weapon" (人工智能武器) concepts described by the Chinese military.²¹⁷ In August 2020, The Paper, a well-circulated state-run media outlet, reported that using AI-based ATR to "equip a missile with a 'super-powerful brain' to achieve precision strikes" is the "lifelong pursuit" of NUDT's State Key Laboratory for Automated Target Recognition (自动目标识别国家重点实验室).²¹⁸ ATR research published by the Dalian Naval Academy is similarly explicit, noting that "AI and computer vision technology provides new technical support for shipborne missiles to attack all kinds of sea and land targets accurately" and, "in the process of target recognition, using deep learning algorithms is an effective way to improve the accuracy of missiles attacking taraets."219

Ultimately, trends in procurement records, research publications, and media reports indicate that the Chinese military and defense industry are developing Albased target recognition and fire control systems, which are essential components of LAWS. Although public information about their research is limited, the NUDT State Key Laboratory for Automated Target Recognition and the CAS Shenyang Institute of Automation appear to be key institutions driving LAWS development in China. Combined with the Chinese government's extraordinarily narrow definition of LAWS, this emphasis on Al-enabled ATR research suggests that the PLA may yet develop weapons capable of autonomously detecting and engaging human targets.²²⁰

Conclusion

he share of procurement activity dedicated to AI is one indication that China's military aspirations extend beyond peripheral security concerns. In the 2020s, intelligentization has become the chief focus of Chinese military modernization, with AI-related systems and equipment already accounting for 5 percent of public contracts awarded by the PLA's five main service branches. This report's narrow look at public procurement records confirms that the PLA awarded AI contracts worth at least \$49 million from April to November 2020, and that it may spend more than \$1.6 billion on AI-related systems and equipment each year.

Investing in AI is part of the PLA's longstanding mission to become a "world-class" military that is "equal to, or in some cases superior to, the United States."²²¹ PLA leaders frequently compare their own capabilities to those of the U.S. military, and public writings from 2021 refer explicitly to degrading and exploiting U.S. information systems. While much of the PLA's focus on systems confrontation and systems destruction appears to still be in early stages of development, a plurality of its equipment contracts are related to information operations and electromagnetic spectrum dominance. Within the next five to 10 years, the Chinese military will likely continue investing in AI to erode the U.S. advantage in undersea warfare; and will seek opportunities to jam, blind, and hack U.S. military information systems.

Contrary to conventional wisdom about bloating in the Chinese defense industry, we find that the PLA has made significant progress engaging the private Chinese technology sector to acquire AI systems and intelligent equipment.²²² Most of the PLA's AI equipment suppliers today are not legacy defense SOEs, but small, private companies that specialize in software development, data management, and IoT device design.²²³ Some Chinese AI companies in our study self-identify as "military-civil fusion enterprises," and benefit from equipment, personnel, information, or capital provided by the state. Others are private technology companies that have welcomed the PLA as a customer.

The PLA's progress toward intelligentization will become increasingly important for the United States in the 2020s as tensions between the two countries continue to rise. In its attempts to harness AI for military advantage, the PLA will face important questions, for example, about decoupling supply chains and developing lethal autonomous weapons. It remains to be seen whether the Chinese military will succeed in becoming a fully intelligentized and world-class military force, but one thing is certain: AI is no longer just an *emerging* technology. Rather than speculate about its far-future implications, defense planners and policymakers would do well to heed the words of science fiction writer William Gibson: "The future is already here—it's just not evenly distributed."²²⁴

Appendix I: Classifying "Intelligent" Equipment Contracts

Tenders in CSET's PLA procurement dataset include four variables. The authors manually extracted another three fields where information was available, and subjectively coded two other fields based on each tender's Name and Content. All nine variables considered in this study are listed below.

Name. Each of the 66,207 tenders in our dataset has a name that offers some information about the purchase. Of them, 45,868 are "public" (公开) and include more detailed information fields, listed below.

Public Unit. Each public tender also mentions an agency or department for which the tender is being filed, typically a large branch of an organization, such as "Strategic Support Force."

Information Type. Public tenders in our dataset included requirements, inquiries, bid solicitations, and notices of contract awards, annulments, and modifications, among other types of information. Of the 45,868 public tenders in our dataset, 18,354 were contract award notices.

Content. Each public tender listed additional, detailed information in the body of the announcement text. The 343 AI-related contracts in our dataset variously included three kinds of information:

End user: The PLA unit or state-owned defense company that intended to use the technology, specified in 232 cases.

Supplier: The company or research institution that successfully won the contract to supply the equipment, specified in 331 cases.

Contract value: The total value of the contract, specified in 205 cases.

Al Relevance. After using fourteen keywords to identify 523 "intelligent" equipment contracts, the authors manually examined project names and descriptions to verify that each was actually related to AI.²²⁵ For the purpose of this paper, the authors included off-the-shelf UAVs and intelligence-related subsystems, intelligent or automatic weather monitoring, and intelligent power distribution as "AI-related," but excluded UAV molds used for manufacturing, wing parts, and "intelligent" or "automatic" systems with no clear connection to AI, such as "intelligent welding systems" and "automatic drilling equipment." 180 contracts were excluded from analysis, leaving 343 AI-related contracts.

Application. The authors then manually categorized each of the 343 AI contracts into one of seven different applications: (1) Intelligent and Autonomous Vehicles; (2) Intelligence, Sur-

veillance, and Reconnaissance; (3) Predictive Maintenance and Logistics; (4) Information and Electronic Warfare; (5) Simulation and Training; (6) Command and Control; and (7) Automated Target Recognition. Tenders that did not fit in any of these seven categories were marked "Other." Categorizing each contract was necessarily a subjective, iterative process. To make the labels more robust, the authors used the Elicit AI research assistant to check their manual coding.²²⁶ Elicit uses language models to code data. For each contract, Elicit used the manual labels for some of the other contracts as training data, then labeled each "intelligent equipment" contract in the dataset. Initially, Elicit agreed with author coding in 50 percent of cases. After one author reviewed the disagreements, recoded some of the data, and reran Elicit, agreement increased to 62 percent. For remaining disagreements, author judgment superseded that of Elicit. Table 5 lists 10 examples of how the authors coded "intelligent" equipment contracts.

TABLE 5 Examples of Coded "Intelligent" Equipment Contracts

TENDER NAME (CHINESE)	TENDER NAME (ENGLISH)	COUNTS AS AI?	APPLICATION(S)
"XX人工智能典型应用场景设计及关键共性技术需求分析"单一来源公示	"XX design and artificial intelligence typical application scenarios demand analysis of key general use technologies" sole source announcement	Yes	Other
"人工智能技术在火箭军应用研究——智能机器人技术在火箭军XX类工程应用研究"项目外协	"Research on military applications of AI technology for rockets - intelligent robotics technology in rocket military XX class engineering applied research project" outsourcing	Yes	Autonomous Vehicles (Munitions)
"效应场重建技术研究" "基于地震波成 像原理弹体侵彻深度算法研究" 2项服务类 集中打包采购项目	Two service-type pooled and packaged procurement projects on "research on effect field reconstruction technology," and "research on projectile penetration depth algorithms based on the principles of seismic wave imaging"	Yes	Autonomous Vehicles (Munitions)
"智能协处理加速卡加工和申威平台测 试"招标结果公告事	"Intelligent co-processor accelerator card processing and Shenwei [CPU and operating system] platform testing" tender announcement	Yes	Other
"航天装备智能巡检系统关键技术研究" 评标结果公示	Announcement of bid evaluation results for the "study of key technology for an aerospace equipment intelligent inspection system"	Yes	Predictive Maintenance and Logistics
"巡航弹与无人机仿真系统开发"外协采 购项目中标公告	"Cruise missile and UAV simulation system development" outsourcing procurement bid announcement	Yes	Simulation and Training
1903项目无人机平台分系统竞争性谈判采 购中标公告	Announcement of the winner of the Project 1903 UAV platform subsystems competitive negotiation procurement tender	Yes	Autonomous Vehicles (Air)
2020-6356燃气涡轮低污染排放预测方法 研究与验证中标公告	Announcement of the winning bid for 2020-6356 low- emission gas turbine prediction methods research and validation	No	N/A
23车间半自动化喷丸设备采购	Procurement of Workshop 23: semi-automated blasting equipment	No	N/A
500kV二极管实验研究平台自动化附属系统项目中标候选人公示	Announcement of finalists for the 500kV diode experimental research platform automated subsystems project tender	No	N/A

Source: CSET corpus of PLA procurement activity, with input from Elicit.

Appendix II: AI-Related Purchases by Service Branch

Relative to defense SOEs or military academies, contract data indicates that the PLA's five service branches are extraordinarily active in adopting AI. The Strategic Support Force, Ground Force, Navy, Air Force, and Rocket Force were responsible for awarding just 20 percent (3,726) of the public contracts in our dataset, but 55 percent (188) of those related to AI. That said, AI-related equipment contracts constitute just 5 percent of all the equipment contracts awarded by PLA service branches in our April–November 2020 dataset.

TABLE 6

Number of Equipment Contracts Awarded by PLA Service Branches, April-November 2020

PLA SERVICE BRANCH	TOTAL NUMBER OF EQUIPMENT CONTRACTS	NUMBER OF AI-RELATED EQUIPMENT CONTRACTS	PORTION OF PUBLIC CONTRACTS RELATED TO AI
Strategic Support Force	1,674	65	3.9%
Ground Force	682	58	8.5%
Navy	1,102	51	4.6%
Air Force	199	10	5.0%
Rocket Force	69	4	5.8%
Total	3,726	188	5.0%

Source: CSET corpus of PLA procurement activity.

The PLA's five main service branches are most focused on using AI to improve navigation and data management in autonomous vehicles; to improve the speed and scale of intelligence collection and dissemination; and to enhance logistics through predictive maintenance. However, each of the services tend to focus on different applications of AI. For example, relative to other branches, the PLASSF is most interested in purchasing AI technology that can be used in information and electronic warfare, whereas the Ground Force tends to purchase more AI solutions for predictive maintenance and logistics. Each of the PLA's service branches are focused on using AI in intelligent and autonomous vehicles and for predictive maintenance, but ISR and information and electronic warfare are also common applications.

PLA STRATEGIC SUPPORT FORCE (PLASSF)

As the service branch responsible for space, cyber, and information warfare, the PLA Strategic Support Force is the most active in procuring AI-related technologies and applications. Of the PLASSF's 65 public AI-related contracts, most were related to intelligence, surveillance, and reconnaissance (ISR); information warfare, and autonomous vehicles.

FIGURE 11



Number of AI Equipment Contracts Awarded by PLA Service Branches, April-November 2020

Source: CSET corpus of PLA procurement activity (188 contracts awarded by service branches).

Public procurement records indicate that the PLASSF is focused on using AI for intelligence and data fusion, especially for applications such as weather monitoring, earth imagery, and battle damage assessment. One of its most expensive public contracts in 2020, valued at \$1.1 million, was for an automatic high-altitude image detection system provided by Nanjing Britronics Machinery Co., Ltd. (南京大桥机器有限公司). The company produces more than 60 types of weather radar and satellite imaging equipment, including an "intelligent high-altitude image detection system" capable of measuring meteorological phenomena between 36 and 200 kilometers above ground.²²⁷ In July 2020, PLASSF Unit 63672 also bought a UAV-borne "frag-

ment distribution measurement system" from Xi'an Kuaizhou Measurement and Control Technology Co., Ltd. (西安快舟测控技术有限公司), an application particularly useful in battle damage assessment.²²⁸ The General Staff Department's Survey and Mapping Research Institute in Xi'an (Unit 61540) was another significant purchaser of AI-enabled ISR equipment within the PLASSF, awarding various contracts for intelligentized forecast correction systems, high-precision positioning algorithms, and high-resolution ocean and climate modeling software.²²⁹ The PLASSF envisions using AI for information and electronic warfare, in applications ranging from multilingual natural language processing to public opinion monitoring, cyber threat intelligence, and adaptive radar jamming. For example, the PLASSF's Engineering Information University awarded various contracts for an AI-based "internet public opinion monitoring and clustering system," "intelligent network traffic analysis system," and a "cyber threat intelligence early warning platform" throughout 2020. Previous research suggests that PLASSF Base 311 (Unit 61716) carried out social media manipulation ahead of Taiwan's 2018 local elections.²³⁰ One of the PLASSF's repeat contractors, EverSec, advertises services for petabyte-scale data storage and processing, AI-based open source data mining, and internet blocking and censorship protocols.²³¹ In addition, multiple PLASSF units have awarded contracts for AI-based fiber optical line protection switches, network amplifiers, and automated frequency modulation systems used in cognitive electronic warfare.²³²

The PLASSF is also awarding contracts for autonomous vehicles, both individual platforms for logistics and sustainment and swarms with potential combat applications. Public reporting indicates that the PLASSF has been experimenting with using UAVs to resupply troops from Lhasa, Tibet, for operations near the Line of Actual Control with India.²²³ The service's procurement records indicate that it has purchased several UAVs and intelligentized simulation systems from Lyncon Tech (西安羚控电子科技有限公司), a leading provider of Chinese drone swarm technology, specifically for use in or near Lhasa. In June 2020, the PLASSF's Equipment Command and Technology Academy (Unit 63628) awarded a \$630,000 contract to AOSSCI Technology for a UAV simulation and training center.

PLA GROUND FORCE (PLAGF)

After the PLASSF, the Ground Force has displayed the most interest in adopting AI, and awarded 58 of the public AI-related contracts in our dataset. Previous studies show that academic AI research sponsored by the PLAGF tends to focus on improving unmanned or robotic systems' ability to navigate difficult terrain, and this priority is also reflected in the service's public procurement records.²³⁴ Of the 58 AI contracts the PLAGF awarded in 2020, the plurality were related to autonomous vehicles, predictive maintenance, and electronic warfare.

The PLAGF is most focused on using AI in autonomous aerial and ground vehicles. Valued at \$890,000, its single most expensive public AI contract involved developing a UAV swarm, to be fulfilled by CASC Shenzhou Flight Vehicle Co., Ltd. (航天神舟飞行器有限公司). The company

holds several patents related to swarm technology and UAV-based applications of the Beidou satellite constellation.²³⁵ Other PLAGF contracts were related to ultra-short-range control link modules and non-line-of-sight transceivers for unmanned and autonomous UAVs. The PLAGF is also leveraging AI for ground vehicles, and in June 2020 awarded a contract to Beijing Laser Bofeng Information Technology Co., Ltd. (北京雷神博峰信息技术有限责任公司), "a major supplier of vehicle-mounted Beidou information terminals and intelligent control systems for petrol vehicles," to develop an autonomous tanker truck.²³⁶ The company specializes in autonomous "IoT vehicles" for logistics and transportation.²³⁷

Predictive maintenance is another clear priority for the PLAGF. Throughout 2020, it awarded contracts for "intelligent supply chain" networks, ammunition shell quality detection software, and equipment failure and maintenance prediction systems. Among these, its most expensive project was a \$275,000 contract for a "self-organized network intelligent packaging system" for bullets. The contractor, Chongqing Jialing Special Equipment Co. (重庆嘉陵特种装备有限 公司), is a wholly owned subsidiary of the defense SOE China North Industries Corporation (NORINCO).²³⁸

To a lesser degree, the PLAGF is also leveraging AI for electronic warfare. In September 2020, PLAGF Unit 63871 awarded Xi'an Ruiweishen Electronic Technology Co., Ltd. (西安睿维申电子 科技有限公司) a \$160,000 contract to develop a "microwave reconnaissance jamming drone." In 2013, the company had won a national Torch Program award for a high-performance digital signal processing platform.²³⁹ The PLAGF awarded a similar contract to TIYOA Aviation (河北天遥航空设备科技有限公司) to develop "electromagnetic weapon" payloads aboard small UAVs. The company specializes in intelligent control systems, video surveillance, and small drone applications.²⁴⁰

PLA NAVY (PLAN)

The Navy is just behind the Ground Force as the PLA's third-most active branch in adopting AI, and awarded 51 of the public AI-related contracts in our dataset. Most contracts were related to autonomous vehicles, ISR, and other applications not neatly captured in our taxonomy. Naval Aviation University (海军航空大学) was the PLAN unit most active in awarding AI contracts, accounting for nearly one third (15) of those in our dataset. Valued at \$1.3 million, the PLAN's most expensive public AI contract involved retrofitting unmanned aerial vehicles with multi-tasking pods, to be filled by AECC Guizhou Liyang Aviation Power Co., Ltd. (中国航发贵 州黎阳航空动力有限公司). Several other PLAN contracts were related to sea floor mapping and AUV development.

Intelligence, surveillance, and reconnaissance is another major focus of the PLAN's AI procurement. Several contracts mention fusing automatic identification system (AIS) ship positioning data to improve situational awareness for submarine and surface fleets. For example, in June and July 2020, the PLAN Submarine Academy (海军潜艇学院) purchased bulk AIS ship tracking data from Elane Inc. (亿海蓝 (北京) 数据技术股份公司) and tasked the company with bulk AIS processing.²⁴¹ Elane runs *shipfinder.com*, a global shipping database with "millions of global shipping and related users."²⁴² The company advertises "real-time monitoring of all satellite AIS ship positions worldwide," updated every five minutes, using a constellation of 108 Orbcomm satellites.²⁴³ Although Orbcomm is a U.S. satellite company, Elane's AIS service is marketed for Chinese users only. Other PLAN units have struck similar contracts to purchase AIS data from Yantai Huadong Electron Technology Co., Ltd. (Huadong Elec-Tech; 烟台华东电 子软件技术有限公司) and the China Transport Telecommunications & Information Center (CTTIC) Information Technology National Engineering Laboratory.²⁴⁴

The PLAN's other AI contracts involve building libraries of undersea sonar signatures and using deep learning to stitch them together. In July 2020, the PLAN's Naval Aviation University awarded Harbin Engineering University with a contract for an "automatic sea-based target detection" system based on "deep learning image recognition." Several researchers at HEU have pioneered an AI-based "seabed image mosaic system," hold relevant patents, and regularly conduct research on the topic.²⁴⁵

PLA AIR FORCE (PLAAF)

With just ten public AI contracts, the Air Force appears much less interested in AI procurement, relative to the Ground Force or Navy. Its AI purchases are mostly related to autonomous vehicles, predictive maintenance, and electronic warfare.

Most public AI research papers sponsored by the PLAAF are related to autonomous flight, a trend that extends to its procurement records.²⁴⁶ Several contracts were related to intelligent flight decision control (智能驾驶决策控制), technology primarily developed by Northwestern Polytechnical University and research institutes subordinate to CASC. One of the primary companies involved in supplying autonomous UAVs to the PLAAF is ChunYi UAV (北京淳一航空科技有限公司), a Beijing-based provider of autonomous aerial and surface-sea vehicles.²⁴⁷ In September 2020, the PLA Air Force paid to lease and operate some of ChunYi UAV's autonomous aerial vehicles. The company's website specifies that its products are useful for "counterterror-ism and aerial dogfight weapons testing and training."²⁴⁸

Some of the PLAAF's more expensive AI contracts are related to predictive maintenance for communication networks. In April 2020, for example, China Eracom Contracting and Engineering Co., Ltd. (中时讯通信建设有限公司), a fiber-optic cable company, won a contract for an "intelligent operation and maintenance management system." That month, the PLAAF awarded a similar contract to China Iconic Technology Co, Ltd. (中徽建技术有限公司), a twice-removed subsidiary of China Telecom, for an intelligent phone network system.

Finally, like the PLAGF, the PLAAF is also interested in using AI for electronic warfare and electromagnetic spectrum dominance. In October 2020, the PLAAF's Air Defense Early Warning Equipment Department (Unit 93209) awarded China Civil Aviation University a contract for "trusted radar target detection" and "research into the dynamic evolution of the electromagnetic environment," using algorithms to enhance battlefield situational awareness and plot the locations of friendly radar units.

PLA ROCKET FORCE (PLARF)

The Rocket Force is the least active service branch with respect to public AI procurement, awarding just four contracts from April to November 2020. The PLARF contracts included using AI to forecast maintenance and support resource consumption; as well as to develop intelligent robotics; a "smart communications warehouse"; and an autonomous, tethered UAV platform.

The PLARF awarded its largest AI contract to China Electronics Technology Corporation (CETC) for an autonomous, tethered UAV platform, to be supplied to the 613 Brigade in Shangrao City.²⁴⁹ Tethered drones are particularly useful for emergency response and communication, as an autonomous UAV can be towed alongside a ground vehicle or watercraft without the need for constant supervision or recharging.²⁵⁰ CETC's 54th Research Institute produces lines of fourand six-rotor tethered UAVs,²⁵¹ while the 7th and 23rd Research Institutes hold patents on UAV mooring cables.²⁵² Other Chinese companies have developed tethered UAVs for emergency communications, such as the DG-X10 and DG-M20.²⁵³

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