Battlefield Singularity:

Artificial Intelligence, Military Revolution, and China's Future Military Power

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Bold. Innovative. Bipartisan.

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ABOUT THE AUTHOR

Elsa B. Kania is an adjunct fellow with the Technology and National Security Program at the Center for a New American Security, where she focuses on Chinese defense innovation and emerging technologies, particularly artificial intelligence. Her research interests include Chinese military modernization, information warfare, and defense science and technology. She is an independent analyst, consultant, and co-founder of the China Cyber and Intelligence Studies Institute (CCISI), which seeks to become the premier venue for analysis and insights on China's use of cyber and intelligence capabilities as instruments of national power. Her prior professional experience includes the Department of Defense, the Long Term Strategy Group, FireEye, Inc., and the Carnegie-Tsinghua Center for Global Policy. Elsa is a graduate of Harvard College (*summa cum laude*, Phi Beta Kappa), where her thesis on the evolution of the PLA's strategic thinking on information warfare was awarded the James Gordon Bennett Prize. While at Harvard, she worked as a research assistant at the Belfer Center for Science and International Affairs and the Weatherhead Center for International Affairs. Elsa was a Boren Scholar in Beijing, China, and she is fluent in Mandarin Chinese.

NOTE ON METHODOLOGY

This paper draws upon an extensive review of the available Chinese-language, open-source resources relevant to understanding the military dimension of China's rise in artificial intelligence, including but not limited to media reporting, official government plans, academic articles by civilian and military scholars, technical publications, and other online resources. There is a listing of references included at the end of the paper. While not comprehensive, this initial report seeks to establish a baseline understanding of these issues and raise critical questions for future research and analysis.

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PREFACE

By Paul Scharre

Artificial intelligence (AI) is fast heating up as a key area of strategic competition. U.S. leaders have signaled that AI is a major component of the Defense Department's strategy to reinvigorate American military technological dominance.[1] In October 2016, the U.S. government released a "National Artificial Intelligence Research and Development Strategic Plan,"[2] one of three reports on AI issued by the Obama administration.[3] Other nations have similarly taken note of the transformative potential of AI. In July 2017, China released its own national-level AI development plan.[4] In September, Russian President Vladimir Putin observed, "whoever becomes the leader in this sphere [artificial intelligence] will become the ruler of the world."[5]

Home to many of the world's top AI companies, China is poised to be a major player in this unfolding competition. In this in-depth analytic report, CNAS adjunct fellow Elsa Kania explores China's strategy for developing and implementing AI technology for military applications. Drawing on open-source Chinese-language documents, Ms. Kania explains Chinese strategic thinking on AI and specific military applications that Chinese leaders envision. Her report is a must-read for national security professionals concerned about maintaining U.S. strategic advantage in an era of rapid technological change.

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EXECUTIVE SUMMARY

Although technological advantage has been a key pillar of U.S. military power and national competitiveness, China is starting to catch up in its quest to become a "science and technology superpower" (科技强国).[6] While the U.S. military possessed an early edge in technologies critical to information-age warfare, primacy in artificial intelligence (AI), likely integral in future warfare, could remain contested between the United States and China. Indeed, the Chinese People's Liberation Army (PLA) is pursuing advances in impactful and disruptive military applications of AI. Although this military dimension of China's rise in AI has remained relatively opaque, the available Chinese-language open-source materials reveal initial trends in PLA thinking and progress.[7]

The Chinese leadership is advancing an "innovation-driven" strategy for civilian and military development, aiming to become the world's "premier innovation center" in AI by 2030.[8] Certainly, a range of challenges, including serious shortcomings in human capital, may inhibit progress, and China presently continues to lag behind the United States in cutting-edge research and development. However, China's rapid rise and future trajectory in AI could be enabled by critical systemic and structural advantages, including likely levels of funding and investment, potential human talent resources, and massive amounts of data. AI is a high-level priority within China's national agenda for military-civil fusion (军民融合), and this strategic approach could enable the PLA to take full advantage of private sector progress in AI to enhance its military capabilities.[9]

Although the PLA's initial thinking on AI in warfare has been influenced by careful analysis of U.S. military initiatives, its approach could progressively diverge from that of the United States, based on its distinct strategic culture and organizational dynamics. The PLA anticipates that the advent of AI could fundamentally change the character of warfare, resulting in a transformation from today's "informatized" (信息化) ways of warfare to future "intelligentized" (智能化) warfare, in which AI will be critical to military power.[10] The PLA will likely leverage AI to enhance its future capabilities, including in intelligent and autonomous unmanned systems; AI-enabled data fusion, information processing, and intelligence analysis; war-gaming, simulation, and training; defense, offense, and command in information warfare; and intelligent support to command decision-making. At present, the PLA is funding a wide range of projects involving AI, and the Chinese defense industry and PLA research institutes are pursuing extensive research and development, in some cases partnering with private enterprises.

This could be the start of a major shift in the PLA's strategic approach, beyond its traditional asymmetric focus on targeting U.S. vulnerabilities to the offset-oriented pursuit of competition to innovate.[11] The PLA is seeking to engage in "leapfrog development" (跨越发展) to achieve a decisive edge in "strategic front-line" (战略前沿) technologies, in which the United States has not realized and may not be able to achieve a decisive advantage. The PLA is unlikely to pursue a linear trajectory or follow the track of U.S. military modernization, but rather could take a different path. Since the 1990s, the PLA has focused on the development of "trump card" (杀手锏) weapons that target vulnerabilities in U.S.

battle networks, seeking to develop, in the words of then-Central Military Commission (CMC) Chairman Jiang Zemin, those weapons that "the enemy is most fearful of."[12] This asymmetric thinking will likely persist in the PLA's approach to AI. For instance, the PLA may seek to use swarms to target and saturate the defenses of U.S. aircraft carriers. However, China is no longer in a position of technological inferiority but rather sees itself as close to catching up with and overtaking the United States in AI.[13] As such, the PLA intends to achieve an advantage through changing paradigms in warfare with military innovation, thus seizing the "commanding heights" (制高点) of future military competition.[14]

As the U.S. and China compete to innovate in AI, the trajectories of their respective advances will impact the future military and strategic balance. The PLA is acutely aware of the criticality of adapting to and capitalizing upon progress in AI, fearing the emergence of a 'generational gap' between its capabilities and that of the U.S. military, which is perceived as a powerful adversary (强敌) and thus the key metric for comparison.[15] Since China may possess the potential to equal or surpass the United States in this critical technology, the U.S. military must recognize the PLA's emergence as a true peer competitor and reevaluate the nature of U.S.-China military and technological competition.

As the PLA attempts to overtake, rather than just catch up with or match, U.S. progress in this domain, it will be vital to understand and take into account its evolving approach and advances. In particular, the PLA's capacity to leverage military applications of AI could prove distinctive due to its model of military-civil fusion, expansive concept of "intelligentization," and focus on AI-enabled command decision-making. Certain PLA thinkers even anticipate the approach of a "singularity" on the battlefield, at which human cognition can no longer keep pace with the speed of decision-making and tempo of combat in future warfare.[16] While recognizing the importance of human-machine collaboration, and likely concerned with issues of controllability, the PLA could prove less adverse to the prospect of taking humans 'out of the loop' to achieve an advantage.

Looking forward, the PLA's militarization of AI will influence the trajectory of this unfolding military revolution, presenting a unique strategic challenge to the United States. In response, the United States must work to formulate a long-term, whole-of-nation strategy to support critical determinants of national competitiveness in AI. While taking steps to mitigate illicit and problematic technology transfers, the United States should ensure that there is adequate funding for and investments in next-generation research and development, averting the risks of an "innovation deficit."[17] It is also critical to sustain and build upon the current U.S. competitive advantage in human capital through formulating policies to educate and attract top talent. However, the U.S. military must prepare for a future in which the United States may no longer possess technological predominance, particularly through focusing on the human factors and organizational capacity that are critical determinants of successful defense innovation.[18] As the intensification of military and strategic competition in AI could result in destabilizing arms race dynamics, the United States should also explore options to mitigate the risks to strategic stability that could result from great powers' pursuit of AI-enabled capabilities to achieve military advantage.

INTRODUCTION

"AI has become a new focal point of international competition. AI is a strategic technology that will lead the future…"[19]
— China's New Generation Artificial Intelligence Development Plan

Today's rapid advances in AI have introduced a new dimension of technological and strategic competition among great powers.[a] China intends to seize the initiative to become the "premier global AI innovation center" by 2030, potentially surpassing the United States in the process.[20] To date, the dynamism of Chinese private sector AI initiatives has been most clearly demonstrated by the evident progress of and intense competition among major Chinese technology companies – notably Baidu, Alibaba, and Tencent – and a dynamic start-up ecosystem, including iFlytek, a leader in speech recognition technology, and SenseTime, which focuses on innovative computer vision.[21] Certain of these enterprises have become increasingly competitive with their U.S. counterparts. For instance, after Microsoft announced that its speech recognition software surpassed human-level language recognition in October 2016, Andrew Ng, then head of research at Baidu, tweeted: "We had surpassed human-level Chinese recognition in 2015; happy to see Microsoft also get there for English less than a year later." [22] Indeed, Baidu has become a global leader in speech recognition and self-driving cars, launching DuerOS, its voice interaction system, and Apollo, an autonomous driving platform, while spending billions on research and development.[23] As China pursues a national strategy of military-civil fusion (or civil-military integration, 军民融合),[b] the PLA may have greater capacity to leverage relevant private sector advances for military applications.

As China catches up with and attempts to surpass the United States in AI, it will be critical to evaluate and understand the trajectory of Chinese advances, particularly in the domain of national defense. As its approach evolves along with the underlying technologies, the PLA may leverage AI in unique and perhaps unexpected ways, likely less constrained by the legal and ethical concerns prominent in U.S. thinking.[c] The PLA's potential structural advantages in exploiting synergies of this dual-use technology, given the closer

[a] For the purposes of this report, I use the term "AI" to refer to narrow (rather than general) AI and associated techniques, including expert systems and machine learning, such as neural networks and deep learning, along with related disciplines, such as computer vision, image recognition, natural language processing, robotic swarms, and human-robot interaction. When relevant, I specify the particular technique or discipline that I am discussing.

[b] China's strategy of military-civil fusion (军民融合) seeks to leverage synergies among civilian and defense industrial bases in order to support military and commercial advances and applications, including through sharing resources and institutionalizing linkages among the PLA, defense industry, private sector, and academia. This approach of military-civil fusion, elevated to the level of national strategy, enables China to transfer dual-use technological advances to build up military capabilities while promoting economic growth.

[c] I do not mean to imply, by referring to "the PLA," that the views of its leadership on these issues are necessarily unified or cohesive at present. At this point, the PLA does not appear to have a formal, official strategy for AI, beyond the high-level focus on military innovation. It is likely that views differ among technical and command officers. As such, this report attempts to evaluate available perspectives, based on open-source resources.

collaboration between academia, industry, and the military, could also enable a critical edge in implementing and operationalizing the latest technological advances. For the United States to compete successfully with a self-proclaimed "world-class" military that is on track to become a major peer competitor,[24] it will be vital to evaluate and understand the PLA's advances in military applications of AI. The future balance in U.S.-China military and strategic competition will be shaped by their relative success in leveraging this disruptive technology to enhance national power and military capabilities.

CHINA'S RISE IN ARTIFICIAL INTELLIGENCE AND FUTURE MILITARY CAPABILITIES

"Artificial intelligence…will lead to a profound military revolution…"[25]
— Lieutenant General Liu Guozhi, director of the Central Military Commission Science and Technology Commission

China's National Agenda and Ambitions for Artificial Intelligence

China aspires to surpass the United States in AI. The Chinese leadership recognizes and intends to take advantage of AI to enhance its economic competitiveness and military capabilities.[d] To date, the magnitude of Chinese publications in deep learning has already exceeded that of the United States as of 2014,[26] and furthermore, China ranks second in AI patent applications, with 15,745 in total filed as of late 2016.[27] Certainly, dramatic increases in quantity do not necessarily correspond with comparable advances in quality, but there are also numerous indications that Chinese research in AI has progressed toward the cutting edge, including in speech recognition and computer vision. For instance, Chinese teams dominated the ImageNet Large Scale Visual Recognition Challenge, an AI computer vision contest, in 2016 and 2017.[28] The 2017 annual meeting of the Association of the Advancement of Artificial Intelligence (AAAI) also marked a milestone, as for the first time there were an approximately equal number of accepted papers from researchers from China and the United States.[29] In July 2017, Chinese AI start-up Malong Technologies won the inaugural WebVision contest, the successor to ImageNet, which leverages 'noisy,' rather than labeled, data.[30] Notably, in November 2017, Yitu Tech, a Chinese facial recognition start-up, even took first place in the Facial Recognition Prize Challenge hosted by the Intelligence Advanced Projects Agency (IARPA).[31] Despite current shortcomings, such as human capital,[e] Chinese advances in AI will likely continue, increasingly benefiting from substantial state support.

Chinese leadership prioritizes AI at the highest levels as a core aspect of national and military power. China's President Xi Jinping himself has highlighted the significance of rapid advances in such "crux" technologies as AI and robotics to China's economic prospects.[32] In the spring of 2017, Premier Li Keqiang included AI in the official government work report for the first time, a notable indication of its perceived importance.[33] The Chinese Communist Party (CCP) also seeks to ensure that AI will develop in accordance with the interests of the Party-State and to leverage it to enable "smart Party building" and enhance social management.[34] The CCP is attempting to bolster social control and stability through new techniques for policing, censorship, and surveillance,[35] such as the installation of millions of surveillance cameras enhanced with AI technology.[36]

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[d] For instance, according to a recent report from PriceWaterhouseCoopers, China is expected to be one of the greatest beneficiaries of the economic contributions of AI, given an expected 26% boost to its GDP by 2030.

[e] According to data from LinkedIn, the U.S. had 850,000 positions filled in AI as of the first quarter of 2017, relative to only 50,000 in China. As such, China ranks a mere seventh in the world in terms of AI positions filled, as of the first quarter of 2017, and Chinese AI experts remain considerably less experienced than their U.S. counterparts.

Within the past several years, a number of China's national science and technology plans have incorporated this focus on AI development.[f] For instance, Made in China 2025 (中国制造 2025), released in May 2015, included intelligent manufacturing and robotics, along with a target to increase domestic market share of autonomous vehicles.[37] The "Internet Plus" Artificial Intelligence Three-Year Action Implementation Plan ("互联网+"人工智能三年行动实施方案), released in May 2016, called for the creation of foundational infrastructure and innovation platforms for AI, along with the building of AI industry totaling billions of RMB by 2018.[38] In August 2016, the 13th Five-Year National Science and Technology Innovation Plan (国家科技创新规划) prioritized both big data and intelligent manufacturing and robotics among a series of new megaprojects targeted for advances by 2030, while also calling for progress in AI, including the development of big data-driven human-like intelligence.[39] The Ministry of Science and Technology later announced the decision to add "AI 2.0" as a new megaproject.[40] In March 2017, China's National Engineering Laboratory of Deep Learning Technology (深度学习技术国家工程实验室) was officially established under the leadership of Baidu.[g, 41] This new laboratory will engage in research on deep learning, including machine-learning-based visual recognition, voice recognition, biometric identification, and new forms of human-computer interaction, in partnership with Tsinghua University, Beihang University, the Chinese Academy of Sciences, and the China Information and Communications Research Institute.[42]

With the release of the New Generation AI Development Plan (新一代人工智能发展规划) in July 2017, China has articulated its ambition to lead the world in AI by 2030, becoming the "premier global AI innovation center."[h, 43] Under this strategic framework, China will advance a three-dimensional agenda in AI: tackling key problems in research and development, pursuing a range of products and applications, and cultivating and expanding AI industry to 1 trillion RMB ($150 billion) by 2030.[44] This new plan, reportedly a multibillion-dollar initiative, will also support advantages in next-generation AI technologies that could result in paradigm shifts, including brain-inspired neural network architectures and quantum-accelerated machine learning. The plan calls for building up national resources for indigenous innovation and pursuing continued advances in big data, swarm intelligence, and human-machine hybrid intelligence, among others. In particular, since China's current human capital in AI remains inadequate, with a severe shortfall relative to current and future demands,[45] the plan focuses on the education and recruitment of leading talent.[46] This and prior AI plans also call for the development of the

[f] There was also initial support for AI, including under the National High Technology Research and Development Plan (国家高技术研究发展计划, "863 Program/Plan"), the National Key Basic Research and Development Plan (国家重点基础研究发展计划, "973 Program/Plan"), and the National Medium and Long- Term Plan for the Development of Science and Technology (国家中长期科学和技术发展规划, 2006-2020).

[g] Li Yanhong, Baidu's CEO, started to advocate for the concept of a "China Brain" plan as early as 2015. To some degree, subsequent government policy initiatives may reflect this private sector advocacy for greater funding to advance Chinese AI research and enterprises.

[h] The phrase "新一代" in the name of the plan has been translated by some analysts as "next generation" (which would be 下一代), but I choose to use the literal translation "new generation" for the purposes of this paper.

underlying hardware, since China currently lags behind in AI chips but is actively attempting to achieve innovation in this domain.[i, 47] With this initiative, Chinese leadership thus seeks to seize a "major strategic opportunity" to advance its development of AI, potentially surpassing the United States in the process. According to this plan, the intended applications of next-generation AI technologies include national defense, such as in support to command decision-making, military deduction (军事推演),[j] and defense equipment.

While in the process of building up indigenous capacity, China will continue to encourage its own AI enterprises to pursue a "going out" (走出去) strategy.[48] This approach includes overseas mergers and acquisitions, equity investments, and venture capital, as well as the establishment of research and development centers abroad. Although such activities have become increasingly prevalent over the past several years, China's New Generation AI Development Plan has added official imprimatur to these efforts.[k] This approach will

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[i] Chinese efforts to develop advanced AI chips merit further consideration as a major indicator of future competitiveness. For instance, in 2016, Cambricon Science and Technology (寒武纪科技), one of China's "pioneers" in the development of dedicated chips for machine learning, launched the Cambricon 1-A, described as the first dedicated processor chip specialized for deep learning, which simulates human nerve cells and synapses. The Chinese Academy of Sciences is investing $1.4 million in funding Cambricon, and as of August 2017, after the latest round of funding, Cambricon became one of China's first AI "unicorns," valued at over $1 billion U.S. dollars.

[j] In this context, the term "military deduction" (军事推演) seemingly refers to planning, analyses, war-gaming, simulation, and other efforts that support strategic and campaign-level thinking and objectives. For instance, the term *bingqi tuiyan* (兵器推演) is used in reference to war-gaming.

[k] Some of the notable initiatives to date include the following: In 2004, Microsoft established a joint laboratory with the Harbin Institute of Technology, which is closely linked to military technological development, focused on natural language processing and speech. In 2011 and 2012, the University of Technology Sydney established five research centers with Chinese universities, including the UTS-Shanghai Jiaotong University Joint Research Centre for Intelligent Systems, the UTS-Beijing Institute of Technology Joint Research Centre for Data Mining and Service Technology, and the UTS-Tsinghua University Joint Research Centre for Quantum Computation and Artificial Intelligence; each of these universities is known to engage in defense-related research and development. In May 2014, Baidu established its Silicon Valley Artificial Intelligence Laboratory (SVAIL). In June 2014, Qihoo360, a leading Chinese cybersecurity company, and Microsoft established a partnership in AI, focused on AI and mobile Internet. In November 2014, Shenzhen-based drive-system maker Best Motion established a $1.2 million R&D center at the University of Nottingham to develop high-quality servo drive systems for use in AI and robotics. In November 2015, the Chinese Academy of Sciences Institute of Automation and Dell established the Artificial Intelligence and Advanced Computing Joint Laboratory, which will pursue the development of cognitive systems and deep learning technologies. In January 2016, BEACON, a center located at the University of Michigan that has received funding from the National Science Foundation, established the Joint Research Center of Evolutionary Intelligence and Robotics, headquartered at Shantou Technical University, also in partnership with the Guangdong Provincial Key Laboratory of Digital Signal and Image Processing, building off of a 2014 agreement for collaborative research. In April 2016, the Torch Innovation Precinct at the University of New South Wales was established as a joint China-Australia science and technology partnership, receiving $100 million in funding, including to pursue research on military-relevant technologies, including unmanned systems, which could potentially expand into AI. In October 2016, Huawei announced it would devote $1 million in funding to a new AI research partnership with the University of California, Berkeley. In March 2017, Baidu announced plans to establish a second laboratory in Silicon Valley to expand its U.S. workforce. In March 2017, the Hangzhou Wahaha Group invested $10 million in the construction of three AI centers in China and Israel as a collaboration between the Chinese Academy of Sciences Institute of Automation and the University of Haifa. In April 2017, Tencent announced plans to open its first AI research center in Seattle. Also in April 2017, Baidu acquired xPerception, a U.S. start-up with a specialty in computer vision. That same month, the China Electronics Technology Group

undoubtedly prove controversial in some quarters and could provoke further friction. Chinese investments in Silicon Valley AI start-ups have fueled the ongoing U.S. debate on whether to update the Committee for Foreign Investment in the United States to expand reviews of Chinese high-tech investments, especially in AI.[49] For instance, Chinese investment in Neurala, an AI start-up known for innovative deep learning technology that can make more reactive robots, which had initially attracted the attention of the U.S. Air Force, has caused concern.[50] Between 2012 and mid-2017, China-based investors engaged in tech investments amounting to $19 billion in the United States, across 641 different deals, with particular focus on AI, robotics, and augmented or virtual reality, according to data from CB Insights.[51] Given China's current human capital shortcomings, Chinese technology companies are also aggressively competing to recruit top talent, particularly from Silicon Valley.[52] Traditionally, China's defense technology base has also taken advantage of foreign technology and knowledge transfer of dual-use technologies,[53] and this "going out" of China's AI enterprises will similarly support dual-use advances. However, in the long term, China will likely become less dependent upon foreign innovation resources through building its own capacity for truly independent indigenous innovation.

China's rapid rise and future trajectory in AI could be enabled by critical systemic and structural advantages. Given the high-level prioritization of AI in a number of national plans, next-generation research and development will likely receive ample government funding, along with increasing investment and financing for commercial applications. There are active efforts to recruit leading talent, such as through the "Thousand Talents Plan," and to expand educational programming. For instance, there are new graduate degree programs in AI at Beihang University and the University of the Chinese Academy of Sciences AI Technology Academy,[54] reflecting a focus on taking advantage of China's sizable human capital base to create a robust pipeline of talent for the future.[55] In addition, the projected growth of China's AI industry is creating a vast potential market that incentivizes rapid commercialization. The availability of massive amounts of data is also considered a strategic edge, since China is on track to have 20% of the world's data by 2020 and 30% by 2030.[56] From the perspective of prominent PLA strategists, data is the strategic resource of the information age, becoming ever more valuable as the advent of AI enables humans to mine it for insight.[57] At present, this massive amount of data is widely considered a critical enabler of future Chinese leadership in AI. However, it remains to be seen whether future advances in the use of generative algorithms and synthetic data could render that factor less salient.[58] Inherently, the value and relevance of data also depends upon context. For instance, the PLA might also struggle to collect, manage, and share the data on its own and potential adversaries' forces that would be relevant for the training of algorithms for military purposes. Overall, these factors – national strategic planning, potential human

(CETC) announced a partnership with the University of Technology, Sydney, which will focus on big data, AI, and quantum technologies. In July 2017, China, France, and the Netherlands renewed an agreement for a joint Sino-European Laboratory in Computer Science, Automation, and Applied Mathematics, in partnership with the Chinese Academy of Sciences Institute of Automation and several European universities, with a major focus on AI. Although this listing is far from comprehensive, it seeks to illustrate the scope and scale of these efforts.

capital, and national data resource base – could serve as a critical foundation to China's AI ambitions, including applications of this dual-use technology in national defense.

The PLA's Initial Strategic Thinking on Artificial Intelligence in Warfare

The PLA intends to leverage advances in AI to enhance its future military capabilities, pursuing an expansive research and development agenda while leveraging private sector progress through a national strategy of military-civil fusion. This intended militarization of AI occurs in the context of the PLA's focus on military innovation, including through military-civil fusion.[59] PLA strategists and academics have characterized current trends as the advent of a new military revolution, in which AI and related technologies will change the metric for military power.[60] The PLA anticipates a shift toward future "intelligentized" (智能化) warfare, in which AI will be as integral as information technology has been in today's "informatized" (信息化) warfare.[l, 61] The process of "intelligentization" (智能化) is considered a new stage in China's informatization revolution, involving the use of AI to transform the economy and the military.[m] The PLA is already funding a range of military applications of AI under the 13th Five-Year Plan, including through the CMC Equipment Development Department and service-level equipment departments and research projects. Although the PLA's strategic thinking on and employment of AI remains at an early stage at this point, this "strategic front-line" technology could become a critical enabler of China's future military capabilities, while perhaps transforming the character of conflict itself.[62]

The PLA seeks to compete with the United States in defense innovation, and its initial strategic thinking on the implications of AI for future warfare will influence its evolving approach to this critical strategic technology. During the prior information technology military revolution,[n] the PLA failed to keep pace with advances in information technology, struggling to achieve the levels of mechanization and "informatization" (信息化) that became so vital to modern warfare. Thus, the PLA is acutely aware of the criticality of adapting to and capitalizing upon today's technological trends, fearing the emergence of another "generational gap" between its capabilities and that of the U.S. military, which is perceived as a powerful potential adversary and thus the critical metric for comparison.[63] In light of current U.S. defense innovation initiatives, the PLA is concerned about the risks of a "technological surprise attack" unless it ensures that its own capabilities keep pace. In his remarks to the PLA, Xi Jinping has called for "strengthening the military through science and technology" (科技强军), while highlighting the unique opportunity and challenges

[l] Although the term "智能化" might also be translated as "smart," I choose to use the translation "intelligentization" for consistency with the translation used in an article from *China Military Science*, a journal released by the influential Academy of Military Science, and also to highlight the parallel to the PLA's concept of "informatization" (信息化).

[m] The same term (智能化) is also used as an adjective to refer to a system that incorporates AI, whether an autonomous UAV or a 'smart' device or system.

[n] I recognize the differences between the concepts of a military-technical revolution, Revolution in Military Affairs, revolution in warfare, etc. and use the term here without particular differentiation. The typical term used in PLA writings (军事革命) could be translated as either "military revolution" or "revolution in military affairs."

resulting from today's global military revolution.[64] Xi has urged that China "seize the high ground" and "vigorously advance military innovation," which requires technological innovation and "unceasing innovation" in military theory, thus "closing the gap" with the United States as rapidly as possible.[65]

At the highest levels, the PLA appears to recognize and intend to capitalize upon the transformation of today's informatized ways of warfare into future "intelligentized" (智能化) warfare. China's new AI plan calls for the application of next-generation AI to support command decision-making, military deduction, defense equipment, and other areas.[66] According to Lieutenant General Liu Guozhi (刘国治), director of the Central Military Commission's Science and Technology Commission, the world is "on the eve of a new scientific and technological revolution," and we are "entering the era of intelligentization" due to rapid advances in AI and its applications.[67] General Liu anticipates AI will accelerate the process of military transformation, causing fundamental changes to military units' programming, operational styles, equipment systems, and models of combat power generation, ultimately leading to a profound military revolution. As he warns, "facing disruptive technology, [we] must … seize the opportunity to change paradigms (弯道超车). Whoever doesn't disrupt will be disrupted!"[o, 68] The PLA presently may have a unique opportunity to take advantage of today's transformation of warfare by leveraging the China's rapid advances and ambitious agenda in AI. Under these conditions, the PLA intends to "seize the advantage in military competition and the initiative in future warfare," seeking the capability to win in not only today's informatized warfare but also future intelligentized warfare, in which AI and related technologies will be a cornerstone of military power.[69]

For the PLA, the coming of intelligentized warfare is considered a stage beyond informatization that will require deeper changes in its approach to force development and modernization. According to Major General Wang Kebin (王克斌), director of the former General Staff Department Informatization Department, China's "information revolution" has been progressing through three stages: first "digitalization" (数字化), then "networkization" (网络化), and now "intelligentization."[70] Through its agenda for informatization, the PLA has sought to integrate information technology into the PLA and to improve its ability to utilize information in warfare.[71] To date, the PLA has succeeded in the introduction of information technology into platforms and systems; progressed gradually toward integration, especially of its command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) capabilities; and seeks to advance toward deeper fusion of systems and sensors across all services, theater commands, and domains of warfare. However, the results of informatization have created new challenges in the effective processing and utilization of data. In this final stage, the advancement of intelligentization could enhance the PLA's capability to process and utilize information at scale and at machine speed, enhancing situational awareness and the speed of battlefield decision-making.

[o] The phrase *wandaochaoche* (弯道超车) implies literally (in the context of driving) overtaking someone around a bend, or metaphorically achieving rapid progress through cutting tightly around a corner.

At this point, the PLA remains in the early stages of speculation and experimentation with AI that could enable deeper military innovation.[p, 72] The PLA's initial thinking on AI in warfare has been influenced by its careful study of U.S. defense innovation initiatives. In particular, PLA researchers have closely tracked the Department of Defense's Third Offset strategy[73] – which has focused on AI and related technologies, including robotics, autonomous operating guidance and control systems, advanced computing, and big data – in order to achieve an advantage relative to strategic competitors and reinforce deterrence.[74] In their writings, PLA academics and officers, not unlike the U.S. military, tend to project that impactful military applications of AI could include intelligent unmanned military weapons systems,[q] intelligentized support to command decision-making, and the expansion of human stamina, skills, and intellect through AI.[75] For instance, the PLA has focused on the utility of intelligent unmanned systems, including swarm intelligence, to achieve a disruptive advantage on the battlefield.[76] The tendency toward perhaps irrational enthusiasm about the potential of AI recurs in the PLA, and its applications have become a major focus of military theoretical research. However, there is also recognition that AI is not "all powerful," such that it is necessary to remain clearheaded and take a targeted and prioritized approach to its applications based on actual military requirements and operational imperatives.[77]

Due to the PLA's distinctive strategic, command, and organizational culture, as leading PLA strategists and AI experts continue to focus on the emergence of "intelligentization," their thinking on and emerging approach to the employment of AI in warfare could diverge from that of the United States. To date, the U.S. military has remained relatively cautious about embracing AI and autonomous systems due to legal and ethical concerns, particularly in the context of use of force decisions.[78] Potentially, there could be fewer or different ethical or legal constraints upon China's employment of AI for military purposes, or at least there has been relatively limited discussion of these issues to date by the PLA.[r, 79] In addition, the PLA has traditionally evaluated warfare through the lens of military science (军事科学), focusing extensively on simulation and war-gaming to derive appropriate military concepts

[p] Based on the author's conversations with PLA academics, including from its National Defense University, which takes primary responsibility for the education of officers, the concept of intelligentization is familiar to academics and instructors, some of whom are starting to incorporate consideration of the potential impact of AI on information warfare and trends in future warfare into teaching. Several authoritative texts produced by the Academy of Military Science, which directly supports the Central Military Commission and is responsible for the formulation of strategy and doctrine, also allude to the concept of intelligentization. However, there does not yet appear to be a coherent, consensus set of ideas or theories on AI in warfare within the PLA, and the thinking of high-level officers and academics will likely continue to evolve and could provoke further debate.

[q] The Chinese term "无人机" is most literally translated as "unmanned." However, the term "uninhabited" better conveys the fact that there are humans involved in command and control. (Thanks to Paul Scharre for raising this point.) For the purposes of this paper, I will use the translation "unmanned" for consistency with the Chinese terminology.

[r] At this point, it is difficult to anticipate whether or to what extent the PLA will seek to ensure that future autonomous weapons will operate in a manner consistent with the Laws of Armed Conflict. The PLA has often approached international law through the lens of "legal warfare" (法律战), rather than as a constraint.

and theories informed by underlying technological conditions.[80] AI will likely take on a greater role in these efforts going forward. The PLA's approach, in which "technology determines tactics,"[81] could also result in a greater degree of willingness to experiment with AI and formulate novel military theories and concepts based on an overall understanding of the technology, rather than immediate imperatives.

While the PLA has traditionally sought to learn lessons from foreign conflicts, its current thinking on the military implications of AI has been deeply informed not by war but rather by a game.[82] In the spring of 2016, AlphaGo's initial defeat of Lee Sedol in the ancient Chinese game of Go (*weiqi*) seemingly captured the PLA's imagination at the highest levels, sparking high-level seminars and symposiums on the topic.[83] The continued success of AlphaGo, including its recent victories over China's top Go players, is considered a turning point that demonstrated the potential of AI to engage in complex analyses and strategizing comparable to that required to wage war – not only equaling human cognitive capabilities but even contributing a distinctive advantage that may surpass the human mind.[84] From the perspective of influential PLA strategists, this "great war of man and machine" decisively demonstrated the immense potential of AI to take on an integral role in decision-making in future warfare. As described in one commentary, "Go and warfare are quite similar: the board may be likened to the battlefield, the game may be likened to the art of warfare, the player may be likened to the commander planning strategies, and the player approaches the game like the commander approaches fighting a mighty army."[85] In this regard, the PLA's apparent fascination with AlphaGo presents early indications of its initial thinking on and potential future use of AI in warfare.

In particular, the PLA may focus on leveraging AI to enhance command and control at the operational and even strategic levels of warfare through intelligent assistance to command decision-making, even seeking to enable decision-making at machine speed. The Central Military Commission Joint Staff Department has called for the PLA to leverage the "tremendous potential" of AI in operational command, planning and deductions, and decision support. In addition, the Joint Staff Department highlights advancing the application of big data, cloud computing, AI, and other cutting-edge technologies to the construction of a joint operations command system.[86] Already, PLA researchers have reportedly achieved initial progress in their efforts to increase the intelligentization of the PLA's command systems.[87] It is difficult at present to evaluate the sophistication of existing systems based on the information available. However, in multiple articles, PLA thinkers have closely analyzed DARPA's program Deep Green. This project, which ran during the mid-2000s, sought to develop a system that would support commanders' decision-making on the battlefield through advanced predictive capabilities, including the generation of courses of action, evaluation of options, and assessment of the impact of decisions.[88] By enhancing the commander's decision-making, Deep Green sought to "keep the enemy firmly inside our decision cycle."[89] Within the foreseeable future, a comparable capability to enable more effective battlespace management could be within the PLA's reach as well. In the meantime, the PLA appears focused on and likely pursuing the use of AI in simulations, war-gaming, and training.[90] For instance, since the PLA lacks actual combat experience and has struggled to enhance the realism of its training, virtual and augmented reality could be seen as viable alternatives.

Looking to the future potential of AI, certain PLA thinkers anticipate that the intelligentization of warfare could result in a trend toward battlefield "singularity" (奇点).[91] At such a point, the human mind could prove unable to keep pace with future intelligentized warfare, as the use of AI and human-machine integration (人机融合) enable ever more rapid decision-making and an accelerating tempo of operations to achieve the initiative.[92] Under such conditions, human commanders would no longer have capacity to remain directly 'in the loop' (人在回路中) but rather possess ultimate decision-making authority (e.g., a model of a "human on the loop," 人在回路上), without actual involvement in each decision in combat. Consequently, there could be major changes in militaries' organizational structures, such that intelligent machines become primary warfighters in the future military while humans remain planners, administrators, and commanders.[s, 93] The introduction of AI to support, and perhaps even eventually supplant, human cognition and decision-making on the battlefield is expected to dramatically accelerate the "OODA loop."[t, 94] According to one Chinese defense industry expert, "information agility," that is, "the priority and mobility of information," has become critical to winning, whether in air, electromagnetic, or cyber operations.[u, 95]

This recognition of the greater imperative of cognitive speed on the battlefield could result in increased reliance upon AI for decision-making.[96] To date, the U.S. approach to AI and automation in the context of the Third Offset has focused on the potential of human-machine teaming, conceptualized as a "centaur model."[97] The PLA, which has closely tracked the Third Offset, likely will similarly pursue forms of human-machine integration and collaboration.[98] For instance, it is telling that PLA theorists are starting to incorporate the distinction between humans "in the loop" and "on the loop" (i.e., exercising supervisory control) into their writings,[99] and even into a patent for a system designed to allow a human operator to control multiple unmanned aerial vehicles (UAVs).[100] However, the PLA's speculation on the potential of a singularity in warfare does raise the question of whether the U.S. emphasis on human intuition and ingenuity might be appropriate for the immediate future but perhaps infeasible for aspects of future warfare that may occur at machine speed. There inevitably will be contexts in which keeping a human fully in the loop becomes a liability, and the type and degree of "meaningful" or supervisory human control that is feasible or appropriate will remain a critical issue.[101] Certain operations and weapons systems, such as air defense and ship-borne ballistic missile defense, already incorporate a high degree of automation.[102] For the U.S. military and the PLA alike, a critical

[s] PLA writings refer to the concepts of human-machine coordination (人机协同), human-machine fusion (人机融合), and human-machine hybrid/mixed (人机混合) intelligence. To date, the PLA appears to have primarily adapted such concepts from U.S. writings, without necessarily establishing clear definitions for them, and it remains to be seen how much its approach to these issues will differ.

[t] This decision-making cycle of Observe, Orient, Decide, and Act (OODA), a concept formulated by Colonel John Boyd, is familiar to and recurrent in the writings of PLA thinkers.

[u] Therefore, according to this Chinese defense expert, warfare has entered a new era of "OODA 2.0," in which machine-based information-gathering, as well as analysis and decision-making systems, cause the OODA loop to become more "flexible and automatic." "OODA 3.0," enabled by AI, is seen as the next stage still to come.

question will be which missions will require or can be enhanced through the introduction of AI and automation, in contrast to those in which doing so could be highly risky or escalatory.[103] Even at the strategic level, AI could exercise considerable influence upon future human decision-making.[104]

Inherently, the PLA's organizational tendencies will shape its approach to AI, despite the relative lack of attachment to the notion of keeping humans fully in the loop. In its command culture, the PLA has tended to consolidate and centralize authorities at higher levels, remaining reluctant to delegate decision-making downward, which can constrain lower-ranked actors from exercising operational initiative.[105] The introduction of information technology has exacerbated the tendency of PLA commanders to micromanage subordinates through a practice known as "skip-echelon command" (越级指挥) that enables the circumvention of command bureaucracy in order to influence units and weapons systems at even a tactical level.[106] This practice can be symptomatic of bureaucratic immaturity and a tendency toward distrust of subordinates. The PLA has confronted and started to progress in mitigating its underlying human resource challenges, recruiting increasingly educated officers and enlisted personnel, while seeking to modernize and enhance political and ideological work aimed at ensuring loyalty to the Chinese Communist Party.[107] However, the employment of AI could appeal to the PLA as a way to circumvent and work around those persistent human and bureaucratic issues,[v, 108] even as those same challenges could tend to hinder its effective adoption.[109] For instance, the effective employment of AI-enabled and automated systems may, in many cases, require more highly trained and skillful personnel. Concurrently, the unique nature of the PLA as a Party military, rather than a national military, could also complicate the operationalization of AI if its use is seen in any way as a risk or challenge to the Party's authority. For instance, Tencent recently shut down chatbots developed by Turing Robot and Microsoft after both appeared to 'go rogue,' with comments criticizing the Party as "corrupt and incompetent."[110]

The intersection of the PLA's focus on scientific approaches to warfare with the preference to consolidate and centralize decision-making could also cause the PLA's leadership to rely more upon AI, rather than human judgment. For instance, Lieutenant General Li Qiaoming (李桥铭), now PLA Army commander in the new Northern Theater Command, has highlighted the importance of big data, along with cloud computing and the Internet of Things, to make command more "scientific" in an effort to overcome the "fog of war" and make the battlefield more transparent.[111] In practice, this tendency could become a source of vulnerability, given the continued fallibility and near inevitability of mistakes in complex AI-enabled systems.[112] On the other hand, the reluctance to delegate authority downward – and tendency to consolidate command authority for strategic capabilities at the highest levels – could also render the PLA's leadership reluctant to 'delegate' to AI-enabled systems

[v] In one of the more interesting imagined use cases for AI, one article anticipates that AI could provide support to small scattered units, ranging from assisting in missions to engaging in ideological work or psychological counseling.

and risk the consequent loss of control.[w] Within the PLA, there could be divergences in the perspectives of special technical officers and (operational) military officers, such as in their respective levels of understanding of the underlying technologies and degrees of enthusiasm for AI-enabled capabilities.[113] In this regard, PLA perspectives on military applications in AI will remain varied, perhaps influenced, in some cases, by bureaucratic competition. The PLA's future advancement of intelligentization could prove analogous to the recent history of its pursuit of informatization, which involved the combination of high-level guidance and planning with localized variability and experimentation in its implementation. Given these dynamics, there may be no singular approach or set of priorities, and the high-level focus on intelligentization could even result in a tendency for different PLA services to leverage it instrumentally in competition for resources.

If the PLA succeeds in realizing the potential of AI across a range of military applications, these technologies could become a critical force multiplier for its future capabilities. During the information technology military revolution, the United States possessed an advantage in the underlying technologies, but the Soviet Union was the first to recognize their transformative potential and to formulate critical concepts such as the reconnaissance-strike complex.[114] Today, the PLA possesses the technological prerequisites for military innovation and is actively engaging with key questions regarding concepts of operations and the form of future warfare. In the process, PLA strategists' thinking is informed by a careful examination of the evolving U.S. approach to AI and automation,[115] but their eventual conclusions about and approach to intelligentized warfare could prove unique, influenced by the PLA's strategic and organizational culture. For instance, several PLA thinkers have projected that the synergies between intelligentized or autonomous systems and directed energy weapons will enable "light warfare" (光战争), involving the combination of real-time information and "zero-hour" attacks.[116]

Based on this review of recent writing and thinking, the PLA's approach to leveraging military applications of AI could prove distinctive given its model of military-civil fusion, expansive concept of intelligentization, and focus on AI-enabled command decision-making. In contrast to the U.S. military's official position, there is also recognition within the PLA that the cognitive demands of future warfare could require taking humans out of the loop.[x] However, it seems unlikely that the PLA will progress imminently toward "full" autonomy, given the organizational tendencies to centralize control and recognition of the advantages of combining human and artificial intelligence. For instance, Lieutenant General Liu Guozhi anticipates that human-machine hybrid (人机混合) intelligence is the highest form of future intelligence.[117] The PLA is also funding research on concepts of human-machine integration or "fusion" (人机融合) and human-machine coordination (人机协同).[118] Looking forward, just as the U.S. military has, at times, struggled with the human

[w] For instance, the PLA's Strategic Support Force consolidates strategic capabilities in space, cyber, and electronic warfare directly under the control of the CMC. The former Second Artillery Force, now Rocket Force, has similarly seemed to ensure CMC-level control of the PLA's nuclear and conventional missiles.

[x] It is unlikely that there would be consensus on this issue within the PLA at present, and, as mentioned, there could be countervailing cultural and organizational tendencies within the PLA that could render it less likely to do so. Nonetheless, it is noteworthy that PLA thinkers openly discuss this possibility.

factors associated with automation, the PLA may not yet recognize the extent to which automation may create new and unanticipated challenges.[119]

China's Prospects for Advancing Military-Civil Fusion in Artificial Intelligence

Since the locus of innovation in AI has shifted to the private sector, the PLA's capacity to take advantage of these advances for military purposes will be a critical variable and structural advantage for the PLA. Consequently, Chinese leadership seeks to ensure that private sector progress in AI can be rapidly transferred for employment in a military context through a national strategy of military-civil fusion, while building up capability in its defense industrial base. China's focus on military-civil fusion is consistent with the dual-use nature of this emerging technology. If successful, this approach would enable the PLA to take advantage of the resulting synergies. PLA officers and academics alike have highlighted the importance of deepening military-civil fusion, especially for such strategic frontier technologies as AI.[120] China's New Generation AI Development Plan explicitly highlights an approach of military-civil fusion to ensure that advances in AI can be readily leveraged for national defense.[121] To actualize this objective, China will continue to establish and normalize mechanisms for communication and coordination among scientific research institutes, universities, enterprises, and military industry units, while seeking to ensure that military and civilian innovation resources will be "constructed together and shared."

This strategic agenda is a high-level priority that will be directed by the CCP's Military-Civil Fusion Development Commission (中央军民融合发展委员会),[122] established in early 2017 under the leadership of Xi Jinping himself.[123] The PLA's CMC Science and Technology Commission, in conjunction with its new CMC Military Scientific Research Guidance Committee (军委军事科学研究指导委员会), will exercise high-level leadership over the PLA's future research and development agenda and also over military-civil fusion, potentially serving a function intended to be roughly analogous to that of DARPA.[124] Of note, in August 2017, the Ministry of Science and Technology and the CMC Science and Technology Commission jointly issued the 13th Five-Year Science and Technology Military-Civil Fusion Special Plan (科技军民融合发展专项规划),[125] which also seeks to advance military-civil fusion and innovation.[126] These new high-level commissions and special plan reflect recognition of the strategic importance of actualizing a highly integrated approach to dual-use scientific and technological development.

Pursuant to this national strategy, the boundaries between civilian and military research and development tend to become blurred, and the PLA is often closely associated with cutting-edge research in AI. In a notable case, Li Deyi (李德毅) acts as the chairman of the Chinese Association for Artificial Intelligence, and he is affiliated with Tsinghua University and the Chinese Academy of Engineering. Concurrently, Li Deyi is a major general in the PLA who has served as a researcher with and deputy director of the CMC Equipment Development Department's 61st Research Institute, which played an integral role in the PLA's development of its integrated command platform.[127] His academic activities, such as the development of self-driving cars, often have potential military applications.[128] The PLA

is evidently undertaking an approach of "shared construction, shared enjoyment, and shared use" ("共建、共享、共用") to leverage synergies between military and civilian developments.[129] For instance, members of the new CMC Intelligent Unmanned Systems and Systems of Systems Science and Technology Domain Expert Group (军委智能无人系统及体系科学技术领域专家组),[y] reportedly visited a new testing area for self-driving cars, intended to be used for military and civilian unmanned vehicles.[130]

There are already indications that the PLA has started to actualize several partnerships and mechanisms for military-civil fusion in AI. For instance, in 2014, iFlytek, a prominent Chinese AI start-up focused on intelligent voice recognition and speech-to-text products, received a license to do business with the PLA.[z, 131] iFlytek is apparently cooperating with the PLA on a voice recognition and synthesis module, which could be particularly useful for the PLA in intelligence processing.[132] Similarly, the NiuTrans system of machine translation company YaTrans has been used for machine translation by the Ministry of State Security, which is responsible for counterintelligence, and the PLA's former Shenyang Military Region, which borders North Korea.[133] In addition, Hikvision, owned by the China Electronics Technology Group Corporation's (CETC) 52nd Research Institute, has pursued collaboration with the PLA to provide its AI-enabled video surveillance technology for national defense and security purposes.[134] For example, the PLA's former General Armaments Department used Hikvision's video surveillance technology to record and analyze training exercises.[135]

There are several new research institutes and joint laboratories that will pursue dual-use advances in these technologies. In 2014, iFlytek Research and the Harbin Institute of Technology, a top engineering university closely linked to military research and development, co-founded a joint laboratory focused on cognitive computing, particularly natural language understanding and progress in human-like intelligence.[136] In late 2016, the Military-Civil Fusion Intelligent Equipment Research Institute (军民融合智能装备研究院) was established as a collaboration between the North China University of Technology and a private technology company, Zhongbo Longhui (Beijing) Information Technology Company Ltd.[137] The institute received support from the Naval Equipment Research Institute, the Army Equipment Department, the Rocket Force's Equipment Research Academy, and other military organizations.[138] It was tasked to pursue research in AI, intelligent robotics, unmanned systems, and military brain science.[139] As of the summer of 2017, Tsinghua University also announced its plans to establish a Military-Civil Fusion National Defense Peak Technologies Laboratory (清华大学军民融合国防尖端技术实验室) that will create a platform for the pursuit of dual-use applications of emerging technologies, including AI.[140]

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[y] Please note that I have only seen one source referencing this expert group to date.

[z] The license in question is known as the "weapons and equipment scientific research and production license (武器装备科研生产许可证), issued by the National Defense Science and Technology Industry Bureau. It is valid from February 2014 through 2019.

There may be considerable obstacles remaining to the actualization of military-civil fusion in AI in practice, but the PLA is actively seeking to overcome them with the creation of these high-level institutions and new mechanisms.[141] Previously, the concept was often far from reality, due to a tendency for the PLA to prefer procurements from the defense industry and obstacles to private companies' ability to meet the appropriate standards.[142] Lieutenant General Liu Guozhi has highlighted the importance of avoiding duplication and creating unified standards to prevent inefficiencies.[143] Certain of these issues may persist, and the Chinese private sector may not always be eager to cooperate with the Chinese government and military. However, the Chinese system enables a state-driven approach to leverage the synergies in this dual-use technology through the efforts of multiple, interrelated policy mechanisms. In some instances, advances from the private sector could apply readily within a military context, as in the case of natural language processing and machine translation, likely already leveraged by the PLA in intelligence. The systems used for self-driving cars could also be readily adapted to military-use autonomous vehicles. So too, computer vision is widely used in facial recognition for commercial purposes but can also be leveraged for military applications, included automated analysis of imagery and automatic target recognition. However, in a number of cases, the algorithms and techniques in question may be more difficult to transfer or retrain. Consequently, the PLA may need to confront challenges related to the collection, sharing, and usage of "defense big data" to train algorithms.

The PLA's Projected Employment of Artificial Intelligence for Military Applications

To date, the PLA has pursued research, development, and testing for multiple military applications of AI, including, but not limited to: intelligent and autonomous unmanned systems, such as swarm intelligence; AI-enabled data fusion, information processing, and intelligence analysis; applications in simulation, war-gaming, and training; the use of AI for defense, offense, and command in information warfare; and intelligent support to command decision-making.[aa, bb] At first glance, these applications correspond reasonably closely to known U.S. priorities under the Third Offset and related defense innovation initiatives. However, the PLA appears to be highly focused on the use of AI in simulation, war-gaming, and training, as well as to support situational awareness and command decision-making.

Necessarily, this analysis relies upon the available Chinese-language sources, including media commentary, academic writings, technical journals, and patents. As such, there are likely research efforts about which there is not information available in open sources. It is also infeasible to evaluate the sophistication of reported advances without more detailed

[aa] This section is roughly ordered based on the PLA's apparent progress in each of these domains, from likely short-term to longer-term capabilities.

[bb] In addition, AI will likely have direct utility in logistics and predictive maintenance, but this does not yet seem to have received attention on par with the applications detailed in this section.

technical information. The PLA's future progress in intelligentization for a range of military applications will therefore merit continued analytical attention.[cc]

Intelligent and Autonomous Unmanned Systems

The PLA is pursuing the development of "intelligent" and autonomous weapons systems, including unmanned aerial, surface, and underwater vehicles, as well as military robotics and cruise missiles. According to the official PLA dictionary, an "artificial intelligence weapon" is defined as: "a weapon that utilizes AI to automatically (自动) pursue, distinguish, and destroy enemy targets; often composed of information collection and management systems, knowledge base systems, assistance to decision systems, mission implementation systems, etc.," such as military-use robotics.[144] Within the foreseeable future, PLA strategists expect that autonomous combat by unmanned systems and the joint operations of unmanned and manned systems will disrupt traditional operational models.[145] Given trends in the research, development, and employment of intelligentized, unmanned weapons and equipment, PLA thinkers anticipate the future land, sea, air, and space battlefields all will be full of unmanned combat weapons, resulting in a "multi-dimensional, multi-domain unmanned combat weapons system of systems on the battlefield."[dd, 146] For future unmanned systems, AI could enable intelligence analysis on the 'front end,' such that the processing of data occurs without having to transmit it back, which could require autonomous learning.[147] PLA academics and researchers are pursuing conceptual and technical research to support such new operational approaches.[148] The introduction of the latest AI techniques, particularly deep learning, could enable this next frontier for Chinese unmanned systems. The known progress in research, development, and experimentation indicates that these efforts have started to advance considerably.

Future Intelligent Unmanned Aerial Vehicles and Swarm Intelligence

While starting to incorporate greater degrees of autonomy into its high-end UAVs, the Chinese defense industry has pursued options for manned-unmanned teaming and multi-UAV operations. The TYW-1, the export version of the BZK-005, a high-altitude long-endurance (HALE) UAV used primarily for reconnaissance by the PLA Navy (PLAN) and PLA Air Force (PLAAF), can operate with a high degree of automation, taking off and landing independently, requiring minimal human intervention in tracking and attacking targets.[149] The ASN-216, in use with the PLAN, is also capable of autonomous (自主) takeoff and landing, flight, and filming.[150] In addition, the *Caihong*-5 ("Rainbow," CH-5), a HALE UAV, could have the capacity to team with other UAVs for multi-drone missions.[151] Beihang University, closely linked to military aerospace technologies, is pursuing research on the control, collaboration, and management of multiple manned and unmanned systems.[152]

[cc] Please note that this is an initial review of the issue, and my analysis of the topic is ongoing. Certain sources and details not included in this paper are available upon request.

[dd] For the PLA, "system of systems" operational capability leverages C4ISR architecture to link systems and services in order to enable information-sharing and facilitate joint-ness. For more on the concept, see Kevin McCauley's report, "PLA System of Systems Operations: Enabling Joint Operations."

The Chinese defense industry has achieved significant advances in swarm intelligence and appears likely to continue to progress in this technique. During the fall 2016 Zhuhai Airshow, official media prominently featured Chinese breakthroughs in swarm intelligence. To date, the efforts of CETC appear to be most prominent. In November 2016, CETC, in partnership with Tsinghua University and Poisson Technology (泊松技术), a private company, revealed its progress in swarm intelligence with a formation of 67 small fixed-wing UAVs utilizing autonomous swarm control, with communication and coordination among UAVs.[153, 154] In the spring of 2017, a formation of 1,000 UAVs at the Guangzhou Airshow by another private company reportedly again broke records.[155] At the time, military experts quoted in Chinese media similarly highlighted that this technique could be used to create a distributed system with payload modules mounted on small drones.[156] However, the actual sophistication of this particular demonstration – and the potential linkage to military efforts – is unclear. Once again, in June 2017, CETC demonstrated its advances in swarm intelligence with the test of 119 fixed-wing UAVs, beating its previous record of 67. This swarm engaged in catapult-assisted takeoffs and demonstrated complex formations.[157] At the time, CETC commentary highlighted that swarm intelligence is the future of intelligent unmanned systems, and CETC UAV expert Zhao Yanjie (赵彦杰) characterized future intelligent swarms as a disruptive force to "change the rules of the game" in warfare.[158]

At present, multiple military and civilian research institutes appear to be working on swarm intelligence and manned-unmanned teaming. These include, but are not limited to, several CETC research institutes; the China Aerospace Science and Industry Corporation (CASIC), including its Third Institute's UAV Technology Research Institute; the Harbin Institute of Technology's National Key Laboratory of Robotic Systems and Engineering; Tsinghua University; Beihang University, and Northwest Polytechnic University, based on their published research and patents on the topic.[159] In September 2017, the PLAAF Equipment Department 2016 announced an upcoming "challenge" for intelligent UAV swarm systems, in which competitors will be judged on the sophistication of the performance of their swarms.[160] The PLA is also funding research on data link technologies for swarm UAVs and the use of deep learning to enhance the control, collaboration, and management of multiple manned and unmanned systems.[161]

Future PLA swarms could be used for reconnaissance, strike, jamming, and other missions. For instance, CGI sequence available in media reports about the CETC demonstration showed a swarm formation in action, first hunting and then dive-bombing and destroying an enemy missile launcher.[162] This technique would possess advantages in efficiency and survivability, due to the distribution of capabilities across the system, as well as lower costs for offense relative to the difficulty of defending against a swarm.[163] These intelligent unmanned systems could serve as an asymmetric means through which to target high-value U.S. weapons platforms, including fighter jets or aircraft carriers. Of note, China's Military Museum includes in one exhibit a depiction of a UAV swarm combat system (无人机蜂群作战系统) with swarms used for reconnaissance, jamming, and "swarm assault" (群打击) targeting an aircraft carrier.[164]

Intelligent Unmanned Surface Vehicles

In the future, a number of variants of intelligent or autonomous USVs may be integrated into the PLAN and the Chinese Coast Guard to establish a persistent presence in disputed waters in peacetime and for potential employment in wartime contingencies. There have been multiple versions of one particular intelligent USV tested to date, the *Jinghai* (精海), designed by the Underwater Engineering Research Institute at Shanghai University.[165] This project started in 2010, and the vessel undertook its maiden voyage in the South China Sea, around the Paracel and Spratly Islands, in 2013.[166] Reportedly, it has the capability to navigate autonomously and intelligently avoid obstacles in support of sensing and reconnaissance missions. The *Jinghai* was evaluated by the former General Armaments Department and the PLAN Equipment Department, [167] perhaps an indication of the PLAN's intentions to acquire such a system.[168] The Chinese Coast Guard has reportedly acquired the M75 High Speed Security Patrol USV, designed for missions of border protection, port security, and surveillance, from China's Zhuhai Yunzhou Intelligence Technology (Yunzhou-Tech).[169]

As the Chinese defense industry develops a greater number and variety of intelligent USVs, the PLAN USVs could start to leverage these systems for combat missions, including anti-submarine warfare. In November 2016, Beijing Sifang Automation displayed its SeaFly intelligent USV, which can learn independently and can avoid obstacles, at the Zhuhai Airshow.[170, 171] In September 2017, the China Aerospace Science and Technology Corporation (CASC) revealed its design for the D3000 stealthy unmanned oceanic combat vessel, which would be capable of engaging in anti-submarine and surface warfare missions.[172, 173] CASC has also unveiled plans for further USVs: the B850, intended for high-speed maritime patrol and interdiction missions, the A1150 for use in hydrographic survey, and the C1500, designed for ASW operations.[174] The PLAN is also funding further research on systems for the "intelligent control" of ships.[175] As the PLAN seeks to enhance its capabilities, intelligent USVs could start to be integrated into its force structure.

Intelligent Unmanned Ground Vehicles

The Chinese private sector's pursuit of self-driving cars has occurred alongside parallel efforts on intelligent unmanned ground vehicles. In 2010, the National Natural Science Foundation of China organized a challenge focused on the development of cars capable of intelligent behavior and decision-making.[176] The units participating included those with a focus on dual-use and military research and development, including the Military Transportation Institute, the Academy of Armored Forces Engineering, Xi'an Jiaotong University, the Beijing Institute of Technology, and the National University of Defense Technology, among others.[177] In 2014, China North Industries Corporation (NORINCO) established the NORINCO Unmanned Ground Platforms Research and Development Center (兵器地面无人平台研发中心), which was intended to develop dual-use unmanned platforms, involving collaboration between several units of NORINCO and a German

company, RoboWatch.[178] Several different unmanned combat vehicles may already have been fielded on at least a limited or experimental basis within the PLA Army.[179]

In the fall of 2016, the PLA Army Equipment Department organized a competition that tested the ability of unmanned ground systems to engage in tasks such as battlefield reconnaissance.[180] The teams that participated included researchers from the Chinese Academy of Sciences, National University of Defense Technology, Academy of Armored Force Engineering, Beijing Institute of Technology, and Ordnance Industry Group (NORINCO).[181] In the future, UGVs may carry out missions including surveillance and reconnaissance, firepower strikes, and logistics assurance and support, with greater degrees of intelligence.[182] Within the foreseeable future, the PLA Army could start to employ greater numbers of unmanned or self-driving ground platforms and tanks with varying degrees of automation and intelligence.

Autonomous UUVs

The PLAN appears to prioritize the development of autonomous UUVs, as reflected in the efforts of multiple research institutes and designated key laboratories. For instance, Beihang University has developed a robofish UUV prototype,[183] and Tianjin University has tested the Haiyan unmanned underwater glider, which could potentially be used for underwater patrols or even combat.[184] The Haiyi (海翼) or "Sea Wing" UUV, an underwater glider designed by the CAS Shenyang Institute for Automation that has been used for scientific missions in the South China Sea,[185] has also been highlighted as having potential military utility, due to its low acoustic signature.[186] Recently, the Haiyi 1000 completed a three-month mission of deep-sea exploration characterized as demonstrating its capability to support submarines engaging in military missions and to enable the detection of foreign submarines, based on the deep-sea data acquired through multiple sensors.[187] These and other systems under development could be leveraged by the PLAN to advance its anti-submarine warfare capabilities, offsetting the traditional U.S. undersea advantage. For instance, there have been reports that the PLAN is seeking to establish an "underwater Great Wall" (水下长城) that might utilize UUVs to enhance underwater monitoring capabilities.[188]

Missile Intelligentization

The sophistication of advanced Chinese missiles may be further augmented through the incorporation of greater degrees of AI and automation. Wang Changqing (王长青), from CASIC's Third Academy's General Design Department, claimed, "our future cruise missiles will have a very high level of AI and automation," such that commanders will be able "to control them in a real-time manner, or to use a fire-and-forget mode, or even to add more tasks to in-flight missiles."[189] In a more detailed presentation on the topic, Wang Changqing, also the deputy director of CASIC's Key Laboratory for Advanced Guidance and Control Technologies (先进制导控制技术重点实验室), highlighted the potential applications of AI to mission management systems, flight management systems, and control and implementation.[190]

In particular, these remarks noted that AI could enable missiles to have sophisticated capabilities in sensing, decision-making, and implementation, including through gaining a degree of "cognition" and the ability to learn. Given the lack of credible technical details available, it is difficult to verify these claims or determine the sophistication of these current capabilities. Nonetheless, CASIC's initial focus on the concept of "missile intelligentization" dates back to the early 2000s, and Chinese research on the topic appears to have continued consistently since then.[191] CASIC's Third Academy claims to have expertise in AI and intelligent robotics, and it recruits personnel with those specialties.[192] Despite the limitations of the available information, it does seem plausible that the Chinese defense industry has achieved at least initial progress in the intelligentization of missiles and is working toward enhancing these capabilities.

AI-Enabled Data Fusion, Information Processing, and Intelligence Analysis

For the PLA, the use of such techniques as machine learning for data fusion, information processing, and intelligence analysis could have impactful short-term applications. As the PLA has become more "informatized," the introduction of information technology throughout the force has created new challenges, including the effective processing of sensor data and raw intelligence to enhance situational awareness, which has become a "bottleneck" for commanders.[193] In this context, advances in intelligent sensing and information processing, such as automation of multi-sensor data fusion and information processing, could enhance situational awareness on the battlefield.[ee, 194] Based on the demonstrated capabilities of AlphaGo, deep learning is seen as likely to enable a substantial increase in the efficiency of intelligence analysis, including intelligentized analysis of massive amounts of data.[195] For instance, the introduction of deep learning algorithms into the analysis process for satellite imagery could greatly enhance the rapidity of processing.[196] The use of big data might also enable a "prediction revolution" that could support the PLA's early warning capabilities.[197]

Ongoing research on such techniques, occurring within a number of defense industry and defense-linked research institutes, as well as the private sector, will likely support continued advances in this application. CETC's 14th Research Institute's (中国电子科技集团第 14 研究所) Intelligent Sensing Technology Key Laboratory (智能感知技术重点实验室) is pursuing research across issues including cognitive radar, big data analytics, and multi-spectral information fusion.[198, 199] Huazhong University of Science and Technology's Image Recognition and Artificial Intelligence Research Institute (图像识别与人工智能研究所), which has received support and recognition from the General Armament Department, has also focused on intelligent information processing and pattern recognition.[200] In addition, the National Defense Science and Technology Key Laboratory for Multi-Spectral Image and Information Processing Technologies (多谱图像信息处理技术国防科技重点实验室) has pursued research in computer vision, image analysis, pattern recognition, intelligent

[ee] In practice, the PLA's capability to do so may remain limited by the stove-piping of data and systems across service and bureaucratic boundaries.

robotics, and intelligent systems.[201] Similarly, AI start-up iFlytek is apparently cooperating with the PLA on a voice recognition and synthesis module, which could be particularly useful for the PLA in intelligence processing.[202] The PLA is also funding multiple projects that address new forms of sensing and information fusion, including AI-enabled techniques for data and image processing, automated target recognition based on machine learning, and multi-source information fusion technologies for intelligent sensing in networked or complex electromagnetic environment.[203]

Defense, Offense, and Command in Information Warfare

The PLA will likely leverage big data analytics, machine learning, and automation to support information warfare, including cyber warfare and electronic warfare. Potentially, these techniques will also enable precision psychological warfare that leverages big data to profile targets and customize attacks to shape individuals' emotions and behavior.[204] Looking forward, the PLA anticipates that the trend toward future "informatized intelligent warfare" (信息化智能战争) necessitates the intelligentization of equipment and integration of AI into command and control, especially for information operations forces.[205]

Cyber Defense and Cyber Warfare

The PLA evidently seeks to leverage AI to enhance the defense of critical military networks and information systems, to scale the effects of offensive cyber operations, and to inform command decision-making in cyber warfare.[ff]

As the PLA's Strategic Support Force (SSF) seeks to build up advanced cyber capabilities, research leveraging big data and machine learning could become an enabler of future advances. The SSF's Information Engineering University has developed methods to detect and mitigate Distributed Denial of Service (DDoS) attacks through pattern matching, statistical analysis, and machine learning, as well as to detect Advanced Persistent Threat detection based on big data analysis.[206] The former General Staff Department's 54th Research Institute, also under the SSF, has patented a method for software vulnerability analysis based on 'fuzzing,' a technique that could be used in penetration testing for offensive or defensive purposes.[207] CETC's 54th Research Institute has received a patent for intrusion detection methods based on deep neural networks.[208]

In particular, given the speed of cyber operations, AI could serve as a critical enabler of rapid command. The writings of several scholars at the Information Engineering University have also addressed the use of data in command decision-making for information operations.[209] For instance, big data analytics could enable massive information retrieval, cross-memory analytics, "full information" computations, and intelligent decision-making.[210]

[ff] In addition to PLA and defense industry research institutes, Qihoo360, a leading Chinese cybersecurity company with close linkages to the government, has already started to incorporate at least limited degrees of automation into its products and services.

Cognitive Radio and Cognitive Electronic Warfare

The PLA could leverage cognitive radio with dynamic spectrum management to enhance communications, while pursuing offensive capabilities in cognitive electronic warfare through the application of machine learning to learn and rapidly devise countermeasures for adversary systems. As the electromagnetic spectrum becomes ever more complex and contested, the introduction of AI will be critical to achieving an advantage.

To date, several research institutes across the PLA, defense industry, and academia have pursued research and development in these technologies. For instance, the Equipment Development Department's 61st Research Institute, as well as likely the 63rd Research Institute, has pursued research and development and received patents related to techniques for cognitive radio and spectrum sensing.[211] The Harbin Institute of Technology and the Xi'an University of Electronic Science and Technology also hold patents for methods of cognitive radio.[212]

Concurrently, the PLA will likely pursue advances in cognitive electronic warfare, building upon its traditional emphasis on this discipline of information warfare.[213] The Strategic Support Force's 54th Research Institute and CETC's 38th Research Institute, among others,[214] are likely engaged in research and development related to cognitive electronic warfare.[215] There is also PLA funding for research on the use of deep learning to enable the determination of signal features in spectrum monitoring.[216]

Simulation, War-gaming, and "Actual Combat" Training

The PLA will likely take advantage of AI to increase the sophistication of its simulations, war-gaming, and even training. Given its lack of actual combat experience, PLA academics have often turned to simulations and computerized war-gaming.[217] Under the leadership of Major General Hu Xiaofeng, a professor at the PLA's NDU, extensive research and development of computerized war-gaming, including campaign-level and strategic-level exercises, has received high-level support.[218] The employment of computerized war-gaming is seen as critical to train commanders in situational analysis and decision-making. Major General Hu Xiaofeng, along with other PLA researchers,[219] is currently focused on the potential for integrating AI into the computerized war-games and military-simulations system to enhance the level of realism and create an artificially intelligent 'Blue Force' (the PLA's equivalent of a Red Team) to fight.[220] In addition, the introduction of AI within war-gaming can also enable its players to experience an approximation of future intelligentized combat.[221] For instance, in September 2017, the China Institute of Command and Control sponsored the first Artificial Intelligence and War-Gaming National Finals, convened at the National Defense University Joint Operations College. It involved a "human-machine confrontation" between top teams and an AI system CASIA-Prophet (先知) 1.0, which was victorious over human teams by a score of 7 to 1.[222] The application of AI to war-gaming is seen as way to enhance research on trends in future warfare, while advancing education and training.[223, 224]

PLA researchers could also utilize AI for simulations and operational planning and analysis in order to model complex dynamics and interactions. For instance, AlphaGo was seen as a demonstration of the potential utility of AI to establish operational models, simulate the trajectory of operations, and assess and optimize the combat plan through the use of big data and computing power.[225] The PLA might also use simulations to investigate the dynamics of human-machine confrontation and interactions among autonomous weapons.[226] Through the simulation and war-gaming of complex battlefield situations in peacetime,[227] the PLA seeks to avoid defeat in wartime through enhancing its combat capabilities.[228]

Eventually, the PLA might even leverage AI to enhance the realism of its training. The PLA is focused on transitioning from a relatively scripted, rigid approach to training to working on warfighting-oriented or actual combat (实战化) training. In the aftermath of AlphaGo's decisive victories in the World Go summit, PLA commentary has highlighted that military training should leverage these capabilities of AI in order to enhance the level of difficulty, complexity, and efficiency.[229] The PLA might attempt to develop "intelligent assistance training systems" in its efforts to ensure that training more resembles actual combat.[230] This use of AI could also enable increased amounts of training despite shortcomings in supply and maintenance that otherwise limit training and drills.[231] AlphaGo's ability to innovate and create unique tactics that surprised human players is seen as an advantage in creating more challenging training scenarios and unexpected tactics. Future PLA training could also make use of augmented reality and virtual reality to compensate for its lack of actual warfighting experience, research the PLA is already funding.[232]

Intelligentized Support to Command Decision-Making

At the highest levels, the PLA prioritizes the intelligentization of its command information systems and has sought to develop intelligent assistance to command decision-making. The CMC Joint Staff Department has called for the PLA to accelerate its construction of a joint operations command system through progress toward intelligentized command and decision-making that takes advantage of the potential of AI, as well as big data, cloud computing, and other advanced technologies.[233] The Joint Staff Department's commentary highlighted that the victory of Google's AlphaGo in the "man-machine war" of *Weiqi* (Go) demonstrated the tremendous potential of AI in operational command, planning deduction, and support to decision-making.[234] The introduction of AI to support the commander is expected to help compensate for human physical and psychological shortcomings and defects and enhance the speed of decision-making – thus accelerating the command cycle – through rapidly providing decision-making recommendations to the commander.[235] Prominent PLA thinkers believe this introduction of AI into the realm of command decision-making is inevitable, and future warfare will involve the combination of intelligentized combat and command platforms.[236] The objective of these efforts is to achieve information superiority and decision-making superiority.[237]

The Joint Staff Department's call for the intelligentization of command and decision-making will continue to be advanced through ongoing theoretical and applied research on this

issue. Major General Hu Xiaofeng, of the PLA's National Defense University,[238] has started to focus on simulations of intelligentized warfare and intelligent assistance to command decision-making.[239] His recent research has closely examined DARPA's Deep Green program.[240, 241] Since the PLA appears deeply interested in Deep Green and has closely studied available English-language materials on this program, PLA researchers could pursue the development of a comparable system.[242]

The PLA may already have achieved significant progress towards command intelligentization, based on media accounts. Liu Zhong (刘忠) of the National University of Defense Technology with its Key Laboratory of Information Systems Engineering (信息系统工程重点实验室) has been engaged in a multi-year research effort dating back to 2006, to optimize and increase the intelligentization of the PLA's command and control systems.[243] Recognizing the complexity of the battlefield and the challenges of command decision, his team has reportedly explored options to integrate increased levels of AI and automation into the PLA's existing command systems in order to enable rapid planning and decision-making.[244, 245] Reportedly, as of December 2015, Liu Zhong's team completed the development of a new advanced system that was provided to some units on at least an experimental basis.[246, 247] Liu Zhong has been praised extensively for his work, which has been characterized as creating an "external brain" (外脑) to assist commanders, enhancing battlespace awareness and management.[248] Although there is not detailed information available about the extent and functionality of this new system's intelligentization, this achievement indicates that the PLA could be on track to achieve such advances in its command decision-making capabilities for joint operations. Such a "command brain" is considered a core capability for future intelligentized warfare.[249]

Concurrently, the China Institute of Command and Control (中国指挥控制学会) has focused on intelligentized command and control in its conferences and publications over the past several years.[250] Of note, Major General Li Deyi, an expert in AI and command automation with the 61st Research Institute, is also involved with the China Institute of Command and Control. Although the activities of the 61st Research Institute, which took a leading role in the PLA's development of its integrated command platform,[251] remain relatively opaque – perhaps due to limits on publication of more sensitive aspects of its research – it may take an integral role in the potential introduction of AI to military command information systems.

Potentially, advances in big data, machine learning, and cloud computing will eventually be incorporated into the integrated command platform itself.[252] In early 2016, the China Institute for Command and Control (CICC) signed a strategic cooperation agreement with the Chinese Academy of Science's Dawn (中科曙光, or "Sugon"),[253] which was established as a high-technology enterprise under 863 Program to support Chinese advances in high-performance computing and has since moved into AI.[254] At the time, Dai Hao (戴浩), chairman of CICC and also a researcher with the PLA's 61st Research Institute, highlighted that this partnership would enable advances in the "cloud-ization" ("云"化) and intelligentization of China's military command information systems.[255] In particular, Dawn's big data and cloud computing technology were seen as providing advanced

technological support and cloud service systems to China's joint operations command mechanism and the construction of military command information systems.

For the foreseeable future, the PLA's attempts to utilize AI to enhance operational command will continue to confront major challenges. First, machine learning algorithms often require massive amounts of data to train, and the appropriate operational data can be difficult to obtain or lacking, as PLA researchers have noted.[256] Even obtaining a comprehensive dataset to account for one's own military is challenging, and acquiring adequate data about an expected opponent is even more difficult.[257] In addition, the complexity of warfare itself remains a constraint, given the fog of war and unpredictable influences of human behavior and decision-making. The "art of command," which requires creativity and ingenuity, is still believed to elude automation, at least for the time being,[258] and Chinese defense experts recognize the critical relationship between natural and artificial intelligence in military command.[259] However, even if AI cannot fully replace the commander, the PLA will continue to pursue the intelligentization of critical functions associated with command decision-making, including information processing, the formulation and evaluation of plans, and rapid assistance to decision-making on the battlefield. For instance, the PLA is funding intelligent decision support and planning technologies for fighter jets in combat through the use of deep learning, genetic fuzzy trees, and other intelligent algorithms.[260]

Relevant Organizations and Potential Funding for Future R&D Activities

The PLA's ability to actualize these intended applications of AI will depend upon the success of current research and development activities and the eventual testing and fielding of these technologies. The PLA's prioritization of defense innovation, particularly in emerging technologies, is evident based on the creation and designation of institutions to guide future PLA research and development of applications and capabilities.[gg] The Central Military-Civil Fusion Development Commission Office, the CMC Science and Technology Commission, and the CMC Equipment Development Department are among the agencies officially designated as responsible for the implementation of the New Generation AI Development Plan.[261] As noted, the CMC Science and Technology Commission will guide defense science and technology development, while the new CMC Military Scientific Research Guidance Commission will reportedly be responsible for strengthening strategic management for defense science and technology, advancing progress in indigenous innovation, and promoting military-civil fusion.[262, 263] The CMC Equipment Development Department, the successor to the former General Armaments Department, and service-level equipment departments will take leading roles in establishing guidance, requirements, and funding for research, development, and testing of weaponry and equipment. In addition, the CMC Intelligent Unmanned Systems and Systems of Systems

[gg] Although this paper focuses primarily on military applications of AI, it is also important to note that the Ministry of Science and Technology is responsible for the implementation of the New Generation AI Development Plan, while the Ministry of Education is tasked with educational initiatives related to AI. The Ministry of Industry and Information Technology, which took the lead on the "Internet Plus" Artificial Intelligence Three-Year Action Plan also seeks to play a central role in AI relevant policy. In addition, local governments at the provincial and municipal levels are pursuing AI plans, providing funding, enabling open data, and creating favorable tax policies.

Science and Technology Domain Expert Group, perhaps in addition to related expert groups, could convene leading experts on these topics, while liaising with academia and industry.[hh, 264] It remains too early to say whether dynamics among these organizations will support Chinese advances in AI or could cause bureaucratic redundancies and inefficiencies, but it is clear that China is creating an expansive institutional framework to advance defense innovation.[ii]

Although it is difficult to produce a credible estimate of aggregate funding levels, an overview of known lines of funding relevant to military and dual-use developments helps to elucidate PLA priorities. Initially, the National High Technology Research and Development Plan (国家高技术研究发展计划, "863 Program/Plan") supported dual-use AI research. As of the mid-1980s, the 863 Plan incorporated major projects involving intelligent robotics, intelligent computing, and intelligent information processing with the creation of the Intelligent Computing Systems Expert Group.[jj, 265] At present, the National Key Research and Development Plan (国家重点研发计划), which replaced the 863 Plan, is also funding research in big data,[266] intelligent robotics,[267] next-generation deep learning, and new deep neural network processors,[268] among other major projects.[269] In addition, the State Administration for Science, Technology and Industry for National Defense (SASTIND), which establishes policies and guidance for long-term research priorities within the defense industry, has issued a Defense Science and Technology Industry 2025 Plan (国防科技工业 2025) that includes a focus on intelligent manufacturing, as well as an opinion encouraging the use of advanced industrial technology, such as intelligent robotics.[270] Within the PLA, the CMC Equipment Development Department and service-level equipment departments in the Army, Navy, Air Force, Rocket Force, and Strategic Support Force will be responsible for several different funding sources that support research and development, including a number of projects involving AI, within the 13th Five-Year Plan timeframe. As these efforts advance, the PLA's success in developing and leveraging military applications of AI will likely vary across applications and organizations.

[hh] There has only been one open-source reference to this expert group to date, and there may also be similar expert groups at the service level and under the CMC Science and Technology Commission and/or Equipment Development Department.

[ii] If this structure results in competition and duplication of effort within the defense industry and the PLA, this dynamic would be consistent with the PLA's approach to informatization, which enabled successful advances but also resulted in inefficiency and corruption. In the past, the General Staff Department's Informatization Department took the lead in implementing this agenda, and its successor, the Joint Staff Department's Information and Communications Bureau, which is responsible for high-level command, control, and communications, could also play a role in the use of AI to enhance these missions.

[jj] As previously noted, in the mid-2000s, the National Key Basic Research and Development Plan (国家重点基础研究发展计划, "973 Plan"), as well as the National Medium and Long- Term Plan for the Development of Science and Technology, have also promoted research in AI.

THE HISTORIC CHALLENGE FOR U.S. COMPETITIVE STRATEGY

"It is hubris to suggest our potential adversaries are not as capable or even more capable of far-reaching and deeply embedded innovation."[271]
— Lieutenant General Jack Shanahan, Director of Defense Intelligence and lead for Project Maven

U.S.-China Strategic Competition and the Dynamics of Military Revolution

China's advances in AI will have immense strategic implications for the United States. Initially, the U.S. military was the first mover and possessed an uncontested advantage in technologies integral to information-age warfare – including information technology, precision weapons, and stealth, so-called "Second Offset" technologies – which remain integral to its military power to this day. However, the current U.S. Third Offset strategy and related or successive defense innovation initiatives must account for the reality that current technological trends, particularly in AI, are not conducive to the preservation of such a decisive edge. In fact, China possesses certain structural and systemic advantages – including national strategic planning, robust human capital potential, and a massive data resource base – relative to the United States that could enable its ambition to lead the world in this critical strategic technology. The United States may retain an edge for the time being but seems unlikely to sustain a decisive advantage in the long term.

At this point, the trajectory of U.S.-China strategic competition in AI remains uncertain, but the outcome could alter future economic and military balances of power.[272] In particular, since the private sector has tended to lead innovation in AI, greater capability to access and implement cutting-edge advances could be a critical factor. In this regard, China's systematic framework for military-civil fusion could create a structural advantage. As in prior military revolutions, the relative capabilities of military organizations to adapt to and rapidly leverage emerging technologies, including the formulation of new operational concepts and doctrine, will be a vital determinant of successful defense innovation.[273] These challenges of innovation and implementation will require concerted effort and adjustment, including the education, recruitment, and training of talent. There will likely be major asymmetries in U.S. and Chinese responses to these technological dynamics, due to differences in their strategic and command cultures, along with their respective organizational capacities.

Despite its tendency to study and learn from the United States, the PLA could formulate unique conceptual frameworks for future intelligentized warfare. Since the 1990s, the PLA has focused on the development of "trump card" (杀手锏) weapons that target vulnerabilities in U.S. battle networks, seeking to develop, in the words of then-CMC Chairman Jiang Zemin, those weapons that "the enemy is most fearful of."[274] This

asymmetric thinking will likely persist in the PLA's approach to AI.[kk] During the previous information technology revolution, the United States possessed a clear technological advantage, but the Soviet Union was the first to recognize and conceptualize the operational implications of technological trends, including the notion of the reconnaissance-strike complex.[275] Certain aspect of the Soviet Union's strategic culture, including a holistic, dialectical cognitive style in contrast to typical U.S. logical and analytical ways of thinking, appear to have contributed to its success in recognizing these discontinuous dynamics of military revolution.[276] The PLA possesses a similar cognitive style, as well as its multi-paradigm conceptual approach,[ll] which could result in different ways of thinking relative to the United States.[277] Potentially, the PLA could be the first to conceptualize or operationalize new concepts of operations for AI in future warfare.

If considerable differences emerge in U.S. and Chinese conceptual, organizational, and operational approaches, these potential asymmetries could lead to unforeseen dynamics on the battlefield. Based on this initial analysis, PLA thinkers and researchers appear very focused on applications of AI in simulations, war-gaming, training, and command decision-making, in addition to more expected use cases as intelligence analysis and unmanned weapons systems. In this regard, the PLA's approach could differ from that of the U.S. military, which has seemingly concentrated on more tactical-level, immediate applications of AI and autonomy so far.[278] There are a number of variables that could advantage or disadvantage the PLA in its attempts to progress beyond current research, development, and experimentation to fielding and using AI-enabled military systems, a process that could involve new talent and training requirements. The PLA's attempts to use AI to mitigate systemic issues within the PLA, such as in human capital and realistic training, could compensate for these shortcomings to enhance its capabilities. However, given adverse tendencies in the PLA's command culture and human dynamics, the introduction of AI could also exacerbate existing issues, such as command micromanagement and mistrust. Even as the PLA seeks to recruit a more educated, highly trained force and to adapt its organizational culture to the demands of modern warfare, these challenges may persist and could limit its capability to actualize military innovation. The PLA might also underestimate the human-factor challenges associated with greater automation.

Potential Differences in U.S. and Chinese Approaches

Although a comprehensive comparison between U.S. and Chinese militaries' approaches to AI would be beyond the scope of the report, it is critical to identify and evaluate the potential impact of initial divergences between U.S. and Chinese thinking on and military employment of AI. According to former Deputy Secretary of Defense Bob Work, critical "building blocks" in the Third Offset strategy included learning machines, human-machine

[kk] The term *shashoujian* (杀手锏) variously translated "trump card" or "assassin's mace," is generally used to refer to asymmetric capabilities that could target U.S. vulnerabilities. The term also alludes to a Chinese folktale in which such a weapon was used for unexpected incapacitation of a stronger enemy through a trick.

[ll] For instance, PLA academics and strategists are familiar with traditional Marxist and Maoist theories on technology and warfare and also tend to study traditional Western frameworks of international relations theory.

collaboration, machine-assisted human operations, human-machine combat teaming, and autonomous weapons, incorporated into a single network 'learning at the speed of light.'[279] As this report reflects, the PLA is working toward a number of these same capabilities, informed by careful study of the Third Offset and ongoing U.S. defense innovation efforts. To date, the PLA has not officially articulated a singular strategy or formal organizing concepts. However, critical aspects of the PLA's initial approach to AI, which will likely to continue to evolve as the underlying technologies, development of capabilities, and theoretical research advance, allow for an evaluation of apparent asymmetries to date.

Models of Military-Civil Fusion and Public-Private Partnership

The PLA may have a greater capability to leverage private sector advances in AI through China's national strategy for military-civil fusion. The establishment of formal mechanisms and institutions to support this agenda could enable effective synergies and deeper collaboration, despite traditional obstacles. To date, there are a number of examples of partnerships between military and civilian sectors and of the establishment of joint laboratories. These efforts will likely expand and intensify as the implementation of China's national strategy for military-civil fusion progresses.

On the other hand, the United States has necessarily focused on cultivating partnerships with the private sector and new mechanisms for funding and procurement, including through Defense Innovation Unit Experimental (DIUx).[280] However, the Department of Defense's (DoD) attempts to pursue closer cooperation with the tech community may continue to face considerable challenges.[281] The complex relationship between Washington and Silicon Valley may become more complicated, even contentious, going forward.[282] Certain elements of the private sector may be unwilling to work with the DoD.[mm] Even when partnership is feasible, issues in acquisition tend to obstruct the rapid purchasing and deployment of new systems, especially from nontraditional suppliers.[283]

An Agenda for "Intelligentization" versus a Mission-Driven Model

The PLA could be embarking upon an expansive agenda for intelligentization that may parallel the scope and scale of its ongoing process of informatization. Traditionally, the PLA's push for informatization has simultaneously taken top-down and bottom-up approaches, with high-level impetus to advance this agenda but allowing for a variety of grassroots efforts.[284] Similarly, in the course of intelligentization, the PLA could seek to incorporate AI throughout its force structure to support a range of relevant applications. In practice, the variety of these efforts could result in inefficiencies or redundancies yet could also enable effective competition and experimentation to support long-term advances.

By contrast, the U.S. military appears to be focusing on leveraging AI for a more limited, defined set of missions with immediate relevance. Initially, AI was almost inextricably linked to unmanned systems in DoD thinking, a perspective that limited more expansive

[mm] For instance, when acquired by Google, DeepMind reportedly required the prohibition of the use of its research for military and government purposes.

assessments of the overall potential of the technology, but the DoD is gradually starting to recognize the range of applications and formulate a broader conceptualization of AI.[285] At present, through Project Maven, the DoD seeks to advance its use of AI, big data analytics, machine learning, computer vision, and convolutional neural networks.[286] In an initial "pathfinder" project, the DoD will seek to automate and augment the video data collected by UAVs, with the intention of developing an algorithm to deploy within a war zone by the end of 2017. [287] The challenge of such an approach might be the balance between focusing on such short-term imperatives and long-term advances for a wider range of missions.

Compensating for or Complementing Human Capital

Although the PLA has sought to recruit a more educated force, continued shortcomings in personnel may remain a major issue in its employment of AI.[288] For the PLA, AI could be seen as an effective means of compensating for persistent challenges of human talent and difficulties in training. The PLA's relative lack of trust in human personnel – as reflected in calls for improved ideological and political work, along with frequent reiteration that the "Party commands the gun" against the backdrop of an ongoing anticorruption campaign – could also contribute to a tendency to see AI as more reliable. However, the effective employment of AI will also demand attention to complex human factors, likely including specialized in training and perhaps even new organizational structures. In this regard, the PLA's ability to overcome these human and cultural challenges could remain a major hurdle.

As a counterpoint, the DoD's focus on AI in the Third Offset has consistently recognized the human element as the United States' "number one advantage."[289] Although this human-centric approach could enable effective human-machine collaboration, the question remains whether the United States will be able to create an "AI-ready culture" in which human operators trust and understand AI enough to leverage it effectively.[290] There could also be bureaucratic and organizational resistance to AI replacing human operators, as there was (and, to some extent, continues to be) to the widespread adoption of unmanned systems. The DoD will also face its own challenges in human capital and talent as it seeks to recruit AI experts in a highly competitive environment. Concurrently, the U.S. military may need to develop new types of training and occupational specialties.

Intelligentized Command Decision-making and/or Keeping Humans In the Loop

The PLA is focused on the use of AI to support command decision-making, based on strategic writings and ongoing research and development alike. The potential for a "singularity" in warfare, at which human cognition may be unable to keep pace with the speed of operations, could necessitate a transition toward a new model of command and control in which AI necessarily takes on a greater role. Former Deputy Secretary of Defense Bob Work has predicted, "authoritarian regimes who believe people are weaknesses in the machine … will naturally gravitate towards totally automated solutions."[291] The PLA could see higher levels of automation as appealing. However, PLA thinkers have also highlighted the importance of human-machine collaboration in command and in manned-unmanned teaming. The PLA's progression towards greater automation could require challenging

adjustments if the PLA remains unwilling to decentralize control, given the tendency of high-level commanders to micromanage and consolidate authorities. At this point, it is too early to come to a clear conclusion, as these dynamics will continue to evolve within the PLA.

Concurrently, the DoD has primarily focused on concepts of human-machine collaboration and teaming, while reiterating that humans must remain "in the loop." Former Secretary of Defense Ashton Carter has declared that the U.S. military will "never" pursue "true autonomy," meaning humans will always be in charge of lethal force decisions and mission-level oversight.[292] General Paul J. Selva, Vice Chairman of the Joint Chiefs of Staff, coined the phrase "Terminator Conundrum" to describe dilemmas associated with autonomous weapons,[293] and he has reiterated his support for keeping humans in the loop because he "doesn't think it's reasonable to put robots in charge of whether we take a human life."[294] However, the U.S. military could face a disadvantage or pressures to adapt if strategic competitors such as China and Russia pursue full autonomy without similar constraints – although it remains unclear when, whether, and in what contexts greater degrees of autonomy will provide a clear advantage.

In practice, the critical question for the U.S. and Chinese militaries alike will be differentiating the degree of autonomy appropriate to particular missions and applications. The current U.S. commitment to having humans "in charge" could also prove difficult to sustain in practice, given technological trends. The United States also has yet to adequately conceptualize the notion of a human "in the loop." For instance, if a human decision, such as about targeting, is informed by intelligence, surveillance, and reconnaissance that was processed primarily through machine learning, can a human truly be said to be adequately 'in the loop' and informed? Although most concerns to date about meaningful human control have focused on lethal autonomous weapons, a mistake, malfunction, or deliberate corruption of an AI-enabled system that processes and analyzes data, information, and intelligence to inform decision-making, at the level of data or the algorithm, could cause a mistake that could inform and thus undermine human decision-making in ways that could be risky or destabilizing.

Relative Likelihood of Respective Approaches and Adherence to Legal Restraints

To date, there has been only limited discussion in the writings of PLA academics and officers of potential legal and ethical issues associated with the military employment of AI and autonomy. There could be an appreciable disconnect between China's official diplomatic position on these issues and the PLA's actual approach. In December 2016, during the UN's Fifth Review Conference on Certain Conventional Weapons, China submitted a position paper calling for the regulation of fully autonomous weapons under international law.[295] Although it is encouraging that China has started to engage with these issues, the PLA's lack of experience with the application of the laws of armed conflict or rules of engagement – as well as its traditional approach of "legal warfare" that seeks to exploit, rather than recognize constraints in, international law – should cause skepticism about its future approach.

The U.S. approach to autonomous weapons is more likely to be shaped by legal and ethical factors, as well as constraints of public opinion. The DoD's 2012 directive on autonomy in weapons systems articulated a commitment to ensuring that human judgment guides their employment, which must be in accordance with the laws of war and rules of engagement.[296] The U.S. employment of military applications of AI may also be influenced by public opinion and a global campaign against "killer robots." Compared to China, the United States could also be more accountable to its commitments to international law, given its relative responsiveness to domestic and international pressures.

RECOMMENDATIONS FOR U.S. POLICY AND STRATEGY

Based on this initial analysis, the U.S. government – and particularly the DoD – should take the following actions to ensure U.S. military and strategic competitiveness in AI:[nn]

1. Recognize and understand the strategic challenge

- *U.S. defense innovation initiatives and competitive strategy should be informed by a nuanced understanding of the PLA's strategic thinking on and advances in military applications of AI.*

As the DoD pursues the Third Offset and related efforts, including Project Maven, these defense innovation initiatives must take into account the trajectory of the PLA's progress in military applications of AI and emerging asymmetries in its approach. To compete with and counter Chinese advances, the DoD should consider – and through, for instance, the Office of Net Assessment, support – research to track the activities of China's defense innovation ecosystem, including the expanding partnerships with the Chinese private sector, progression of research and development, and initial experimentation with the employment of AI.

- *The DoD should support war-games, tabletop exercises, and operations research to examine impactful military applications of AI and potential battlefield dynamics among adversaries with different strategic and organizational cultures.*

Beyond current initiatives, the DoD should expand efforts to evaluate the range of short-, medium-, and long-term applications of AI in warfare. Such programming should focus on the interactivity of emerging technologies with the strategic cultures and organizational dynamics of different militaries, particularly potential adversaries, but also examine the implications of AI for interoperability with allies and partners. These efforts should include a variety of defense, technical, and regional experts in order to examine potential dynamics of use and decision-making involving AI-enabled capabilities on the battlefield. Such efforts should support future strategic planning and the development of countermeasures.

2. Formulate a long-term, whole-of-nation strategy to support critical determinants of national competitiveness in AI

- *The United States must safeguard critical strategic technologies while recognizing the inevitability of technological diffusion*.

The current efforts to constrain illicit and problematic technology transfers in AI and other emerging technologies could constitute an initial step to mitigate attempts by the Chinese government to take advantage of foreign resources to support indigenous innovation. For instance, proposed reforms to CFIUS, which is responsible for reviewing investments and

[nn] Please note that this is not intended to be a comprehensive set of policy proposals, but rather a series of recommendations informed by the content of this report.

acquisitions involving foreign nationals that could impact U.S. national security, could be a key measure, if targeted appropriately.[297] Clearly, China has a history of exploiting licit and illicit means of technology transfer, including through large-scale industrial espionage enabled through both cyber and human means,[298] as well as through the pursuit of joint ventures, strategic partnerships, overseas investments, and acquisitions targeting cutting-edge strategic technologies. Given these risks, U.S. enterprises' engagement with China in AI should be calibrated based on an awareness of its official strategy for military-civil fusion and the resulting dual-use dilemma associated with potential transfers of knowledge, expertise, and technology. For instance, targeted attempts could constrain the transfer of critical hardware components of AI, such as dedicated machine learning chips.

Although the United States should seek to restrict Chinese investment and attempted technology transfer in cases where there is a clear risk,[299] it will prove difficult, if not infeasible, to control the diffusion of knowledge, technology, and people in a globalized, networked world.[300] Today, the majority of cutting-edge research and development tends to occur within the private sector. The flows of data, talent, and capital across borders are challenging to constrain, particularly given the intense competition and tremendous commercial incentives. There are plenty of cases, including issues of AI safety and standards, in which collaboration is warranted and mutually beneficial. It is also clear that international cooperation in science and technology is critical to advancing the frontier of knowledge. As such, while monitoring and mitigating illicit technology transfer, the United States must refrain from responding in ways that could result in unintended economic consequences and undermine the dynamism of its own innovation ecosystem. It is important to recognize that even in the unlikely event that the United States succeeded in entirely limiting technology transfer and diffusion, China's rapidly advancing indigenous capabilities would nonetheless remain a strategic challenge. China's capability to pursue independent innovation has increased considerably, as Chinese advances in AI and quantum information science aptly demonstrate.[oo] Consequently, U.S. attempts to control technology transfer will not be sufficient absent a more comprehensive strategy.

- *The U.S. government must target funding to basic and applied research and development.*

It is concerning that there has been a continuing decline in U.S. investment in basic research, even as China has intensified investments in critical emerging technologies. For instance, the Trump administration's proposed fiscal year 2018 budget called for the National Science Foundation funding for intelligent systems to be cut by 10 percent, to a mere $175 million.[301, 302] Such a decrease in funding for basic research would be troubling. It is vital that the U.S. government ensures adequate funding for scientific research, averting the risks of an "innovation deficit" that could severely undermine long-term competitiveness.[303] Relative to China, the United States tends to be highly successful in basic research but sometimes less effective in the operationalization of scientific advances,

[oo] The problematic, even dangerous assumption that China "can't" innovate – and can only rely on mimicry and intellectual property theft – is outdated, yet recurs despite considerable, even overwhelming, evidence to the contrary.

including due to inadequate funding at that stage, which could result in critical technological advances remaining in the lab rather than becoming available for commercial or military use.[304] There also tends to be shortfalls in the funding available to research and start-ups for which the potential for commercialization is limited or unlikely to be lucrative in the foreseeable future. Despite ample private sector financing of research and development, U.S. government funding continues to serve a critical function in enabling innovation.

Looking forward, the United States should sustain and expand investments in this critical emerging technology, focusing on not only impactful applications but also long-term research. The National AI Research and Development Strategic Plan, released in the fall of 2016, could serve as a starting point to support and guide a national agenda for funding research and development, including through national laboratories.[305] Concurrently, DARPA, IARPA, In-Q-Tel, and DIUx should expand and coordinate efforts to support the research, development, and fielding of AI-enabled capabilities. The Army, Naval, and Air Force Research Laboratories might also expand their focus upon advanced research to deliver these new operational platforms to the warfighter. In particular, the development of new techniques and technologies to counter or exploit adversary AI, while mitigating potential vulnerabilities in U.S. systems, should be a priority.

- *The U.S. government, and particularly the DoD, should seek to advance public-private partnership in AI.*

Since the locus of innovation has shifted to the private sector, the DoD should sustain and expand existing efforts to create closer public-private partnerships, such as DIUx. To take full advantage of advances in AI, the DoD may also need to reform current practices in procurement and acquisitions to enable greater agility. In addition, the DoD might explore options to create fellowships enabling career AI experts and technologists to have flexible 'on-ramps' to serve short stints in government to contribute their expertise.

- *The United States must compete to attract the world's top talent, while focusing on education and training to create a robust human capital pipeline.*

The United States must invest in education and compete to attract and recruit leading talent to enhance its competitiveness in AI and avoid an otherwise problematic deficit in the requisite human capital.[306] The DoD might consider expanding funding to the Army, Naval, and Air Force Research Laboratories to support the hiring and retention of top talent in AI. Concurrently, for the United States to ensure a robust human capital pipeline for future advances in AI, it will be critical to support expanded educational programming and support students in these fields through scholarships and grants. For instance, the DoD might expand its existing STEM scholarships, perhaps increasing the number of fellowships and/or creating a new track within the National Defense Science & Engineering Graduate Fellowship for students intending to pursue doctoral degrees in AI and related disciplines.[307] The Department of Education should also build upon and expand existing STEM education programs.

3. Mitigate the risks of uncontrollable escalation to ensure strategic stability

- *The DoD should create a working group involving military and technical experts, including from the private sector, national laboratories, and service research laboratories, to evaluate potential risks associated with the military employment of AI by the U.S. military and potential adversaries, including the impact on crisis stability and escalation dynamics.*

Such a working group should address the operational risks associated with multiple applications of AI and formulate recommendations to mitigate them. This initiative should draw upon the full range of available expertise to create a threat model that considers the potential accidents that might arise, such as unexpected errors or enemy manipulation, and associated consequences for AI within range of military applications. The working group should also assess the risks and advantages of developing different forms of "counter-AI" capabilities.

- *The DoD should develop procedures and a formalized mechanism to test the reliability and anticipate potential accidents resulting from AI.*

Building upon current efforts, the DoD should establish a standardized and coordinated approach to ensure the safety, security, and reliability of AI systems, including robust testing prior to fielding and the use of methods to verify results. In the process, the DoD should engage and collaborate with private sector experts. In addition, this mechanism should explore the development of technical mechanisms for error recognition and correction, as well as potential 'circuit breakers' or fail-safes for AI systems.

- *The DoD should consider supporting Track 1.5 or 2 engagement and dialogue on AI and other disruptive technologies between the United States and China.*

Against the backdrop of intensifying strategic competition, great powers are unlikely to accept constraints upon capabilities considered critical to their future military power. At this point, despite recurrent concerns over the risks of "killer robots," an outright ban would likely be infeasible. At best, militaries would vary in their respective adherence to potential norms. The military applications of AI will enable new capabilities for militaries but also will create new vulnerabilities. This militarization of AI could prove destabilizing, potentially intensifying the risks of uncontrollable or even unintended escalation. There will likely be major asymmetries between different militaries' approaches to and employment of AI in warfare, which could exacerbate the potential for misperception or unexpected algorithmic interactions.

Under these conditions, a pragmatic approach to mitigating the risks of the militarization of AI should focus on issues on which great powers would have common aversions. Despite the intensification of great power competition, the United States, China, and Russia still share commitment to strategic stability and recognize the risks of inadvertent escalation.

At this point, these militaries' respective approaches to AI remain at relatively nascent stages and will continue to evolve as the technology advances. Now is the time to start considering the ramifications of these technological trends and collaboratively evaluating appropriate parameters that might mitigate the risks of escalation or miscalculation among great powers.

CONCLUSIONS AND QUESTIONS FOR FUTURE ANALYSIS

This report constitutes an initial review of PLA's strategic thinking on and progress in military applications of AI, which remain relatively nascent at this point. Given the limitations of the available information, the analysis herein is necessarily somewhat speculative but seeks to highlight initial trends and raise questions that might guide future research on these issues. China's rise in AI will create new potential capabilities and opportunities for the PLA, particularly if military-civil fusion enables the effective transfer of private sector advances for military use. In practice, however, there will likely be continued obstacles to the effective sharing, acquisition, and fielding of AI systems. Traditionally, China's defense technology base has also taken advantage of foreign technology and knowledge transfer of dual-use technologies, and it will likely continue to do so under China's New Generation AI Development Plan.[308] However, China's advances in independent innovation in this dual-use technology, with the impetus of this plan, will also become critical enablers of the PLA's future capabilities.

The PLA may have the capability to leverage AI to achieve an advantage on the future battlefield, yet its employment will also introduce certain vulnerabilities. As militaries progress toward greater degrees of reliance on AI – whether in the context of intelligence analysis, weapons systems, or command decision-making – this trend could place a premium upon the ability to manipulate or exploit these "intelligentized" systems. PLA strategists have discussed options for countermeasures against adversaries' military employment of AI,[309] which might include interference, damage, and destruction through kinetic or non-kinetic (e.g., electromagnetic, microwave weapons) means, or even attempts to make the enemy lose control of its AI and modify its procedures, to result in an 'uprising' that could advantage one's own side.[310] Despite the focus on "explainable" AI,[311] to the extent that certain forms of AI remain a 'black box' beyond the full awareness and understanding of human users, it could be difficult to detect or counter such measures.[312]

As the United States and China compete to innovate in this new technological domain, the asymmetries between their approaches could result in unexpected, destabilizing dynamics. In practice, even potential differences between U.S.- and Chinese-developed AI – resulting from the data used to train the underlying algorithms and the associated parameters – could cause unforeseen battlefield interactions or misperceptions. Although AI has already surpassed human capabilities in multiple contexts, the mistakes that arise are often mistakes no human would make and can be difficult to predict or mitigate.[313] There are also a number of cases already in which AI has seemingly taken on human characteristics and prejudices as a result of the data used to train the algorithms and design choices of developers.[314] This future cognitive aspect of AI could become particularly pronounced between algorithms produced in different national, cultural, and normative contexts. Given these dynamics, the future employment of AI on the battlefield could intensify the risks of misperception among militaries in crisis or conflict scenarios. The pressures to automate or intelligentize weapons and even command systems to outpace the enemy's decision-making and command cycles would exacerbate the risks of momentum-driven escalation, which could be highly destabilizing.[315]

Although the trajectory of these dynamics and future challenges remains difficult to anticipate, this initial analysis and projection does raise a number of research questions that merit future consideration.

- What are the primary obstacles for China in the transfer of civilian advances in AI to a military context? How readily will different elements of the PLA be able to overcome these challenges?

- Within what timeframe will China's AI-enabled capabilities be mature and reliable enough to employ in unmanned weapon systems, intelligence analysis, information/cyber operations, command decision-making, and other applications in a conflict scenario?

- How could unique aspects of different militaries' strategic cultures impact their approach to the employment of AI?

- How might elements of various militaries' command cultures impact their willingness to rely on AI to support and assist command decision-making?

- What will be the primary sources of bureaucratic and organizational resistance to the increased use of AI in the PLA and the U.S. military, respectively?

- How will different military organizations approach ethical and legal questions associated with intelligent and autonomous systems? How will these considerations impact the design and use of AI for military purposes?

- How and to what extent will AI developed through unique sources of data, with different parameters and within different cultural contexts, differ in function? What are the operational implications of those differences?

- What operational concepts and organizational constructs will enable the military potential of AI and automation to be maximized? How will various military organizations approach and succeed in these aspects of defense innovation?

- If the advent of AI in warfare results in a military revolution toward intelligentized or algorithmic warfare, which aspects of today's paradigm of "informatized" warfare will be rendered obsolete and require dramatic or discontinuous changes?

- As the PLA looks to and learns from the U.S. military's approach to AI and automation, to what extent will its own conceptual frameworks and employment of these technologies converge or diverge with those of the United States?

- To what extent will intelligent and autonomous systems be vulnerable to misperception or manipulation? Are there effective countermeasures to these forms of "machine-age" psychological warfare?

- How might these trends exacerbate the risks of misperception, crisis instability, and uncontrolled escalation? What pragmatic practices or norms could mitigate those risks?

Although this report cannot fully or adequately address these and other key issues at this point in time, it seeks to establish an initial baseline and highlight the imperative of future analysis that continues to examine the implications of PLA's advances in and approach to AI in warfare. Since the development of AI remains at an early stage, and it will likely continue to evolve rapidly, continued study is critical to understand these questions and evaluate future trends.

As the United States and China compete to innovate in AI, the trajectories of their respective progress will deeply impact the future military and strategic balance. Although the United States remains ahead in AI for the time being, China is no longer in a position of technological inferiority relative to the United States but rather has become a true peer competitor that may have the capability to overtake the United States in AI.[316] Consequently, the PLA is seeking to achieve an advantage over the United States through changing paradigms (弯道超车) in warfare with its own agenda military innovation, thus seizing the "commanding heights" (制高点) of future military competition.[317] As the PLA attempts to overtake, rather than just catch up with or match, U.S. progress in this domain, it will be vital to understand and take into account its evolving approach and advances. Looking forward, the PLA's employment of AI will influence this unfolding military revolution,[318] presenting a unique strategic challenge to the United States.

APPENDIX

Chinese military-relevant research efforts in AI and automation extend across academic institutions, national laboratories, defense industry research institutes, and PLA research institutes. Although a full review of this ecosystem would be beyond the scope of this report, several institutions are worthwhile to note.

- There are multiple institutes associated with the Chinese Academy of Sciences (CAS, 中国科学院) involved in research related to AI, such as the Institute of Intelligent Machines (智能机械研究所) and Institute of Automation (自动化研究所), as well as the National Key Laboratory for Pattern Recognition (中国科学院模式识别国家重点实验室). In addition, the Chinese Academy of Sciences Institute of Computing Technology's Key Laboratory of Intelligent Information Processing (智能信息处理重点实验室) is pursuing research on natural language processing and translation and intelligent human-machine interfaces, among other areas.[319]

- The National Key Laboratory of Intelligent Technologies and Systems (智能技术与系统国家重点实验室), established in 1986 at Tsinghua University, focuses on research including basic principles and methods for AI, intelligent information processing, intelligent robotics, and interdisciplinary research in cognitive neuroscience.[320] Tsinghua researchers have collaborated with CETC in the development of swarm intelligence. In June 2017, Tsinghua University has also established the Military-Civil Fusion National Defense Peak Technologies Laboratory (清华大学军民融合国防尖端技术实验室), which will pursue dual-use advances in AI.[321]

- Beihang University is closely linked to the development of military aeronautical and astronautic technologies, including autonomous UUVs and intelligent UAVs, including for swarming and manned-unmanned teaming. Notably, Beihang University has established one of China's first master's degree programs in AI, in collaboration with industry partners including Baidu.[322]

- Under CETC, the Electronics Studies Research Institute (电子科学研究院), with which swarm intelligence expert Zhao Yanjie is affiliated, has been instrumental in CETC's development of swarm intelligence.[323] In addition, CETC's 14th Research Institute includes the Intelligent Sensing Technology Key Laboratory (智能感知技术重点实验室), which has pursued research on cognitive radar and multi-spectral data fusion, and CETC's 38th Research Institute may be pursuing research and development of cognitive electronic warfare capabilities.

- Within CASIC, the Third Academy's National Defense Key Laboratory for Advanced Guidance and Control Technologies (先进制导控制技术重点实验室) is engaged in research on the application of AI to the guidance and control of missiles. In addition, the Aerospace Science and Industry Intelligent Robotics Company Ltd. (航天科工智能

机器人有限责任公司) focuses on intelligent robotic systems, as well as intelligent sensing and recognition technology, primarily for defense and military applications.[324]

- The Aviation Industry Corporation of China (AVIC) 613rd and 615th Research Institutes are engaged in research to leverage AI technologies, including deep learning, to support planning and decision-making for fighter jets in combat.[325]

- The National University of Defense Technology (NUDT) Institute of Automation (自动化学院) is engaged in a range of research involving big data and AI, leveraging synergies with NUDT's National Key Laboratory for High-Performance Computing. There are a number of NUDT researchers pursuing advances in such topics as deep learning, computer vision, and parallel and distributed computing. In July 2017, NUDT's Computer Science Institute procured a dedicated deep learning workstation. In addition, NUDT's Key Laboratory of Information Systems Engineering (信息系统工程重点实验室) has engaged in research to optimize and increase the intelligentization of the PLA's command and control systems.

- Under the CMC Equipment Development Department, the 61st and 63rd Research Institutes, likely among others, are engaged in research and development related to AI such in cognitive radio, networking, and electronic warfare. The 61st Research Institute played a critical role in the construction of the PLA's integrated command platform. Under the leadership of AI expert Major General Li Deyi, the 61st Research Institute has engaged in research in AI and applications, potentially including options for its incorporation into PLA command systems. The 61st and 63rd Research Institutes are likely pursuing research and development related to cognitive radio, software-defined radio, and spectrum sensing.[326]

- In late 2016, the National Development and Reform Commission approved the creation of over a dozen national engineering laboratories involving big data technologies and applications.[327] For instance, the National Engineering Laboratory of Big Data Systems and Software (大数据系统软件国家工程实验室) is led by Tsinghua University, in collaboration with the Chinese Academy of Sciences Institute of Computing Technology, the Beijing Institute of Technology, and Alibaba's Aliyun.[328] The National Engineering Laboratory of Big Data Analysis Technologies (大数据分析技术国家工程实验室) is led by Xi'an Jiaotong University, the Chinese Academy of Sciences Institute of Computing Technology, and Beijing University, in collaboration with the Chinese Academy of Sciences University, the CAS Computer Network Information Center, Dawn/Sugon Information Industry Co. Ltd., and National Innovation Science and Technology Co.;[329]

- In March 2017, China's National Engineering Laboratory for Deep Learning Technology (深度学习技术国家工程实验室) was established under the leadership of Baidu.[330, 331] This new laboratory will engage in research on deep learning, including machine-learning-based visual recognition, voice recognition, biometric identification,

and new forms of human-computer interaction, in partnership with Tsinghua University, Beihang University, the China Information and Communications Research Institute, and the Chinese Academy of Sciences.[332]

- In April 2017, the National Engineering Laboratory for Virtual Reality and Augmented Reality Technologies and Applications (虚拟现实/增强现实技术及应用国家工程实验室) was established under the leadership of Beihang University.[333]

- In May 2017, the National Engineering Laboratory for Brain-Inspired Intelligence Technology and Applications (类脑智能技术及应用国家工程实验室) was established, with the aim of developing AI technologies that learn from the mechanisms of the human brain and promoting the development of brain-inspired neural chips and brain-inspired intelligent robotics.[334] This University of Science and Technology of China will take the lead in its construction, in collaboration with Fudan University, the Chinese Academy of Sciences Shenyang Institute of Automation, the Chinese Academy of Sciences Institute of Microelectronics, and Baidu.[335]

Although a full mapping of Chinese defense industry efforts in AI and related technologies would be beyond the scope of this paper, the scope and scale of these efforts indicates a sustained focus that will likely only intensify going forward. The Chinese defense industry is actively pursuing research and development for a range of AI applications while actively recruiting AI talent. The pursuit of partnerships with academia and the private sector, under the aegis of military-civil fusion, could enable the leveraging synergies inherent in this dual-use technology. The success of these research efforts remains to be seen, but the PLA is evidently committed to defense innovation in this domain.

ENDNOTES

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[5] Associated Press, "Putin: Leader in Artificial Intelligence Will Rule World," September 4, 2017, https://www.cnbc.com/2017/09/04/putin-leader-in-artificial-intelligence-will-rule-world.html.

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[8] "Xi Jinping: Comprehensively Advance an Innovation Driven Development Strategy, Promote New Leaps in National Defense and Military Construction" [习近平：全面实施创新驱动发展战略 推动国防和军队建设实现新跨越], Xinhua, March 13, 2016, http://news.xinhuanet.com/politics/2016lh/2016-03/13/c_1118316426.htm. See also the official strategy released on innovation-driven development: "CCP State Council Releases the "National Innovation-Driven Development Strategy Guidelines" [中共中央 国务院印发《国家创新驱动发展战略纲要》], Xinhua, May 19, 2016, http://news.xinhuanet.com/politics/2016-05/19/c_1118898033.htm.

[9] For the purposes of this paper, I choose to use the term "military-civil fusion" (军民融合) as the translation rather than "civil-military integration," to avoid confusion with a similar but distinct term (军民结合). For a more detailed analysis of the dynamics of China's military-civil fusion strategy, see: Greg Levesque and Mark Stokes, "Blurred Lines: Military-Civil Fusion and the "Going Out" of China's Defense Industry," Pointe Bello, December 2016, http://www.pointebello.com/researchandinsights/.

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