June 7, 2019

Testimony before the U.S.-China Economic and Security Review Commission
Hearing on Trade, Technology, and Military-Civil Fusion

Chinese Military Innovation in Artificial Intelligence

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Xi Jinping has called upon the Chinese People's Liberation Army (PLA) to become a world-class military (世界一流军队) by mid-century.[1] Chinese military modernization has been directed towards learning from and targeting the U.S. military, which is seen as a powerful adversary (强敌). Since the 1990s, the PLA has concentrated on developing asymmetric capabilities aimed at exploiting potential American vulnerabilities and undermining current American advantages. The PLA aspires not only to equal but also surpass the U.S. military by achieving an advantage in the course of the ongoing Revolution in Military Affairs (RMA) that is being catalyzed by today's advances in emerging technologies. Chinese military strategists anticipate a transformation in the form and character of conflict, which is seen as evolving from today's "informatized" (信息化) warfare to future "intelligentized" (智能化) warfare.[2] The PLA may even offset U.S. military power if successful in leapfrogging ahead in the course of this transformation. However, the PLA continues to confront critical challenges to operationalizing artificial intelligence (AI) across a range of applications, from issues of talent to the management of data and adaptation as an organization. The advent of AI on the future battlefield might disrupt the balance of power in ways that risk jeopardizing strategic stability and undermining deterrence in the U.S.-China relationship. Looking forward, as this rivalry intensifies, the United States must recognize the imperative of investing in our own innovation and sustaining our core competitive advantages.

The PLA is actively exploring and experimenting with new concepts and capabilities to leverage artificial intelligence to enhance its combat power and deterrence. Chinese defense academics and military strategists are actively exploring ideas and theories of 'intelligentized operations,' seeking to determine new mechanisms for victory.[3] The use of AI in war-gaming and operations research could contribute to conceptual advancements, including the exploration of new notions of human-machine integration and coordination.[4] In the process, the PLA is closely studying and adapting lessons learned from U.S. concepts and initiatives, but there is often a significant asymmetry of information, insofar as the state of AI and advances in China often receive less attention from American strategists. The primary purpose of this testimony—and the author's research over the

past couple of years, which is based entirely on open sources that are readily available—has been to contribute to improved understanding of the implications of these military and technological advancements in the People's Republic of China, in ways that can inform future American competitive strategy.[5]

A New Era of Chinese Military Innovation

The PLA is pursuing and prioritizing military innovation. Chinese leaders assess a new Revolution in Military Affairs (RMA, 军事革命) is underway that presents urgent challenges and historic opportunities for China. In August 2014, the Politburo devoted a study session to the topic of new trends in global military developments and promoting military innovation. At the time, Xi Jinping discussed the emergence of a "new RMA," calling for China to keep pace with the times (与时俱进) in "vigorously advancing military innovation" in order to "narrow the gap and achieve a new leapfrogging as quickly as possible."[6] Xi Jinping's exhortation continues a legacy and trajectory of military modernization that can be traced to the initial reaction of Chinese leaders, including Jiang Zemin himself, to the Gulf War and American attention to the RMA.[7] In his remarks at the time, Xi called upon the PLA to carry forward its tradition of innovation through striving to develop new military theories, institutional structures, equipment systems, strategy and tactics, and models for management that could fulfill the demands of its missions in an era of informatized warfare.[8] For China, the emphasis on leveraging science and technology to rejuvenate its military (科技兴军) is central to the Party's "powerful military objective in the new era."[9] This Chinese strategy of "innovation-driven development" could transform the PLA.

Throughout its history, Chinese military strategy has evolved and been adjusted in response to new assessments of the form or character of conflict.[10] The latest revision of China's "military strategic guideline" (军事战略方针) to "winning informatized local wars," was confirmed by the 2015 defense white paper, China's Military Strategy, which also discussed a "new stage" in the global RMA resulting from increasing prominence and sophistication of long-range, precise, smart [*sic*, or "intelligent," 智能],[11] stealthy, and unmanned weapons and equipment."[12] Chinese concerns about the U.S. Third Offset Strategy, which was seen as threatening to create a new "generational difference" (时代差) between U.S. and Chinese military capabilities, appears to have influenced and intensified this imperative of innovation.[13] However, the PLA's approach to leveraging the same technologies that the U.S. military has prioritized will differ as a result of its distinct strategic culture, institutional conditions, and operational requirements. Preparing to "fight and win" future wars, the PLA is determined to seize the initiative in the strategic technologies of the future.[14]

The PLA's military reforms, launched in late 2015, have advanced a historic restructuring that is intended to enable the PLA to increase its capability for integrated joint operations across all domains of warfare.[15] In the course of these reforms, the Strategic Support Force (战略支援部队), which has integrated the PLA's space, cyber, electronic, and psychological warfare capabilities, has been directed to pursue innovation and develop new capabilities to contest these new frontiers of military power.[16] These reforms have included the creation of the Central Military Commission (CMC) Science and Technology Commission, which has taken on a mission of promoting national defense science and technological innovation, launching new plans, funds, and contests focused on "frontier" (前沿) technologies.[17] Concurrently, the transformation of the PLA's Academy of Military Science (AMS) has also positioned this influential institution to integrate theoretical and

technological innovations. Notably, AMS has established a new National Defense Science and Technology Innovation Research Institute (国防科技创新研究院),[18] including a new Artificial Intelligence Research Center, that has already brought together several hundred researchers and is actively recruiting new civilian personnel and military scientists.[19]

Chinese leaders believe artificial intelligence is a strategic technology that is critical across all dimensions of national competitiveness, with the potential to transform current paradigms of military power. Beijing's decision to prioritize AI to enhance China's economic development and military capabilities is evident across a growing number of plans, policies, and authoritative statements.[20] In July 2017, the New Generation Artificial Intelligence Development Plan elevated AI as a core priority, catalyzing what has become a whole-of-nation strategic initiative.[21] Since then, this agenda has progressed at all levels and through the efforts of across a range of stakeholders, building upon and harnessing the robust efforts of China's dynamic technology companies, while introducing strong state support and funding that amounts to hundreds of billions in investments.[22] This plan also discussed the implementation of a strategy of military-civil fusion (军民融合) in artificial intelligence, while calling for strengthening the use of AI in military applications that include command decision-making, military deductions (e.g., wargaming), and defense equipment.[23]

Meanwhile, the concerns of Chinese defense academics and military strategists with the potential impact of AI in future warfare have been heightened by the launch of the U.S. Third Offset strategy and influenced by an increased awareness of the rapid progress of AI as a field.[24] In particular, AlphaGo's defeat of Lee Sedol in the game of Go in spring 2016, which appeared to demonstrate the potential advantages that AI could provide in future command decision-making, shaped these assessments, prompting high-level attention.[25] Starting around that timeframe, the PLA writings highlighted with increased frequency the assessment that today's "informatized" warfare was undergoing a transformation towards future "intelligentized" (智能化) warfare, catalyzed by the rapid advances in these emerging technologies, a conclusion that has since received official imprimatur.[26] Writing in an authoritative commentary in August 2016, CMC Joint Staff Department called upon the PLA to leverage the "tremendous potential" of AI in operational command, planning and deductions, and decision support, while urging the advancement the application of big data, cloud computing, artificial intelligence, and other cutting-edge technologies to the construction of the PLA's command system for joint operations.[27] Significantly, in October 2017, in his report to the 19th Party Congress, Xi Jinping urged that PLA, "Accelerate the development of military intelligentization" (军事智能化), and improve joint operations capabilities and all-domain operational capabilities based on network information systems."[28]

This authoritative exhortation has elevated the concept of "intelligentization" as a guiding principle for the future of Chinese military modernization. The PLA's apparent enthusiasm for embracing AI reflects a recognition of the potential dividends of success or leadership in this new RMA. In October 2017, Lieutenant General Liu Guozhi (刘国治), director of the CMC Science and Technology Commission, personally emphasized the imperative of promoting intelligentization, arguing, "This is a rare strategic opportunity for our nation to achieve innovation surpassing and to achieve a powerful military, and it is also a rare strategic opportunity for us to achieve turning sharply to surpass (弯道超车)."[29] Whereas the PLA was a spectator and latecomer to the prior RMA, this new RMA presents an opportunity for the PLA to perhaps emerge as the first to realize disruptive capabilities, including based on breakthroughs in new theories for intelligentization.[30] Although the PLA continues to confront certain challenge in catching up,[31] its relative backwardness

also presents the potential for certain advantages in the process of "leapfrog development" (跨越发展) in its technological advancement.[32] In particular, the PLA possesses fewer legacy weapons and platforms and appears to be prioritizing investments in next-generation weapons systems, such that it and could prove capable of introducing new systems more rapidly, for instance, than the U.S. military.

In practice, the process of intelligentization appears to involve the development and operationalization of artificial intelligence and the enabling and related technologies that are required for its realization for military applications.[33] In practice, intelligentization is intended to build upon prior stages of mechanization and "informatization," the process through which the PLA has introduced information technology and undertaken the development of its C4ISR (command, control, communications, computers, intelligence, surveillance, and reconnaissance) capabilities.[34] For the PLA, force construction requires simultaneous undertaking of all three processes, which may present distinct difficulties but also enables the leveraging of synergies among them.[35] The concept of military intelligentization is not only about AI but "refers to the overall operational description of the force systems consisting of people, weapons equipment, and ways of combat," according to one PLA scholar.[36] This new 'system of systems' consists of not only intelligent weapons but also a new military system of systems that involves human-machine integration and with (artificial) intelligence in a 'leading' or dominant (智能主导) position.[37]

Chinese military scientists and strategists are undertaking extensive theoretical research on the impact of AI on future warfare. These initial conceptual developments will likely influence future directions in PLA strategy and doctrine. In April 2016, the Academy of Military Science, specifically their journal *China Military Science*, convened a workshop on the implications of AlphaGo's recent match with Lee Sedol for future command decision-making, bringing together senior strategists and researchers.[38] Starting 2016, a series of seminars on future warfare have been held annually, organized by the China Electronics Technology Group (CETC)'s Strategy Research Center and the National University of Defense Technology, which have convened an array of prominent researchers from the military and defense industry to discuss the impact of such technological advancements.[39] The Chinese Association of Artificial Intelligence (CAAI) in February 2018 organized a seminar that involved academicians from the Chinese Academy of Engineering, the China Institute for Command and Control, the PLA Academy of Military Science, and National University of Defense Technology, as well as the Army, Naval, Air Force, and Rocket Force research institutes,[40] to discuss the role of AI in the RMA.[41] This seminar was described as undertaking "innovation in theoretical and technology integration" (理技融合创新), concentrating on new theories and innovation for intelligent command and control for a new era. In the aggregate, these activities can be characterized as robust indications that the PLA is engaged in the intellectual exploration and speculation that can establish a conceptual framework for future experimentation and operationalization.[42]

The PLA's premier academic and research institutions have been tasked to pursuing innovation, in disruptive and emerging technologies. During his visit to the PLA's Academy of Military Science in May 2018, Xi Jinping called for AMS to concentrate "increasing the intensity of innovation in emerging domains, and strengthening the incubation of strategic, frontier, and disruptive technologies."[43] His remarks emphasized the importance of placing innovation in a prominent position and pursuing innovation in military theories, national defense science and technology, military science and research work on organizational models. During his visit, Xi also spoke to

Major General Li Deyi (李德毅), who is currently a research fellow with the AMS Systems Engineering Research Institute, who is focusing on unmanned systems and artificial intelligence.[44] The PLA's National University of Defense Technology (NUDT) is considered an "important highland for indigenous in national defense science and technologies" that is concentrating on "developing the key technologies for national defense in the intelligent era."[45] The PLA's National Defense University has also started to explore the impact of AI in its research and teaching, including war-gaming activities.[46]

Chinese military science and research on the dynamics of future intelligentized operations are informed by close study of U.S. ways of war-fighting and intended to 'offset' or undermine current American military advantages.[47] As an authoritative commentary in *PLA Daily* urged, "Keep an eye on future opponents, adhere to using the enemy as the teacher, using the enemy as a guide, and using the enemy as a target... We must develop technologies and tactics that can break the battle systems of powerful adversaries and counter the high-end combat platforms of powerful adversaries."[48] Although the PLA has not yet finalized or formalized doctrinal concepts for intelligentized operations, a review of the range of semi-authoritative and authoritative writings can reveal some initial insights about the current trajectory and continued evolution of this thinking among the community of scholars and scientists who are engaged with these issues. For instance, in early and seemingly relatively impactful writings, Major General Li Bingyan (李炳彦), who has served as a senior editor of the *PLA Daily* newspaper and a researcher for China's National Security Commission, has argued for a concept of "light warfare" (光战争), which would leverage directed energy (i.e., 'light') technologies in conjunction with autonomous systems for "zero-hour" attacks enabled by real-time information, informed by a study of the U.S. Third Offset strategy.[49] Zhang Zhanjun (张占军), a senior researcher with the Academy of Military Science's Theory and Operational Regulations Research Department,[50] who also serves as editor-in-chief of its journal *China Military Science*, wrote a lengthy commentary in October 2017 on how the PLA might compete to seize the initiative in future maritime combat, arguing, "using new-type combat forces to fight in new domains such as networks and space, we must implement asymmetric autonomous operations (非对称自主作战).[51] The PLA's traditional concentration on devising capabilities designed to target perceived weaknesses an adversary's ways of warfare will likely persist in conceptual and technological developments that leverage these emerging technologies.

It is noteworthy that the latest edition of *The Science of (Military) Strategy* released in 2017 by the PLA's National Defense University has added a new section on "military competition in the domain of (artificial) intelligence" (智能领域军事竞争), in an unusual, off-cycle revision of this authoritative textbook,[52] of which Lt. Gen. Xiao Tianliang (肖天亮), who remains the vice commandant of the PLA's National Defense University, is the editor.[53] The section discusses the "new military intelligentization revolution" underway that involves strategic competition among nations worldwide that are seeking to "seize this new strategic commanding heights in military affairs." Beyond the trend of increased prominence of intelligent unmanned systems, intelligent operational systems are expected to become 'unavoidably 'the dominant forces on the battlefield in future warfare. As a strategic guidance for the character of competition in this new frontier:

> "military intelligentization advances new and higher requirements for armed forces construction; it is provides a rare opportunity for latecomer militaries [to undertake] leapfrog development, achieving turning sharply to surpass (弯道超车). It is necessary to actively

confront the challenge of intelligentization, planning and preparing a strategy for the development of military intelligentization [and] seizing the commanding heights of future military competition."

According to *Science of Military Strategy*, the strategic guidance for this new domain in military competition involves a number of lines of effort through which the PLA intends to be guided by the following principle and objective.[54]

- "Scientifically undertake planning and programs, and advance holistically the construction and development of military intelligentization."

This undertaking is characterized as a complex endeavor of systems engineering that involves the develop of intelligent systems across all domains, the exploration of new styles and theories of intelligentized weapons and operations, while influencing and requiring the reform and adjustment of military organizational structures. This process requires "top-level design," a plan and roadmap for development, and focal points and breakthroughs.

- "Strive to attack core technologies, seizing the initiative in the development of military intelligentization."

The capability to achieve breakthroughs in core and critical (核心关键) technologies is seen as a critical determinant of success or failure in competition in military intelligentization, which will require overcoming current bottlenecks. This pursuit of advances in fundamental research will also concentrate on increasing original innovation capabilities in interdisciplinary research involving brain science, cybernetics, and biological sciences.

- "Strengthen cutting-edge research, and unceasingly deepen military theoretical innovation."

This new direction in force construction requires theoretical guidance. For instance, research is required on a number of major problems that include the opportunities and challenges of promoting intelligentization, along with the changes in combat styles that might result from the employment of intelligentized weapons and equipment. In this process of inquiry, it will be important to focus on future trends with an eye to the dynamics of actual combat and the threat of a powerful adversary (强敌), a term that is often a byword for the U.S. military.

- "Promote deeper military-civil fusion, and leverage societal resources for the development of military intelligentization."

The implementation of military-civil fusion can concentrate on leveraging basic advances that include deep learning, machine perception, and intelligent robotics. In practice, these efforts will involve the mechanisms to promote the sharing of resources and collaboration in research and applications, leveraging new institutional mechanisms. The objective is to ensure the coordination and complementarity of economic and national defense construction in the process.

- "Properly manage each kind of relationship, and achieve the scientific development of military intelligentization.

This agenda must be implemented in accordance with future military requirements, while balancing between drawing lessons from foreign militaries and engaging in entirely indigenous innovation. The PLA must also balance between pursuing incremental development to fulfill national security requirements, while also taking full advantage of the opportunity for 'leapfrogging' ahead with the ultimate objective of seizing the strategic commanding heights in order to surpass the current leader, implicitly the U.S. military.

As the PLA continues to concentrate on revising military policies and doctrine, these research activities may contribute to future revisions to PLA military strategic guidelines (军事战略方针) and operational regulations (作战条令) that are still under development.[55] The inclusion of discussion of competition in artificial intelligence in this authoritative textbook reflects a further formalization of the PLA's strategic thinking on the importance of military intelligentization. While the PLA's process of adjusting certain elements of its doctrine remains ongoing, there are indications that new theories and concepts involving AI could be incorporated into future revisions. According to Wang Yonghua (王永华), a scholar with the Academy of Military Science's Operational Theories and Regulations Department, writing in November 2018:

> "At present, to research and develop concepts of operations, it is necessary to focus research on the profound influence of such high-tech groups as artificial intelligence, big data, and Internet of Things upon the methods and routes for combat victory. [We must] research the development of changes to winning factors of information, forces, time, space, and spirit; study the impact of the interactions of space, cyber, electromagnetic, deep sea and other spaces' with traditional combat spaces on future operations, developing new operational concepts though future combat research and design."[56]

However, these concepts must enter the PLA's "operational regulations" in order to act as a basis for future military operations and training, and the PLA's process of transforming concepts into doctrine requires a more formal process of evaluation and authoritative assessment, including on the basis of ideological considerations. In this regard, it would be premature to say that the PLA has a formal doctrine or framework of firm policies established for questions of autonomy and artificial intelligence. Nonetheless, this theoretical research is nonetheless informative regarding the direction that these initiatives are taking.

Across such writings, there is often recurrence of the assessment that the tempo and complexity of operations will increase to an extent, changing the role of humans on the battlefield. Already, today's informatized warfare has placed a premium upon competition in the cognitive domain, demanding rapid processing of information and evaluation of the operational environment in order to enable superior decision-making.[57] Looking forward, "on the future battlefield, with the continuous advancement of AI and human-machine fusion (人机融合) technologies, the rhythm of combat will become faster and faster, until it reaches a "singularity" (奇点): the human brain can no longer cope with the ever-changing battlefield situation, unavoidably a great part of decision-making power will have to be given to highly-intelligent machines," by the assessment of Chen Hangui (陈航辉), a researcher with the Army Command College.[58] As a result, the role of humans could transition from being 'in' the loop, to 'on' the loop, and perhaps even out of the loop.[59] Although there is not sufficient evidence to conclude that the PLA is likely to take humans 'out of the loop' entirely, this expectation that there will be a future point at which "the rhythm of intelligentized operations will

be unprecedentedly accelerated," beyond the capabilities of human cognition, does recur across a number of PLA writings that appear to be reasonably authoritative.[60] However, PLA thinkers to appear to recognition of the importance of balancing human and machine elements in decision-making, which is emphasized as an important 'dialectical relationship,' as Chen Dongheng (陈东恒) and Dong Julin (董俊林) researchers with the PLA Academy of Military Science have highlighted.[61]

The realization of intelligentization will also involve and require a number of supporting and interrelated technologies. For instance, cloud computing is recognized as important to realizing intelligentization, including to improve the management of military data.[62] The recent advances in AI chips and the requisite can enable improved analytic and processing capabilities 'at the edge.'[63] In practice, such future warfare could involve a range of intelligentized weaponry, enabled by the Internet of Things (IoT), and leveraging networked information systems that are integrated across all domains.[64] Some military scientists have emphasized that 5G will be vital to enabling the process of intelligentization, since such increases in connectivity can allow for improvements in data sharing, new mechanisms for command and control, and enhanced systems to fulfill future operational requirements.[65] In particular, 5G is anticipated to allow for machine-to-machine communication among sensors, drones, or even swarms on the battlefield, as well as improvements in human-machine interaction.[66] As China looks to construct a more integrated information architecture, 5G could become critical to this new 'system of systems.'[67] Ultimately, it is not AI alone but the synergies of AI as a force multiplier for a range of weapons systems and technologies, also including directed energy, biotechnology, and perhaps even quantum computing, that could prove truly transformative.

Chinese military scholars and scientists are also focused on the challenges that data presents. From a practical perspective, data, recognized as a "pivotal strategic resource," is expected to become "an important foundation for the creation of the intelligentized battlefield,"[68] on which dominance in artificial intelligence could constitute the "core mechanism" for victory.[69] In July 2018, the PLA's first "military big data forum" was convened by the Chinese Academy of Sciences, Tsinghua University, and Chinese Institute of Command and Control in Beijing.[70] The symposium concentrated on the importance of military big data, with an emphasis on ways that the military could learn lessons from enterprises and government in the management of big data. Among the participants was Song Jie, vice president of Alibaba Cloud (Aliyun), who discussed how Alibaba had leveraged big data to achieve a major advantage relative to traditional business infrastructure.[71] At the time, He You (何友), who is director of PLA Naval Aeronautical University's Information Fusion Research Institute (信息融合研究所所) argued that defense competition "is centering on cognitive advantages and decision-making advantages" that require data.[72] In a prominent commentary in February 2019, PLA scholar Zuo Dengyun (左登云) emphasized, "data is the "blood" of maritime operations…It is necessary to obtain massive amounts of information through data deposits, grasp the weaknesses of enemy systems through data mining, share the operational situation through data presentation, and open up multi-domain joint channels, activating the "sense" of "smart" network empowerment."[73] In the future, "without data, (you) can't (fight) a war" (无数据不战争), and the PLA is concerned with improving its collection, management, and processing of data.[74]

Increasingly, Chinese strategic thinkers are arguing that the advent of AI could change the fundamental mechanisms for winning future warfare. The increased prominence of intelligent

weapons on the future battlefield could result in "remote, precise, miniaturized, large-scale unmanned attacks" becoming the primary method of attack, according to Yun Guanrong (游光荣) of the Academy of Military Science.[75] Given the ways that AI can increase the tempo, accuracy, efficiency of operations, their prediction is that "[artificial] intelligence will transcend firepower, machine power, and information power, becoming the most critical factor in determining the outcome of warfare."[76] In future intelligentized warfare, today's "system of systems confrontation" could become instead a "game of algorithms" in which algorithmic advantage is a dominant determinant of operational advantage, as Li Minghai (李明海) of the PLA's National University of Defense Technology has anticipated.[77] The employment of superior algorithms could dispel the 'fog' of the battlefield and enable decision-making advantage, while increasing the efficiency of operations.[78] In particular, decision-making could leverage the respective strengths of human and machine cognition, while leveraging a 'cloud brain' that allows for swarm and distributed decision-making, enabled by deep neural networks. As a result, new 'extreme' styles of operations could emerge, particularly penetrating the cognitive and information domains. Beyond the battlefield, AI is also expected to contribute to more far-reaching transformations that could result in the intelligentization of logistics support, models of combat power generation, organizational mechanisms, and education and training.[79]

The capability to counter or subvert an adversary's capabilities in AI could become a critical determinant of victory in intelligentized operations. PLA academics and strategists have discussed options for countermeasures against adversary's military employment of AI,[80] 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.[81] In particular, "counter-intelligentized operations" would involve to "paralyze the enemy's artificial intelligence, this the "brain"; cutting the enemy's combat network, this the "nerve"; and draining the enemy's combat data, this the "blood," as Maj. General Li Dapeng (李大鹏) of the PLA's Naval Engineering University has argued, calling for research on such techniques as counter-swarm combat, adaptive electronic warfare, and intelligent cyber warfare.[82] The use of AI can identify weak links and important targets in an adversary's system for joint operations, including to enable assaults intended to collapse an opponent's system of systems architecture.[83]

Artificial Intelligence in the People's Liberation Army

The PLA has been actively pursuing research, development, and experimentation with an array of applications of artificial intelligence. The PLA's interest in AI is not a recent phenomenon. Chinese research and development of dual-use advances in robotics and early artificial intelligence can be traced back to the mid-1980s, at which time the 863 Plan also launched a project that involved robotics and intelligent computing.[84] Certain initiatives to apply expert systems to military operations research date back to the late 1980s and 1990s.[85] Some Chinese military researchers who are active in work on decision support systems, such as Major General Liu Zhong (刘钟) of the PLA's National University of Defense Technology, have been leveraging what might be considered 'AI' in their research since the mid-2000s.[86] Some lines of effort in weapons development, such as the application of advanced algorithms to work on hypersonic glide vehicles can also be traced back to the mid-2000s.[87] The Chinese defense industry's attempts to make cruise and ballistic missiles more 'intelligent' build upon advances in Automatic Target Recognition (ATR) that also predate the recent concern with autonomous weapons. As early as 2011, the PLA's official dictionary included the

definition of an "AI weapon" (人工智能武器) as "a weapon that utilizes AI to pursue, distinguish, and destroy enemy targets automatically (自动); often composed of information collection and management systems, knowledge base systems, decision assistance systems, mission implementation systems, etc."[88] The trajectory of weapons research and technological development in China since the 1990s, particularly robust research undertaken by various elements of the Chinese Academy of Sciences, has established a fairly robust foundation for today's transition from informatization to intelligentization.

Today, as Xi Jinping calls upon the PLA to pursue military innovation, such efforts are redoubling. The stakeholders that have a designated involvement in promotion and implementation of China's New Generation Artificial Intelligence Development Plan include the Central Military-Civil Fusion Development Commission Office, the Central Military Commission (CMC) Science and Technology Commission, and the CMC Equipment Development Department. The PLA's Central Military Commission (CMC) Science and Technology Commission is guiding and supporting research in such 'frontier' technologies, including through a new 'rapid response small group' that seeks to leverage commercial technologies.[89] The CMC Equipment Development Department, which is responsible for defense armaments development, is also funding and promoting research involving unmanned systems and artificial intelligence, including supporting dual-use technological developments, with guidance from an "AI Expert Group." It is likely that support for AI has been and will be included in the PLA's plans for weapons development. The PLA Army, Navy, Air Force, Rocket Force, and Strategic Support Force are all pursuing their own service-specific projects and initiatives through their respective equipment departments and through their research institutes and partnerships. To date, each service in the PLA has started to field and deploy a number of unmanned (i.e., remotely piloted) systems, of which some have at least a limited degree of autonomy.[90]

The PLA's pursuit of military intelligentization is intended to enhance and augment existing weapons systems, while also enabling novel capabilities. The patents, funding, and technical publications that are often openly published and demonstrated provide initial indications of the direction of these developments, and there are also certainly classified programs underway about which no or fewer details are known. The PLA should be expected to leverage AI across an array of applications in all domains of warfare and a range of missions in combat and to support operations. Based on the information that is readily available, the PLA is exploring and/or pursuing research and development of technologies and. potential capabilities that include, but are not limited to:

- leveraging machine learning in support of predictive maintenance through leveraging deep learning for fault prediction,
- the application of machine learning to remote sensing and battlefield environmental support,[91]
- the employment of natural language processing for analysis in military intelligence,
- machine learning techniques that can function under conditions of limited computing capabilities,
- the exploration of options to leverage artificial intelligence for political work and psychological operations, including potentially the use of deep fakes,
- the improvement of algorithms for Automatic Target Recognition (ATR) to improve precision,[92] including identification of multiple targets in real time based on the use of neural networks,

- the application of virtual and augmented reality to modeling, simulations, and actual combat training,
- the use of deep learning and other algorithms to model the dynamics of offense and defense in free air combat,
- the introduction of AI to war-gaming as a tool for training and evaluating the dynamics of intelligent confrontation,
- the use of neural networks for missile guidance to enable greater autonomy in cruise missiles for control and targeting, [93]
- the introduction of new approaches to spectrum management and techniques for electronic warfare,[94]
- the use of artificial intelligence to improve communications and to secure networks against jamming,[95]
- new techniques for data fusion intended to improve situational awareness, including through integrating information from sensors and unmanned systems in support of anti-submarine warfare,
- the use of expert systems and more advanced techniques for decision support to commanders or to the operators of specific platforms (e.g., fighter jets and submarines)
- overcoming obstacles to and challenges of human-machine interaction, involving new models to improve reliability
- the application of neural networks to the guidance of hypersonic glide vehicles to enable more precise and autonomous control,
- the use of AI technologies for cyber security and cryptography, including in advanced steganography,[96]
- increased autonomy in 'unmanned' systems across all domains of warfare, including a number of aerial vehicles, ground vehicles, surface vessels, and underwater robotics, as well as autonomous submarines,
- new algorithms and architectures for swarm intelligence aimed at enabling 'swarm combat,'
- new techniques to enable autonomous flight control of new-energy long-range unmanned aerial systems (UAVs),
- methods for modeling and evaluation of unmanned equipment to test reliability and functionality,
- 'AI satellites' and software-defined satellites for military, commercial, and dual-purpose applications with the onboard capability for intelligent processing,[97, 98]
- wearable systems for individual personnel intended to enhance situational awareness and decision-making on the battlefield
- the management of massive amounts of military data, including through parallel processing, in support of joint operations,
- improving the integration and processing of information for the PLA's integrated command platform, and
- capabilities and techniques to counter or subvert an adversary's AI systems via manipulation of data and/or exploitation of hardware vulnerabilities, among others.

Please note that this listing is not intended to be comprehensive but rather generally representative of the overall directionality of these efforts that can be readily verified based on open sources.

The PLA's research, development, and experimentation with applications of artificial intelligence can also be examined within the priorities and missions of each service, which are here outlined in an initial review of known efforts.

PLA Army

The PLA Army (PLAA) has primarily concentrated on military robotics and ground systems to date. The PLAA Equipment Department has organized a series of biannual competitions, known as "Crossing Obstacles" (跨越险阻) for the development of unmanned ground systems in 2014, 2016, and 2018.[99] Each competition has involved a range of teams from academic, industry, and military research institutes, reaching a total of 136 teams as of 2018.[100] The Army Equipment Department has also established an Expert Advisory Group for Ground Unmanned Systems (地面无人系统专家咨询组).[101] The PLAA Equipment Department has been reportedly reevaluating its plans for armaments development against priorities from the 19th Party Congress, including unmanned operations, artificial intelligence, and electromagnetic attack.[102]

PLA Navy

To date, the PLA Navy has deploying and experimenting with a range of intelligent/autonomous surface vessels and underwater vehicles.[103] Notably, the *Haiyi* (海翼) or "Sea Wing," underwater glider designed by the Chinese Academy of Sciences (CAS) Shenyang Institute for Automation, has been used so far for primarily scientific missions but also possesses potential military application.[104] The Sea Wing, which has a low acoustic signature, could be leveraged to enable the detection of foreign submarines, thus potentially enhancing to enhance PLA anti-submarine warfare capabilities.[105] To date, various variants of this glider are known to have been operated not only in the South China Sea,[106] but also as far afield as the Indian Ocean,[107] and even in support of Arctic exploration.[108]

The PLAN is also exploring and could expand its employment of unmanned and autonomous vessels. Notably, China has also established the world's largest facility for the testing of such vessels at the Wanshan Marine Test Site in Zhuhai.[109] To date, the *Jinghai* (精海), an 'intelligent' vessel with the reported capability to navigate autonomously, appears to be in use with the PLAN and might support maritime sensing and domain awareness.[110] Some of the future unmanned warships under development by the Chinese defense industry could augment the PLAN's growing fleet.

Reportedly, the PLAN is also developing AI-enabled submarines to advance Chinese capabilities in undersea warfare, through a classified military program known as the 912 Project.[111] This disclosure in English-language reporting appears to constitute a deliberate signaling of potential future capabilities. Although fully autonomous submarines may remain a long-term objective, the introduction of AI technologies for decision support on submarines, including to improve acoustic signa processing, could prove more feasible in the meantime.[112]

The PLAN is funding and engaging in ongoing research that concentrates on data fusion. Indeed, He You (何友), who also holds a rank of rear admiral (i.e., as a technical general) in the PLAN and serves as the current director of the Military Key Laboratory of Naval Battlefield Information Perception and Integration Technologies, is actively engaged in research on "advanced maritime information acquisition and processing technologies to achieve continuous, real-time and accurate

monitoring and forecasting of marine targets."[113] Rear Admiral He You has highlighted new trends in research in information fusion, enabled by advances in artificial intelligence, that could have highly promising military applications, including target recognition, situation evaluation, and impact estimation, going forward.[114] The PLAN is directly funding and supporting a number of research projects involving new techniques in data fusion, image and information processing, and target recognition.

PLA Air Force

The PLA Air Force (PLAAF) is continuing its research, development, and operationalization of a range of UAVs with varying degrees of autonomy, while exploring new techniques for swarming and manned-unmanned teaming. In 2018, PLA Air Force's Equipment Department organized a competition for the development of swarms with greater degrees of autonomy,[115] capable of collaboration and coordination for involving racing, cooperative reconnaissance, searching, and assaults; and autonomous confrontation. This contest involved 448 players from 50 teams, of which winners came from the Air Force Engineering University and Harbin Engineering University.[116]

The PLAAF is experimenting with expanding its use of small drones from commercial companies in support of logistics. In October 2017, the PLA Air Force Logistics Department introduced major partnerships with logistics companies, including Jingdong (JD) and SF Express,[117] which are known for their use of drones in logistics.[118] In January 2018, the PLAAF engaged initial trials of using drones from these rapid delivery companies to deliver supplies troops in the field.[119] This initial drill is intended to mark the start of a new trend towards the development of unmanned and intelligent technologies in support of logistics, which the Air Force Logistics Department is continuing to pursue." [120]In particular, Jingdong (JD) has reportedly constructed a logistics hub base in conjunction with the Air Force Logistics Department,[121] while continuing to pursue research and develop more large-scale drones for use in commercial and military logistics,[122] such as the JDY-800, which can carry over 840 kilograms of cargo for distances up to 1,000 kilometers.[123]

As PLAAF thinkers evaluate the impact of AI on future warfare, there is active interest in the impact of AI on new styles of air combat and as applied in weapons systems and supporting equipment.[124] For instance, AI technologies are expected to have applications in detection, route planning, and task management, and such new techniques as augmented reality also could be applied to special operations. Reportedly, the PLA Air Force is funding at least seven classified projects that involve AI technologies, including intelligent imaging, unmanned swarm combat platforms, agile coherent radar, and cognitive radar.[125]

PLA Rocket Force

The PLA Rocket Force (PLARF) is exploring applying machine learning, including neural networks, to remote sensing and domain awareness in ways that could support targeting in future operations or contribute to improved maintenance of weapons systems. Of the research published and publicly available from Rocket Force Engineering University researchers, there is a strong emphasis on applying machine learning techniques to remote sensing, including the use of adversarial networks in a new framework for domain adaptation and classification based on deep convolutional neural networks,[126] as well as to hyperspectral image classification.[127] Their research has focused on fault diagnosis and prediction, leveraging new techniques for the modeling of complex systems, and on advances in robotics and multi-agent systems.[128] The PLARF Engineering University also

contributed as a co-organizer to an international workshop on AI and evidential reasoning that was convened in January 2018 included a focus on intelligent reasoning and decision-making.[129]

PLA Strategic Support Force

The PLA Strategic Support Force (PLASSF) is looking to leverage advances in AI in support of its missions of space, cyber, electronic, and psychological warfare. The PLASSF is also engaged in extensive research and academic activities through a number of institutes and its flagship universities, the Information Engineering University and Aerospace Engineering University. Pursuant to changes to the PLA's system for civilian personnel, the PLASSF has been recruiting researchers with a background in AI, including for positions focused on "aerospace artificial intelligence." At PLASSF Information Engineering University (IEU) researchers have focused on applications of AI to cyber security, remote sensing, cryptography, and intelligent chipsets, among others.[130] The PLASSF IEU that its future institutes will concentrate on advancing innovation in fields including big data, artificial intelligence, and quantum information.[131] PLASSF researchers are also exploring the application of artificial intelligence to electronic reconnaissance and countermeasures.[132]

Today's advances in AI could be integral to China's future space capabilities. For instance, researchers with the PLASSF Aerospace Engineering University (AEU) have published on concepts for data-driven spatial target recognition that applied machine learning algorithms, including convolutional neural networks, to develop models for identification.[133] In May 2018, the AEU teams participated in the "Eye Cup" (眼神杯), a competition that was co-sponsored by a research program through the National Natural Science Foundation of China on basic theories and key technologies for spatial information networking, concentrating on SAR remote sensing image recognition, optical remote sensing image recognition, and remote sensing satellite tracking, leveraging machine vision and image processing.[134]

Military Science and Research Institutions

The PLA's premier institutions for military science, the Academy of Military Science and National University of Defense Technology, are pioneers for Chinese military initiatives in advancing artificial intelligence. The PLA's National Defense University will also be an important contributor to strategic research and education in this context.

Academy of Military Science

In the course of the PLA reforms, the PLA's Academy of Military Science (AMS) has experienced a surprising and far-reaching transformation, integrating new directions in science and technology with its traditional concentration on military strategy and doctrine. The recent reorganization at AMS positions it to advance this agenda, with the creation of the National Defense Science and Technology Innovation Research Institute (国防科技创新研究院) as of July 2017,[135] which is referred to in English as the National Innovation Institute of Defense Technology (NIIDT).[136] Initially, in early 2018, AMS reportedly introduced a contingent of 120 top researchers, a significant proportion of whom had PhDs, to pursue research that included military applications of artificial intelligence and quantum technologies.[137]

Based on initial estimates, NIIDT includes several hundred researchers in total and is recruiting for continued expansion.[138] This new institute includes an Artificial Intelligence Research Center,[139] which pursues research on intelligent algorithms, robotics operating systems, intelligent computing chips, big data, and cognitive radio and communications; an Unmanned Systems Technology Research Center, which focuses on the design, research and development, integration, verification, and application of intelligent unmanned systems and systems of systems; and the Front-line Cross-Disciplinary Technologies Research Center (前沿交叉技术研究中心), which will pursue research in neurocognition, quantum technologies, and flexible electronics, among others.[140] To date, these institutes are starting to publish actively, in Chinese and English language journals, on a range of topics, including, for instance, networking among robotic systems. [141] NIIDT intends to cooperate to establish research centers in collaboration with other universities, research institute, and high-tech enterprises on intelligent aerospace, intelligent maritime, and intelligent manufacturing technologies. There are also virtual centers affiliated with the center, the Intelligent Computing Research Center and the Intelligent Countermeasures Research Center.[142]

AMS will likely continuing deepening this scientific direction under the leadership of Lt. Gen. Yang Xuejun (杨学军). Yang Xuejun was formerly the commandant of NUDT and is known for his research in supercomputing. His selection to lead AMS is another noteworthy indication of its transformation. Yang Xuejun has co-authored some publications on robotics and artificial intelligence, and he is personally engaged on the subject of AI in future warfare.[143] Under his leadership, AMS may continue to undertake more extensive collaboration with scientific institutions in ways that may bolster this defense innovation capability. For instance, AMS has also signed a strategic cooperation framework agreement with the Chinese Academy of Sciences, which involves joint research and talent training, as well as the construction of a platform for collaborative innovation.[144]

National University of Defense Technology

The National University of Defense Technology (NUDT, 国防科技大学) is building upon its existing strengths to expand its AI research. The NUDT Institute of Automation has long engaged in a range of research involving big data and AI, leveraging synergies with NUDT's National Key Laboratory for High-Performance Computing. NUDT's Key Laboratory of Information Systems Engineering has engaged in research to optimize and increase the intelligentization of the PLA's command and control systems.[145] The National Defense Science and Technology Laboratory for Precision Guidance and Automatic Target Recognition (ATR) is engaged in research on leveraging information processing and intelligent image processing for ATR.[146] At NUDT's Academy of Electronic Countermeasures, researchers are also exploring the potential of artificial intelligence and development of advances in electromagnetic weaponry.[147] NUDT's new Academy of Intelligent Sciences (智能科学学院) is intended to advance a range of objectives in intelligentization.[148] This institute has also developed and prominently demonstrated swarms of UAVs.[149] In June 2018, a team from the National University of Defense Technology was also at the top of a competition organized by Apple and Google for "robust vision."[150]

National Defense University

The PLA's National Defense University (NDU) has been at the forefront of exploring opportunities to leverage AI in wargaming, simulations, and operations research. In particular, Major General Hu

Xiaofeng (胡晓峰) has been very active in exploring the potential of AI in war-gaming and command information systems.[151] Notably, NDU has convened a number of competitions that involve the use of AI in war-gaming that have involved "human-machine confrontation" and "machine-machine confrontation." NDU has also engaged in strategic research on guidance and implementation of intelligentization, often involving senior scholars and strategists.

Defense Industry Initiatives

Pursuant to ongoing reforms, the Chinese defense industry has also been seeking to become more innovative through investing and pursuing in next-generation research and development. This shift is influenced by not only state policies but also apparently commercial incentives that stem from to the potential for profits from export markets. It is worth noting that, as a counterpart to Made in China 2025, the National Defense Science and Technology Industry 2025 Plan (国防科技工业 2025) was released by 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, in June 2015.[152] This plan included a focus on robotics and intelligent manufacturing, as well as an opinion encouraging the use of advanced industrial technology, such as intelligent robotics.[153]

The results of increased innovation in the Chinese defense industry have been featured prominently, while attracting the attention of international customers. For instance, during the 2018 Air Show at Zhuhai, drones and intelligent weapons systems were a major attraction.[154] In particular, certain of the "new concept" weapons under development that are anticipated to be relevant for future warfare, include hypersonic weapons and new energy weapons, while new modes of operations could involve manned-unmanned coordination, as well as stealthy and distributed approaches to combat.

The Chinese defense industry has often confronted impediments to original innovation but is actively engaging with these new directions of development. China's state-owned defense conglomerates are adapting and starting to prioritize the incorporation of AI, recruiting AI engineers and pursuing new partnerships with universities. These major players in weapons development are actively involved in cutting-edge research, but their activities often remain relatively obscured, relative to more prominent activities in the private sector and universities. However, there are a number of initial indicators of increased engagement in AI development.

The China Electronics Technology Group Corporation

The China Electronics Technology Group Corporation (CETC) has been prominently involved in demonstrations of swarms of drones. Starting in June 2017, the China Electronics Technology Group (CETC), a leading state-owned defense conglomerate, has tested swarms of 67, 119, and then 200 fixed-wing UAVs, which engaged demonstrated complex formations.[155] CETC has also launched its own action plan for special projects involving new-generation artificial intelligence.[156] The plan undertakes an "X+AI" approach that emphasizes the potential synergies of AI with various sector and applications that are integral to the company's core businesses in defense and commercial technologies. In particular, this initiative has highlighted data intelligence, machine intelligence, and group/swarm intelligence as major directions for development. Among the applications it is focusing on are smart cities, industrial robotics, and medical applications. CETC

has also started to focus on AI chip development. CETC claimed to have 7,000 AI researchers in total as of mid-2018 and has continued to recruit new engineers and researchers in this field.[157]

CETC has contributed to the Chinese military's command platforms and a range of military information systems, and its research will likely be at the forefront of upgrading this existing software to integrate new technologies.[158] CETC has also developed the "Integrated Joint Operations Platform" that has been used by police in Xinjiang according to research from Human Rights Watch.[159] Notably, Baidu has partnered with the China Electronics Technology Group (CETC), a state-owned defense conglomerate, through the Joint Laboratory for Intelligent Command and Control Technologies (智能指挥控制技术联合实验室), to pursue applications of big data, cloud computing, and artificial intelligence, in military command and information systems.[160]

China Aerospace Science and Technology Corporation

The China Aerospace Science and Technology Corporation (CASC), which is the primary contractor for China's space program, is also prioritizing expanding its efforts in AI. The CASC's Chinese Academy of Launch Vehicle Technology (CALT) has been very active in exploring AI research and applications, including launching its own dedicated initiative for AI development.[161] CALT established the Joint Innovation Laboratory for Human-Machine Hybrid Intelligence (人机混合智能创新联合实验室) with Tianjin University in March 2018, and their research will focus on human-computer interaction and aerospace applications.[162] In addition, the Aerospace Group (Artificial) Intelligence Research Center (航天群智能研究中心) at the Qian Xuesen Space Technology Laboratory has concentrated on research on deep learning and related theories and algorithms.[163]

The China Aerospace Science and Industry Corporation

The China Aerospace Science and Industry Corporation (CASIC), which is the primary developer and manufacturer of Chinese missiles, has been engaged in research and application of AI for at least the past couple of years. Since as early as 2015, the CASIC 3rd Academy 35th Research Institute started to pursue breakthroughs in core technologies that include target detection and recognition techniques based on deep learning and deep neural network compression, as well as smart sensors that combine data from multiple radars.[164] Notably, in 2016, this CASIC team organized an innovation competition for "Radar Target Classification and Recognition Based on Artificial Intelligence," which was the Chinese defense industry's first major event of this kind, involving major universities with particular proficiency in AI research applying that expertise to find intelligent processing solutions for targeting.[165]

In 2017, CASIC established a new Artificial Intelligence Technology Research Department that built upon its prior track record of expertise in information processing to pursue new directions in intelligentization. Going forward, the team also plans to introduce AI technologies into the process of weapons systems design and to explore further opportunities to advance military (artificial) intelligence developments.[166] In addition, CASIC's Second Academy Second Department has established an Artificial Intelligence Laboratory as of 2017, which has started to pursue research involving deep learning as applied to intelligent assistance inn driving, among other applications.[167]

The China Shipbuilding Industry Corporation

The China Shipbuilding Industry Corporation (CSIC) is exploring advances in robotics and unmanned or autonomous vessels, while also looking to leverage intelligent manufacturing to improve shipbuilding. For instance, CSIC researchers have developed a prototype deep-sea crawling robot that can crawl or cruise longer distances underwater, described as capable of navigating the complex terrain of the seabed.[168] During a September 2018 defense exhibition, a CSIC subsidiary revealed "JARI," a multi-purpose unmanned surface vessel (USV) that was reportedly designed for use by the PLAN and for export as a warship.[169] In supporting enhancing shipbuilding capabilities, the China Shipbuilding Industry Corporation is also focused on new techniques to employ intelligent manufacturing, concentrating on "AI+ research."[170]

The Aviation Industry Corporation of China

The Aviation Industry Corporation of China (AVIC) has pursued research on leveraging AI for decision support and to enhance weapons systems under development. In October 2017, AVIC established two new laboratories, the Robotics Research Center/Machine Vision and Intelligent Sensing Joint Laboratory (机器人研究中心/机器视觉与智能识别联合实验室成立), in collaboration with Xi'an Jiaotong University, and a Machine Vision and Intelligent Sensing Joint Laboratory (机器视觉与智能识别联合实验室) with Northwestern Polytechnic University, which will pursue cooperative research on these topics.[171]

Autonomy for New Expeditionary Capabilities

The PLA's advances in autonomy will also have relevance for its ambitions for deep sea and polar exploration. These domains are recognized as emerging frontiers of competition.

Deep Sea Exploration—and Dominance?

As China pursues deep sea exploration and seeks increase its operational capabilities in this domain, advances in robotics and autonomy are a critical priority in which there has been robust progress to date. Chinese researchers have developed a robust range of unmanned and autonomous underwater vehicles that appear to be at the forefront of global developments. For instance, the Sea Wing glider has established a world record for depth in the Mariana Trench, where it was deployed down to reach a depth of 11,034 meters.[172] Some of the advanced gliders entering employmebt include the Haiyan and Qianlong, which are all being used for deep sea exploration that could support future resource exploitation and operations.[173]

China's development of deep sea capabilities could improve situational awareness in this critical maritime domain. There have been reports that there is an "undersea great wall" under development that could involve seabed sensors for detection to be integrated with a network of underwater systems.[174] Notably, the Chinese government is funding the development of a deep sea base, named after Hades, lord of the underworld, for underwater science and submarine operations.[175] Sanya's Institute of Deep-Sea Science and Engineering is taking the lead on this project, which will receive 1.1 billion RMB or at least $160 million in funding to start in seeking to pioneer unique advances in technology and applications.[176]

Polar Exploration

As China undertakes surveying and scientific observations in the undersea domain, the use of gliders and submersibles introduces a critical capability. The Chinese Academy of Sciences Shenyang Institute of Automation (CAS-SIA) developed an Arctic Autonomous/Remote Vehicle (ARV),[177] a 'new concept' underwater vehicle, first employed as early as 2008.[178] In August 2014, a second-generation ARV accompanied the Snow Dragon on China's sixth Arctic expedition, conveying a variety of measurement equipment that contributed to enhancing Arctic ice monitoring. Notably, the Sea Wing (海翼) glider, also developed by CAS-SIA, was first used in 2018, during China's ninth Arctic expedition.[179] This glider has also been used in the South China Sea and may have relevance in undersea surveillance that could support antisubmarine warfare.[180] Characterized as highly autonomous, the gilder can operate under own power for up to three months prior to recovery, collecting data at depths of up to 1000 meters to monitor hydrological conditions and transmitting data back via satellite signals.[181]

The use of drones can contribute to localized sensing and surveying of the polar landscape. For instance, the Polar Eagle *(Ji Ying,* 极鹰), a fixed-wing UAV developed by Beijing Normal University, was first used for remote sensing in Arctic in September 2015, when it completed a three-dimensional mapping of a glacier near Yellow River Station, and has since been used in Antarctica.[182] This UAV, powered by lithium battery, is capable of operating for up to one hour with flight ceiling of 1,500 meters. The variants of the *Ji Ying* that have been used in polar regions contribute to capturing imagery of areas that are not visible via satellite due to overcast weather or inaccessible difficult conditions.[183, 184]

In the Arctic and Antarctic, the use of unmanned (surface) vessels (USVs) may become more prevalent due to the difficult conditions. In China's November 2017 Antarctic expedition, China's Snow Dragon was accompanied by the M80B "seabed exploration unmanned boat," which was jointly developed by the People's Liberation Army (PLA) Naval Surveying and Mapping Research Institute, the State Oceanic Administration's South China Sea Survey Technology Center, and Yunzhou Tech.[185] [186] The preference for employment of the M80B reflects that the harsh climate and complex maritime environment would render the use of manned vessels for survey and detection dangerous. The M80B is described as having a battery life of over 100 nautical miles and a maximum load weight of 150 kilograms, while conveying a range of acoustic detection equipment, magnetic detectors, and mobile laser scanners.[187]

Similarly, given the perilous conditions of transiting over ice, UGVs can contribute to surveys and resupply, as well as the determination of safe transit routes. For instance, the "Polar Rover" (极地漫游者), which uses turbines for wind energy, has been tested so far in Antarctica.[188] This robotic system, jointly developed by Beihang University, CAS-SIA, and the Polar Research Institute of China, was intended to gauge the feasibility of using renewable energy for long-term, unattended presence, such as to support environmental monitoring, while demonstrating a higher level of automation.[189] In February 2018, Chinese researchers first used a small UGV, developed by CAS-SIA,[190] to undertake a topographic survey in the Antarctic in support of the determination of routes, traveling over 200 kilometers in 25 days.[191]

Military-Civil Fusion in Strategy and Practice

The PRC's pursuit of a strategy of military-civil fusion could provide a systemic and structural advantage that could contribute to national priorities in innovation, if its implementation overcomes current obstacles. In 2016, under Xi Jinping's leadership, the Outline of the National Innovation-Driven Development Strategy (国家创新驱动发展战略纲要) was launched, which initiated a new direction and guidance for China's future development.[192] As this strategy highlights, the capability to innovate is considered a core enabler of national power, and China's past weaknesses and experiences of predation are attributed its past failure to keep pace with scientific and technological revolutions. These authoritative guidelines assert, "disruptive technologies are constantly emerging, continually reshaping the world's competitive landscape, changing the balance of forces among states."[193] The core concern is that, "Our nation is not only facing a rare historic opportunity to catch up and leapfrog but also confronting the serious challenge of a gap that could widen."[194] This strategy highlighted the importance of military-civil fusion, including closer coordination and sharing of resources, as an important pathway to enabling this innovation.

Xi Jinping has taken personal responsibility for the implementation of this agenda, leading the Central Commission for Military-Civil Fusion Development (国家军民融合发展委员会), which was established in January 2017. As it progresses, this concept encompasses not only a more integrated approach to technological development, but is also applied to missions that include talent, logistics, and mobilization.[195] Some of China's senior leaders and scientists, including Zhou Ji (周济), dean of the Chinese Academy of Engineering, believe that artificial intelligence will be the most important military-civilian dual-use technology in the coming decades.[196] The implementation of this priority is starting to take shape through a range of plans and policy initiatives. For instance, the 13th Five-Year S&T Military-Civil Fusion Special Projects Plan (科技军民融合发展专项规划), released in September 2017, highlighted intelligent unmanned and cross-disciplinary technologies among its priorities, while also calling for integrated development of space, cyber, biology, new energy, and maritime technologies.[197]

During his remarks for the 19th Party Congress' work report in October 2017, Xi Jinping emphasized:

> "We should ensure that efforts to make our country prosperous and efforts to make our military strong go hand in hand. We will strengthen unified leadership, top-level design, reform, and innovation. We will speed up implementation of major projects, deepen reform of defense-related science, technology, and industry, achieve greater military-civilian integration, and build integrated national strategies and strategic capabilities."[198]

The Chinese government attempts to harness and support the dynamism of market activity in AI to promote national strategic purposes has extended to experimentation with new techniques for state support and funding.

New Capital for Military-Civil Fusion

The Chinese government has been launching a number of new state-driven investment funds, as well as "guidance funds" (引导基金) at various levels. These new vehicles for funding often combine government direction with a combination of state funding and private venture capital. This paradigm of partnership indicates a further blurring of boundaries between market and governmental objectives and investments in AI. The total funding that has been allocated for a wide

variety of guidance funds appears to reach the range of several hundred billion dollars, by some estimates.[199] However, a smaller portion of that funding is directly relevant to AI development, and the recency of the launch of these initiatives makes it difficult to evaluate within what timeframe or how effectively the funding will be allocated.

Today, experimentation with new policies and platforms is continuing. Notably, during the World Artificial Intelligence Conference in September 2018, China's State Development and Investment Corporation (SDIC) initiated the launch of the All-Nation Artificial Intelligence Venture Capital Service Alliance (全国人工智能创业投资服务联盟).[200] This initiative is a "national, industry, and open public service platform" created through National Development and Reform Commission. Among the investment institutions involved in launching this 'alliance' are Sequoia Capital, Huaxing Capital, and Softbank China, as well as AI research enterprises, including Baidu, Tencent, Tsinghua University, and the Chinese Academy of Science. It was created with support from the National Emerging Industries Enterprise Investment Guidance Fund (国家新兴产业创业投资引导基金), which was itself launched in January 2015 with the objective of promoting innovation and "mass entrepreneurship." As of 2017, that fund had reached a scale of 17.86 billion RMB or $2.58 billion, and a sizable proportion of the funding may go to AI enterprises.[201]

The promotion of military-civil fusion as a strategy is increasingly leveraging guidance funds as an important mechanism to drive capital and activities. For instance, one national fund for military-civil fusion industrial development launched in September 2016 involved 30.2 billion RMB or $4.4 billion in its initial round of funding.[202] These activities are expanding in response to a State Council opinion released in December 2017, which called for "expanding the investment and financing channels for the development of military-civil fusion," including through the establishment of funds for investments in military-civil fusion industries and encouraging local governments to launch their own funds to promote high-tech military industries.[203] As of mid-2019, tens of billions of RMB (or several billion dollars in countinng) of funding had already been dedicated to military-civil fusion through funds launched in localities that included Sichuan, Shanghai, Hebei, Henan, Guangdong, Zhejiang, Shaanxi, Guizhou, Hunan, Heilongjiang, Liaoning, among other cities and provinces.[204] These funding mechanisms have been described as prominent and even "indispensable" to deepening the implementation of military-civil fusion, stimulating high-tech industries.

Local Initiatives

As of 2019, the majority of China's cities and provinces have launched their own efforts to promote military-civil fusion. While the scope and scale of these activities is beyond the scope of this testimony, and the results of more nascent initiatives are difficult to evaluate, an initial survey of some relevant initiatives can illustrate some of the current directions of development.

Beijing

Beijing is home to some of China's leading companies, universities, and institutions of defense research, constituting a vital center of military research. In particular, Tsinghua University, often characterized as 'China's MIT,' is strongly and institutionally committed to military-civil fusion and to supporting the advancement of military applications of AI. Tsinghua Vice President You Zheng has highlighted the university's contributions to military research and to enabling China's emergence

as an "AI superpower."[205] Tsinghua launched the Military-Civil Fusion National Defense Peak Technologies Laboratory, which will create a platform for the pursuit of dual-use applications of emerging technologies, in June 2017.[206] With support from the Central Military Commission, Tsinghua is also building the High-End Laboratory for Military (Artificial) Intelligence.[207]

Increasingly, the high-tech zone of Zhongguancun has focused on advancing military-civil fusion in emerging technologies. The Zhongguancun Military-Civil Fusion Industry Alliance, established as early as 2014, has growth to include 600 members, while taking on hundreds of projects, including in robotics and intelligent equipment.[208] The alliance organized a special contest in December 2017 that involved advances in cyber security, unmanned systems, and perception and recognition capabilities.[209] Within Zhongguancun, a new Military-Civil Fusion Industrial Park (中关村军民融合产业园) was also established in early 2018.[210] During the Beijing Civil-Military Integration Expo 2019, among the systems on display was a new 'armored multipurpose drone launching vehicle.'[211] This new system is capable of launching a dozen of drones to conduct reconnaissance or even accurate 'suicide attacks,' distracting and swarming the enemy.

In June 2018, the Beijing Science and Technology Innovation Fund (北京科创基金) was launched as a new sizable and long-term government guidance fund in China that is designed to focus on next-generation information technology, nanotechnology, big data, artificial intelligence and other "high-end hard technology" fields.[212] The parent fund is 30 billion yuan ($4.46 billion) to start, with plans to increase the size 100 billion RMB ($14.86 billion), across a number of sub-funds that may amount to as many as 102, in total, with a focus on high-tech industries, signing agreements with Peking University, Tsinghua University, and the Chinese Academy of Sciences, among others.

Shanghai

The Shanghai municipal government has been very active in providing policy support for AI that is extending into efforts that might bolster military advances. Shanghai's new Military-Civil Fusion Industry Investment Fund launched in 2017 at a scale of 4 billion RMB or $579 million, intends to include a focus on dual-use intelligent equipment.[213] [214] For 2018, Shanghai will support special military-civil fusion projects that include dual-use artificial intelligence and intelligent equipment.[215]The PLA's NUDT is cooperating with the Shunde district of Shanghai on the establishment of a military-civil fusion innovation park based on total investments of 1.5 billion RMB or over $217 million that will include, including an industrial zone focused on artificial intelligence and information security.[216] The Shanghai Artificial Intelligence Industry Fund was officially launched as of September 2018. This new initiative jointly established by several venture capital players, including CICC Capital and Shanghai Kechuang, in collaboration with the Shanghai government, which plans to increase its scale to from the 10 billion RMB or $1.49 billion raised to start towards the range of 100 billion RMB ($14.86 billion) in the future.[217]

Tianjin

Tianjin has been distinctly forceful in its promotion of AI. The city announced the launch of the New Generation Artificial Intelligence Industry Fund,[218] which amounts to 100 billion RMB ($16 billion), based on a combination of state and venture capital funding, in May 2018.[219] In August 2018, Tianjin has uniquely launched a special action plan for military-civil fusion in the domain of science and technology that aims to build a platform for collaborative innovation and realize the

transformative applications of intelligent science and technology by 2020.[220] Tianjin is a hub of research activities and collaboration. In addition, the new AI Military-Civil Fusion Innovation Center (人工智能军民融合创新中), located next to the National Super Computer Center in Tianjin, was established by the local government in partnership with the Academy of Military Science in October 2017.[221] The city plans to strengthen and accelerate collaboration with the National University of Defense Technology and the People's Liberation Army Information Engineering University. [222] Tianjin is also exploring options to build a military cloud and a new virtual simulation platform system to support simulations and equipment development.

Shenzhen

Shenzhen is the home base for some of China's most high-tech and successful companies. Unsurprisingly, there are active efforts to start to harness that dynamism in support of military missions, including the use of drones developed through commercial technologies. Concurrently, the CMC Science and Technology Commission is exploring new mechanisms for leveraging commercial technologies with the launch of China's first "defense S&T innovation rapid response small group" (国防科技创新快速响应小组) in Shenzhen.[223] This team will leverage "the innovation advantages of the Shenzhen Special Economic Zone to rapidly respond to the needs of national defense S&T innovation," while "accumulating experience in promoting the formation of a flexible and highly efficient defense technology innovation value chain." The priority fields highlighted for this program include biology, new materials, manufacturing, and artificial intelligence. According to a notice released in April 2018, some of the priorities for the new projects, all of which were required to be completed in six to twelve months, included the development of maritime intelligent target recognition technology based on video imagery and a module for intelligent human-machine interaction.[224] In April 2019, this team co-organized a competition for the development of intelligent processing algorithms for massive optical remote sensing satellite data. This new model for rapidly developing and accessing commercial technologies is still at an early stage but does demonstrate the PLA's capability to experiment with new mechanisms for defense innovation, seemingly adapting American approaches in the process.

Qingdao

Qingdao has emerged as a major center for military-civil fusion in maritime technologies through leveraging its existing strengths in research and industrial activities. As of 2017, the Underwater Vehicle Intelligent Equipment Base (水下无人航行器智能装备基地) was established in Qingdao, undertaking research and development, as well as the design and manufacture, for a range of marine robotics and engineering equipment, including the white Dolphin (白豚) autonomous underwater vehicle.[225] When a new "demonstration zone" was established in April 2018, initial investments amounted to 9.17 billion RMB or $1.33 billion, which included plans to support aerospace equipment, strategic emerging materials, and marine science and technology.[226] In Qingdao, the first forum on military-civil fusion of the AI industry was convened in April 2018. [227] These discussions and exchanges, convened by Harbin Engineering University, concentrated on fields that included intelligent underwater robots, high-speed unmanned boats, smart ships, and target recognition.

Prominent Enterprises

The forceful implementation of military-civil fusion has reflected an attempt to change a status quo in which a relatively smaller proportion of private companies were directly involved in military projects and procurements. Several examples provide indicators of successful enterprises that have actively pursed opportunities for military sales.

Yunzhou-Tech

Yunzhou-Tech has emerged as a leader in the development of unmanned vessels. The company, which claims to hold a quarter of the global patents for unmanned vessels and to have fully mastered the core technologies in question, has achieved major advances that include multi-sensor intelligent detection and autonomous navigation, actively engaging in military-relevant research, including testing a shark swarm of drone vessels in June 2018.[228] Yunzhou-Tech is recognized for its significant contributions to military-civil fusion, have develop a wide array of models and designs.[229] Certain of these vessels appear likely to be acquired by the PLA Navy for supporting and/or operational functionalities, including with capabilities in patrolling, reconnaissance, and electromagnetic countermeasures.[230] Notably, during the 2018 Airshow China at Zhuhai, Yunzhou-Tech displayed the Look Out II unmanned missile vessel, equipped with four precision missiles capable of hitting targets up to 5 kilometers away.[231] Although the drone vessel itself is described as autonomous, the operation of its missiles is still designed to be subject to human control. The Look Out II project director has emphasized its speed, stealth, and cost effectiveness.

Ziyan

Ziyan is a private enterprise that has developed capable drones and unmanned helicopters that with varying degrees of autonomy that are starting to enter usage for policing, paramilitary, and military operations.[232] The company's founder Wang Jiangping (王江平) leveraged the perspective of experience in PLAAF aircraft maintenance and subsequent international business activities that reportedly exposed him to military experts and modern drone technology in building a company that has proven competitive against traditional contenders within China and internationally.

Since Ziyan tested its first drone in December 2015, the company has achieved relatively rapid success. To date, a number of its drone helicopters, including the "Blowfish A2," which is semi-autonomous and can be equipped with radar, jamming devices, and guns or bombs under its spine, have been exported internationally to at least four countries so far.[233] Ziyan has been working on a series of unmanned helicopters, known as the ZYG 800, ZY-50 and ZY-280, which vary in capability but are all capable of autonomy.[234] In February 2019, Ziyan displayed and demonstrated during an international defense exhibition its unmanned helicopter intelligent swarming technology, which can now realize self-organizing networks of smart swarms and be switched to 'attack' model to go after targets autonomously in a coordinated manner.[235]

Some additional examples of companies that have contributed to military-civil fusion and/or provided their commercial technologies in support of military activities include, but are not limited to:

- Hikvision, which has been partly owned by the CETC's 52nd Research Institute, has provided its AI-enabled video surveillance technology for national defense and security purposes.[236]

- Skyeye Data is a next-generation information technology company that concentrates on big data, cyber security, artificial intelligence, etc., collaborating with the National Defense Science and Technology University, the Strategic Support Force Information Engineering University, for which it providing a platform for 'open technology applications and innovation' that aims to integrate "production, learning, research, usage, and warfare."
- iFlytek has promoted its products in voice recognition to Chinese military, where it may have utility in intelligence, in addition to well-documented involvement in supporting surveillance.[237]
- Kuang-Chi (光启) Technologies, which has specialized in the development of metamaterials and aerospace technologies, has also expanded into AI, including its application to new materials developments.
- Sensetime's new SenseRemote 'remote sensing image intelligent interpretation solution,' which combines visual AI technology and spatial information, would possess relevance for military applications.[238]
- Sugon (曙光), initially established as a high-technology to support Chinese advances in high-performance computing, has signed an agreement partnership with the China Institute for Command and Control, through which it would support cloud adoption for China's military command information systems.[239]
- Ruichen Xinchuang (睿辰欣创) is a leader in the national defense simulation industry that has developed a virtual military simulation platform and developing new techniques for assessments, including launching an AI R&D center in 2012.
- Vimicro Corporation, a fabless chip company, has developed chips that appear to be used for defense applications.[240]
- DeepBlue (深之蓝) specializes in underwater robotics and is enthusiastically supporting military-civil fusion through developing a range of gliders for defense and commercial applications.[241]
- Aobo (遨博)Intelligent Technology Company, which emerged from research at the Beihang Robotics Research Institute, has developed autonomous controllable robots for the military industry.
- Alibaba's Damo Academy has been named in government plans and policies in Hangzhou as contributing to military-civil fusion initiatives.[242]

These initiatives are incomplete and continuing to progress with varying degrees of success, but nonetheless illustrative of initial initiatives that are underway.

Some early attempts to integrate and facilitate increased collaboration in research have a long history in China and are being deepened and expanded. In one notable early initiative, in November 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.[243] 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.[244] It was tasked to pursue AI research to include intelligent robotics, unmanned systems, and military brain science.[245] For instance, some of its initial research involved the 'brain control' of unmanned systems.

Prominent Academic Institutions

The academic ecosystem for AI research in China is extensive and rapidly expanding within it. Of the major universities and academic research institutions, a significant proportion are engaged in research that supports or has relevance to defense applications. In particular, the Chinese Academy of Science is a powerhouse in artificial intelligence, which is evident from its strength in patents and publications, and a number of the research institutes and laboratories under its umbrella specialize in military-oriented research.[246] Those universities and laboratories that possess particular relevance for these efforts include, but ar ennot limited to:

- Tsinghua University, which has launched a High-End Laboratory for Military (Artificial) Intelligence (军事智能高端实验室);[247]
- Beijing University of Aeronautics and Astronautics (Beihang) University, which has engaged in research on autonomy and human-machine teaming, including prominent initiatives at the Beihang Robotics Research Institute;
- Harbin Engineering University, which has strengths in robotics and autonomy, including the National Key Laboratory of Intelligent Robot Technology;
- Northwest Polytechnic University, which includes the National Defense Science and Technology Key Laboratory for Special Drone Technologies;
- Beijing Institute of Technology, which has reportedly established an "intelligent weapons experimental class" that has recruited an initial class of 30 highly talented students to pursue degrees and innovative research under the mentorship of senior weapons scientists;[248]
- Nanjing University of Aeronautics and Astronautics (Nanhang) University, which established its Artificial Intelligence Academy and Artificial Intelligence Research Academy in July 2018;[249]
- Xi'an Jiaotong University, which launched a new Academy of Artificial Intelligence and has contributed to a base for the AI and robotics industry;[250] and
- Xidian University, which established a new Academy of Artificial Intelligence in spring 2019; among others.[251]

Pursuant to the implementation of military-civil fusion as a national strategy, a growing number of universities that have not engaged in as extensive research to support military initiatives in the past may become more involved going forward.

Challenges and Shortcomings in Chinese Military Innovation

The PLA's ambitions and advances in robotics, autonomy, and a range of applications of artificial intelligence should not be dismissed or underestimated, but there are also likely difficulties and shortcomings that will impede its implementation of this agenda. Not unlike the U.S. military or any bureaucracy, the PLA will confront a number of constraints and challenges in the process. It remains to be seen whether attempts to overcome such impediments will prove successful.

- *The PLA's capacity to innovate as an organization may be impeded by bureaucratic politics and its culture as an organization, particularly considering the disruption that results from the ongoing reforms.*

The Chinese military, not unlike any bureaucracy, may struggle to adopt and adapt new technologies that may, in some cases, present threats to existing equities. The PLA has been assessed to be an organization that is highly hierarchical, operating in a top-down manner with a high degree of centralization of power. These features, including the low levels of trust often considered

characteristic of authoritarian militaries, could impede more junior officers and enlisted personnel from having the opportunity to exercise initiative and experiment with new technologies and techniques. Such typical difficulties could be exacerbated by the disruption that has resulted from significant organizational restructuring that remains ongoing, seemingly encountering some resistance in the process. For these reasons, despite the PLA's rhetorical commitment to innovation, implementation may be impeded such dynamics. Moreover, if the slowdown of China's economy constrains the resources available for military modernization, the tradeoffs between the development of new capabilities and sustainment of existing platforms could become more acute.

- *The PLA's capability to leverage AI could be hindered by continued shortcomings in talent and human capital.*

For the PLA, persistent challenges in recruitment and perhaps continuing shortcomings in the technical proficiency of its officers and enlisted personnel could challenge its agenda for intelligentization. The PLA has attempted to overcome prior difficulties to expand the recruitment 'high-quality' talents, including through targeting those with higher levels of education. As of spring 2019, over 2,500 colleges and universities nationwide have established recruitment workstation.[252] There have also been reforms to the PLA's personnel management to shift from 'civilian cadre' to civilian personnel, who receive benefits comparable to those of civil servants. The new rounds of recruitment for these civilian positions have aimed to attract candidates with M.A. and PhD degrees who have backgrounds in computer science and artificial intelligencne in the latest round of recruiting.

However, the PLA will be competing for high-tech talent at a time of relative scarcity, including because of intense demands from a growing private sector, and there are particular bottlenecks in the availability of AI talent to date. The application of an approach of military-civil fusion to talent development could contribute to resolving this problem, including through dedicated programs that leverage closer collaboration with the tech sector, such as a new degree program offered in Beihang University to which Baidu is contributing.[253] As Chinese universities expand their educational programming in AI, and as plans and programs for the recruitment of overseas talents continue to expand, the PLA may have a more sizable pool of talent to draw from. These attempts to cultivate 'first-class talent' continue, but progress will take time to achieve.[254]

Despite progress in increasing the realism of its training, the PLA may continue to struggle to match the sophistication required for preparations for future warfare.

The PLA's training was once highly scripted and has improved in sophistication, but may remain inadequate relative to the complexities and challenges of future intelligentized operations. PLA officers and researchers recognize the importance of innovation in techniques for training in response to new demands. However, the adoption and promulgation of new techniques that could eventually be incorporated into the PLA's official Outline of Military Training and Education, which was last revised in 2017, could prove challenging.[255] Potentially, the PLA's experimentation with techniques involving the use of virtual reality and artificial intelligence to training, as well as war-gaming, could enable future improvements in realism that could facilitate preparation for actual combat, despite the PLA's lack of experience. In particular, the complexities of managing human factors in training with complex systems could present particular challenges for the PLA.

The PLA appears to struggle with revising its doctrine and may confront difficulties in adopting new theories and concepts in practice.

The Chinese military does not appear to have fully revised its doctrine since 1999, despite ongoing, rolling revisions that have involved some updates. The new, 'fifth-generation' of operational regulations (作战条令), including campaign guidelines (战役纲要) has been under development since 2004 and was nearly but not fully launched in 2008. Despite ongoing research activities, which appear to have contributed to limited adjustments, the PLA appears to have yet to finalize this process, which appears to indicate a lack of consensus and/or institutional impediments. This 'third front' of PLA reforms will be a priority in 2019, as the PLA looks to complete new military policies, guidelines, and regulations. The apparent complications of doctrinal development also raise questions about whether the PLA will be able to incorporate new theories and concepts of intelligentized operations into this framework in practice or could confront comparable difficulties in the process.

The PLA appears to have difficulty in managing and integrating its data, including due to bureaucratic challenges and limited adoption of cloud computing.

The PLA appears to be encountering a number of challenges in the management of its data, which will be critical to the adoption of AI. The level of stove-piping and fragmentation across bureaucracies within the PLA could remain an impediment to progress. Chinese military researchers have expressed concern that there are current inadequacies in data mining, analytic processing capabilities, awareness of security and secrecy, and support of training data. Moreover, the PLA will have to deal with practical difficulties of cleaning and labeling disparate sources of data for use, which can be time and labor intensive, but could be facilitated by the access to cheap services for data labeling that has been available in China.[256] The adoption of shared infrastructure, including cloud computing, to enable deployment will also be required for the PLA to achieve an integrated approach to AI development. If the redundancies, inefficiencies, and corruption often associated with informatization recur in the process, the PLA may be hindered from effective utilization of these technologies.

In this regard, while China may appear to possess a data advantage given the aggregate amount of data that it possesses as a nation, that edge may prove limited in actuality and unlikely to directly translate into military advantage. However, the PLA may benefit from easier access to sources of data that may be leveraged for dual-purpose applications, such as remote sensing, leveraging deepening integration with academic and commercial endeavors. The access to data enabled by the expansion of initiatives through Digital Silk Road, including research collaborations that involve data sharing, also could increase the PLA's capabilities going forward. In some cases, certain sources of data that may be made available to the Chinese military, including in support of intelligence, after theft or exfiltration, may also be beneficial.

The PLA's lack of combat experience could result in a failure to appreciate the challenges of operating highly complex and automated or autonomous systems under actual combat conditions.

The PLA approaches warfare through the lens of military science. Lacking operational experience in its recent history, the PLA has confronted the unique challenge of 'learning without fighting,' often based on engaging in theoretical research that examines trends and technologies. Traditionally,

military innovation in peacetime has been considered particularly challenging, and the PLA is unlikely to be an exception in that regard, yet the sense of threat and urgency that comes with facing a 'powerful adversary' appears to have overcome inertia that often impedes change. The progress in 'actual combat' training, including involving confrontations between blue and red forces, could compensate for the lack of operational experience. Nonetheless, the PLA may fail to appreciate the extent to which the full complexity of warfare can extend beyond that anticipated in theories or exercises.

Whereas initial American enthusiasm about the notion of a Revolution in Military Affairs was tempered by the realities of combat and the failures of certain capabilities to materialize as anticipated, the PLA's focus on the notion of a RMA has persisted, seemingly without a comparable recalibration of expectations. For instance, certain Chinese military writings go so far as to claim that these advances could render the battlefield 'clear and transparent,' lifting or perhaps lessening the fog of war.[257] In actuality, the advent of AI could change that fog, perhaps creating new sources of confusion and novel cognitive challenges.

The particular ideological constraints and characteristics for the PLA as a party army may impede or condition its development in ways that could prove unique.

The PLA is a Party army, not a national military, and that reality could constraint and condition its approach to AI. Xi Jinping has consistently reiterated that the PLA must adhere to the Party's "absolute leadership," expanding and emphasizing the importance of innovation in "political work" that is intended to ensure that obedience. At first glance, these imperatives of capability and controllability could appear to be at odds in some cases. For instance, time dedicated to political activities is time taken away from training, and the imposition of ideological indoctrination seems unlikely to be conducive to the creativity that can enable innovation. Moreover, certain idiosyncrasies might be introduced into the PLA's approach to AI as a result of the ideological environment within which it is being developed. Some writings have called for a dialectical approach to AI or emphasized the importance of ensuring that AI possess certain political qualities and adhere to the necessary ideological requirements, avoiding any disloyalty.[258]

The implementation of military-civil fusion might prove inefficient and be undermined by poor coordination or corruption.

The scope and scale of Chinese initiatives in military-civil fusion indicate the potential to provide a systemic advantage, yet the implementation of the various efforts within this agenda remains nascent. The decision to elevate the concept of military-civil fusion as a national strategy—and to create institutional mechanisms dedicated to its implementation—can be characterized as indicative of the difficulties and challenges that such policy support is intended to overcome. The Chinese defense industry has remained relatively inefficient and tending towards monopoly, and beyond these traditional stakeholders, there had been relatively limited involvement by China's emerging technology companies in supporting national defense, given institutional obstacles to their participation and competition. In some respects, China's concept of military-civil fusion must be recognized as influenced by a close study of the U.S. history of successes of closer collaborations between the military, industry, and academia. However, the relative strength of China's innovation ecosystem in AI, including the relative willingness of companies to support defense applications, bolstered by ample resources and experimentation with new initiatives could start to change the equation.

The massive investments dedicated to promoting military-civil fusion and the development of emerging technologies may not be allocated efficiently and could create distortion.

China has a mixed track record on S&T plans. The implementation of industrial policies has varied greatly over time and across sectors, from apparent successes in 5G to more lackluster progress in semiconductors. The current initiatives to promote military-civil fusion are mobilizing massive amounts of capital, combining state funding with private investments, in ways that could accelerate innovation in critical emerging technologies, while promoting robust efforts in the defense industry. However, given that so many of these funds and mechanisms were launched recently, and the funding is just starting to be allocated, it is too soon to come to a definitive conclusion about the likely return on investment from these initiatives. Some of these efforts may be effective despite perhaps unavoidable inefficiencies, but there is also a risk such largescale investments could prove counterproductive through creating distortion. For instance, there have even been concerns about the potential for an AI bubble or AI winter.

There are still certain weaknesses in key and core technologies within China's technological ecosystem that will be difficult to redress.

Despite its strengths, China's innovation capabilities still possess distinct weaknesses in AI. There are more robust efforts in applications than in basic and cutting-edge research. Fewer algorithms and platforms have been developed indigenously to China to date. In some of the "key and core technologies," including semiconductors, China's efforts to catch up have achieved limited success to date, but recent progress in AI chips appears to be more promising. The increased support for research, including new open innovation platforms and national laboratories, could contribute to this transition towards more original innovative research in the future. However, for the time being, China's progress continues to depend partially upon access to 'international innovation resources,' including talent and knowledge.

PRC Tactics for the Transfer of Technology and Knowledge

Even as its indigenous capabilities for innovation are increasing, the PLA continues to leverage international engagement and collaborations to enable training, education, and the transference of skills and knowledge. Indeed, in recent history, China's attempts to catch up in defense and technological development have often involved attempts to access and absorb foreign technologies through licit and illicit means. These tactics and techniques have evolved and adapted but remain prominent as applied to the new priorities of emerging technologies. Insofar as China today aspires to advance beyond catching up towards leading in next-generation developments, the theft of IP outright may have less relevance in these fields, including because the state of research in AI is quite open to begin with. Since there has been greater scrutiny upon and pressure against China's tech transfer tactics and industrial espionage, certain of these activities are also becoming more targeted and obfuscated. The tactics employed range from outright illegal to those that exploit the openness of the scientific community through leveraging the norms that are prevailing regarding research collaborations. Although the U.S. has been a prime target, it is clear that these efforts are global in scope and scale. For instance, the semiconductor sector has been targeted extensively in the United States in theft and attempted acquisitions, and the recent acquisition of Danish semiconductor companies indicates the adaptability of these global activities.[259]

In particular, the targeted recruitment of talent is a clear priority and imperative to overcome the current bottleneck of human capital.[260] Xi Jinping has personally emphasized, "talent is the first resource," urging, "introducing foreign talents and intelligence is an important element of China's opening up to the outside world" and other important instructions." The undertaking of this "talent work" (人才工作) has involved the creation of a growing number of 'offshore science and technology talents offshore innovation and entrepreneurship base.'[261] The intense concerns about shortfalls in talent, relative to the demands for it, including in AI, have motivated the 'talent warfare' that is characteristic of this competition.[262] Often, these mechanisms for recruitment, such as a wide array of talent plans, are aimed at those who the Chinese government calls 'overseas Chinese' (华侨).[263] However, there are also numerous scientists who have no familial or historical connection to China who have been recruited through and participated in such programs.

Often, such activities are described as a "going out" (走出去) of Chinese enterprises, which have increased their engagement in research, investment, and acquisitions internationally, complemented with parallel attempts to facilitate the "bringing in" (引进来) of tech and talent back to China.[264] In the United States and worldwide, some of the recent mechanisms aimed at access to talent and cutting-edge technologies include a number of 'innovation centers' and 'innovation and entrepreneurship bases.' In lieu of a more detailed mapping, several notable examples can serve to illustrate this pattern of activities.

- Zhongguancun (ZGC) Capital, which supports the activities this high-tech zone of Beijing, has launched a number of incubators and incubation centers.
    - The ZGC Innovation Center in Silicon Valley (中关村硅谷创新中心) was established in May 2016 to incubate and 'accelerate' start-ups, including to help facilitate their pursuit of opportunities for cooperation with Chinese enterprises.[265, 266]
    - The ZGC Boston Innovation Center was launched in of April 2018, with Beijing government officials in attendance. The establishment of this incubator was characterized as important to "build the ecosystem of Zhongguancun's overseas collaborative innovation resources."[267]
        - The 'Z-Park' incubator involves sub-centers that concentrate on bio-tech, artificial intelligence, information technology, blockchain, and virtual reality.[268]
    - The ZGC "Innohub" Innovation Center in Heidelberg, Germany was established in May 2018.[269]
- The China Association for Science and Technology (Shenzhen) Overseas Talent Offshore Innovation and Entrepreneurship Base (中国科协（深圳）海外人才离岸创新创业基地) plans to establish a total of overseas innovation centers based on a cooperation agreement with the Shenzhen Municipal Government signed in May 2015.[270]
    - The "Radical Force Innovation Boston Innovation Center" (源创力波士顿创新中心) was established in May 2017.[271]
    - The first seven locations planned for these centers include San Francisco, Seattle, and Boston in the United States; London, England; Evelyn, France; Tel Aviv and Haifa, Israel; and Toronto, Canada.
- The non-profit "Silicon Valley Global," which oversees the New Silicon Valley Offshore Incubator, has served as a bridge and matchmaker in support of the 'bringing in' of innovation to China.[272]

- For instance, Silicon Valley Global signed an agreement with the Baoding Overseas Talents Offshore Innovation and Entrepreneurship Base, committing to support its incubator base for overseas talent.[273]

Pursuant to the Digital Silk Road, Chinese companies may gain access to new sources of data that can reinforce China's advantage in AI development, while expanding the deployment of Chinese cloud computing.[274] There is a strong emphasis on promoting global scientific cooperation under the umbrella of One Belt, One Road in ways that may also provide access to unique sources of data.

In some cases, Chinese military scientists have been sent to study abroad at international institutions, concealing their actual affiliations, or engaged in problematic collaborations with foreign researchers on research that may have defense applications. The PLA's National University of Defense Technology has been particularly prominent in these exchanges and research collaborations.[275]

Implications for U.S.-China Strategic Rivalry and Technological Competition

I assessed in my testimony to the Commission in February 2017, "China's advances in artificial intelligence may have immense strategic implications… China evidently possesses the potential to compete with—or even leapfrog—the United States in artificial intelligence…[which] could become a vital force multiplier for its future military capabilities."[276] Since then, the evidence that the PLA is emerging as an AI powerhouse has become increasingly compelling, and there are additional indications of the momentum that is building up behind these initiatives, including basic research and applications in AI that are increasingly at the forefront of global developments. Today, it is clear that competition in AI is a new frontier of U.S.-China rivalry, and Chinese leaders are determined to seize this "strategic commanding heights." Xi Jinping declared in his remarks to a Politburo study session in the fall of 2018:

> "Accelerating the development of a new generation of AI is an important strategic handhold for China to gain the initiative in global science and technology competition, and it is an important strategic resource driving our country's leapfrog development in science and technology, its industrial optimization and upgrading, and a comprehensive leap ahead in productivity."[277]

The implications of these advances could become a fundamental determinant of the future balance between these great powers. The impact of AI across economic development and military modernization may be unpredictable but could prove transformative. The new technological revolution that is occurring through the advent of emerging technologies with powerful synergies among them could reshape our economies, societies, and militaries in ways that are difficult to anticipate. Initially, China's potential for innovation tended to be dismissed; presently, there can be, at the other extreme, a tendency to overestimate or exaggerate its strengths, while neglecting to recognize and reinforce American advantages or undertake competitive strategy that is informed by assessments of China's persistent weaknesses.

Looking forward, American military-technological superiority cannot be assumed, but rather must be contested. China's emergence as a technological powerhouse—and would-be superpower—presents a compelling competitive challenge. At the same time, since commercial developments have been a primary impetus for today's advancements in emerging technologies, within fields in which

research has been open and internationally collaborative, the diffusion of ideas, knowledge, and the technologies themselves has occurred more readily. Neither the United States nor China may achieve an absolute or enduring advantage, yet their relative trajectories in taking advantage of the opportunities that these technologies present could change the future balance of power across economic and military dimensions of power. Within this military rivalry, the relative capacities of the U.S. and Chinese militaries as organizations to operationalize these emerging capabilities could be the critical differentiator. Chinese military strategists are seeking to seize the initiative, believing "first-class militaries design warfare, second-rate militaries are trailing in warfare, and third-rate militaries have to contend with warfare."[278] The PLA's ambitions to be a truly world-class military (世界一流军队) imply its intention to be at the forefront of shaping and 'designing' the conditions of future battlefield.[279] The challenge of intelligentized warfare is seen as rendering the creation of new concepts imperative, including responding to the threats of enemy advances and studying new strategies to defeat an adversary.[280]

As the PLA has started to catch up with the U.S. military, its attention has shifted to seizing the advantage in future military competition. Xi Jinping has established that modernization is intended to be "basically completed" by 2035, declaring, "by the mid-21st century, our people's armed forces will have been fully transformed into world-class forces."[281] The PLA's conceptualization of the bar for becoming a "global first-class" or "world-class" military (世界一流军队) remain subject to debate and perhaps continued evolution. Could the PLA equal, or perhaps surpass, the U.S. military? Will the Chinese military remain primarily regional or progress towards global power projection? To what extent will the PLA imitate or adhere to American antecedents, or could the Chinese military possess distinct priorities and paradigms of military power? Inherently, the trajectory of Chinese military modernization remains contingent upon China's capacity to sustain economic growth, and the PLA is still implementing disruptive reforms and attempting to overcome bureaucratic impediments to innovation. Despite these uncertainties, there are initial indicators that the PLA is actively exploring novel directions in its development, from expanding into the new frontiers of the deep sea and polar regions, to increasing its investing in more expeditionary capabilities. The PLA's advances in autonomy in advanced weapons systems, including hypersonic glide vehicles, could extend its reach for strategic assaults in ways that reinforce its deterrence and war-fighting capabilities. As the PLA is called upon to defend China's overseas interests, the use of unmanned and autonomous weapons systems also could be favored as an option that allows for flexible options. In a range of regional contingencies, these new capabilities could introduce a degree of unpredictability, from crises involving the use of drones in disputed territories to the potential accidents that might result from the increased complexity of human factors in such systems.

As U.S.-China military rivalry intensifies at a time of technological transformation, these trends may present new risks to strategic stability under complex geopolitical circumstances. There are real reasons for concern that arms racing dynamics could create adverse incentives for AI deployment, at worst creating dynamics in which concerns of speed and relative capability take precedence over safety and surety. However, it is encouraging that military specialists and technology stakeholders in the United States and China alike appear to be aware of and actively engaged on these issues.[282] In this context, the frequent framing of an "AI arms race" is also problematic insofar as this conceptualization can be misleading and has significant limitations, including the reality that "AI" is best considered a general-purpose enabling technology that has a diverse array of applications. At the same time, the qualitative character of how AI can enhance military capabilities creates a level of uncertainty that impedes assessments of relative advances and the overall impact on the military

balance. At worst, such uncertainty can exacerbate a tendency towards arms racing dynamics, including because of a tendency towards worst-case scenario thinking and overestimation of a potential adversary's capabilities. Since the contributions of AI to military power are essentially intangible, there are incentives for militaries to signal, display, and demonstrate relevant capabilities, such as swarming, in attempts to bolster deterrence, including through activities that may be intended for purposes of deception or misdirection. As the U.S.-China military-to-military relationship evolves going forward, there may be opportunities to progress towards greater clarity and transparency through dialogue on shared concerns of strategic stability, including questions of risk mitigation and crisis management.

Policy Recommendations and Considerations

At the nexus of U.S.-China competition and cooperation in artificial intelligence, American policymakers confront complex challenges that raise urgent questions for U.S. policy. The core concern for American strategy should be ensuring future competitiveness and contesting leadership in strategic technologies. For the U.S. military, initiatives for defense innovation must take on a new level of urgency and will require rethinking of current practices and techniques.

I. Surge support to sustain future American competitiveness in science and technology.

- Increase and commit to sustaining funding for basic research and the long-term development of strategic technologies.
    - Consider increasing support for science to levels comparable to that of the Cold War.[283]
- Create a strategy for artificial intelligence in education through the Department of Education, including to encourage experimentation in new approaches to the use of AI in education and education in AI at the state and local levels.
    - Prioritize improving the accessibility and affordability of STEM education at all levels, including creating new scholarships to support those studying priority disciplines.
- Sustain openness to immigration, welcoming graduating students and talented researchers, while potentially offering a fast-track option to citizenship.
- Explore the expansion of coordination and cooperation with allies and partners in innovation, including deeper collaboration in research, development, and experimentation with new technologies and their applications.
- Identify categories of U.S. data (e.g., faces, biometrics, genomic information, sensitive personal information) that should be prioritized for protection.
    - Enhance and enforce cyber security standards and requirements for contractors and laboratories engaged in sensitive academic research.

II. Contest and compete for competitive advantage in an era of emerging capabilities and challenges.

- Ensure that the implementation of the National Defense Strategy is fully resourced to enable innovation and experimentation.
- Recognize the criticality of talent, and undertake necessary reforms to the personnel system.
    - Support new approaches to identifying and rewarding technical expertise, such as the Computer Language Initiative that the Air Force has launched.[284]

    - Implement training, education, and incentives to improve proficiency and readiness in computer science, big data analytics, and machine learning.
- Sustain and increase support for defense innovation initiatives, including funding the Joint Artificial Intelligence Center at the levels deemed necessary.
    - Prioritize investment in future capabilities, not only sustainment of existing programs.
    - Explore new options for venture capital and novel funding mechanisms to catalyze commercial innovation.
- Deepen partnership with stakeholders in universities and technology companies.
    - For instance, the Air Force's recent partnership with MIT's Computer Science and Artificial Intelligence Laboratory is a promising initiative that may establish a valuable precedent.[285]
- Prepare for a mobilization of innovation and industrial resources in potential scenarios of large-scale conflict.
- Consider supporting dialogues and military and/or governmental engagement on issues of AI safety and security between American and Chinese counterparts.

III. Pursue carefully calibrated countermeasures to mitigate the risks of exploitation of the openness of the American innovation ecosystem.

The United States today confronts the unique challenge of strategic competition with a rival with which there is a high level of economic interdependence that including technological entanglement. The American and Chinese innovation ecosystems have been often synergistic in ways that can be mutually beneficial, but can also be exploited or even weaponized.[286] The current rebalancing and recalibration of the U.S.-China economic and technological relationships could reduce current frictions and mitigate concerns over potential vulnerabilities. However,

- Identify organizations engaging in talent recruitment that are linked to the Chinese central and local governments or to the Chinese Communist Party (CCP).
    - Require their registration as foreign agents, and track their activities in the United States and worldwide, sharing information with allies and partners where appropriate.
- Focus on early warning and enforcement to prevent illicit transfers of technology and hold those engaged in such activities accountable.
    - Enhance counterintelligence capabilities, increasing funding and personnel where necessary, including by augmenting language and technical expertise.
- Engage in outreach to companies and universities to ensure their understanding of policies, and appropriate precautions for the protection of sensitive technologies.
    - Consider reestablishing the now-disbanded FBI National Security Higher Education Advisory Board or a similar mechanism to facilitate and institutionalize such engagements.[287]
- Review recent and ongoing research and commercial partnerships on prioritized technologies that involve support and funding from foreign militaries, governments or state-owned/supported enterprises, evaluating the dual-use risks and potential externalities in each case.
    - Create an advisory board of scientists who can provide an independent assessment and perspective on cases in which the facts or nature of scientific activities are unclear or disputed.

- Introduce safeguards to ensure that the enforcement of U.S. laws and policies is undertaken in a manner that is appropriately balanced.
    - Ensure that students or scientists who are suspected of having violated U.S. laws or regulations receive due process through a careful evaluation of the totality of the circumstances.
    - Undertake an independent assessment of past incidents in which U.S. law enforcement, counterintelligence, and/or indictments have been mistaken or wrongly charged against individuals later determined to be innocent of wrongdoing.[288]
        - Commit to transparency and accountability about the findings, and actively implement changes that are deemed necessary.
- Create mechanisms for intelligence-sharing and enhanced collaboration with allies and partners in response to the common challenge of tech transfer.
    - Establish a regular working group among the "Five Eyes," as well as select allies and partners, to discuss best practices and lessons learned in responding to issues of tech transfer, as well as more rapidly exchange timely information about current threats.

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Currently, Elsa is a PhD student in Harvard University's Department of Government, and she is also a graduate of Harvard College (summa cum laude, Phi Beta Kappa). Her thesis was awarded the James Gordon Bennett Prize, and her dissertation will examine Chinese military learning and innovation in historical perspective. Her prior professional experience includes time with FireEye, the Department of Defense, Long Term Strategy Group, and the Carnegie-Tsinghua Center for Global Policy. While at Harvard, she has also worked as a research assistant at the Belfer Center and the Weatherhead Center. Elsa was a Boren Scholar in Beijing, China, and she maintains professional proficiency in Mandarin Chinese.

Endnotes

[1] [1] "Xi Jinping's Report at the Chinese Communist Party 19th National Congress" [习近平在中国共产党第十九次全国代表大会上的报告], Xinhua, October 27, 2017, http://www.china.com.cn/19da/2017-10/27/content_41805113_3.htm

[2] Pang Hongliang, a professor at the PLA's National Defense University, was among the earliest academics to start actively writing on the topic of intelligentized warfare, including publishing two books on the topic. Pang Hongliang [庞宏亮], "The Intelligentization Military Revolution Starts to Dawn" [智能化军事革命曙光初现], *PLA Daily*, January 28, 2016, http://www.mod.gov.cn/wqzb/2016-01/28/content_4637961.htm.

[3] See, for instance, this seemingly authoritative commentary emphasizing the importance of human-machine cooperation: Lu Zhisheng [陆知胜], "The Typical Style of Intelligentized Operations: Human-Machine Cooperation!" [智能化作战的典型方式：人机协同！] *PLA Daily*, October 17, 2018.

[4] For an initial analysis of this trend, see: Elsa B. Kania, "Learning Without Fighting: New Developments in PLA AI War-Gaming," *China Brief*, April 9, 2019, https://jamestown.org/program/learning-without-fighting-new-developments-in-pla-artificial-intelligence-war-gaming/

[5] This testimony builds upon and is informed by prior research that the author has undertaken since 2016, including: Elsa B. Kania "Battlefield Singularity: Artificial Intelligence, Military Revolution, and China's Future Military Power," Center for a New American Security, November 28, 2017, https://www.cnas.org/publications/reports/battlefield-singularity-artificial-intelligence-military-revolution-and-chinas-future-military-power. Elsa Kania, "The PLA's Unmanned Aerial Systems – New Capabilities for a "New Era" of Chinese Military Power," U.S. Air Force China Aerospace Studies Initiative, August 10, 2018, https://www.amazon.com/dp/1724598112/ref=cm_sw_r_cp_ep_dp_1WSCBbDCCR3GX. Elsa B. Kania and John K. Costello, "Quantum Hegemony? – China's Ambitions and the Challenge to U.S. Innovation Leadership," Center for a New American Security, September 12, 2018, https://www.cnas.org/publications/reports/quantum-hegemony

[6] "Xi Jinping: Accurately Grasp the New Trend in Global Military Developments and Keep Pace with the Times, Strongly Advancing Military Innovation" [习近平:准确把握世界军事发展新趋势 与时俱进大力推进军事创新], *Xinhua*, August 30, 2014, http://news.xinhuanet.com/politics/2014-08/30/c_1112294869.htm

[7] See, for instance: "Jiang Zemin and Military Transformation with Chinese Characteristics" [江泽民与中国特色军事变革] https://webcache.googleusercontent.com/search?q=cache:W4ONiqi73O4J:https://www.wxyjs.org.cn/sgdbzysxyj/201402/t20140217_147993.htm+&cd=5&hl=en&ct=clnk&gl=us

[8] "Xi Jinping: Accurately Grasp the New Trend in Global Military Developments and Keep Pace with the Times, Strongly Advancing Military Innovation" [习近平:准确把握世界军事发展新趋势 与时俱进大力推进军事创新], *Xinhua*, August 30, 2014, http://news.xinhuanet.com/politics/2014-08/30/c_1112294869.htm

[9] "Launching the Engine of Innovation for Strengthening and Rejuvenating the Military"[发动强军兴军的创新引擎——军队代表委员热议科技兴军], Xinhua, March 12, 2019, http://www.xinhuanet.com/mil/2019-03/12/c_1210079238.htm.

[10] M. Taylor Fravel, *Active Defense: China's Military Strategy Since 1949*. Vol. 2. Princeton University Press, 2019. M. Taylor Fravel, "Shifts in Warfare and Party Unity: Explaining China's Changes in Military Strategy." *International Security* 42, no. 3 (2018): 37-83.

[11] Although the translation "smart" is used in the official version of this Defense White Paper, I choose to use the translations "intelligent" or "intelligentized."

[12] Ministry of National Defense of the People's Republic of China [中华人民共和国国防部], "China's Military Strategy" [中国的军事战略]," May 26, 2015. See also the official English translation of the white paper: http://english.gov.cn/archive/white_paper/2015/05/27/content_281475115610833.htm

[13] See also: Li Bingyan [李炳彦], "Major Trends in the New Global Revolution in Military Transformation and the Form of Future Warfare" [世界新军事变革大势与未来战争形态], February 24, 2016. Li Bingyan is a member of the National Security Policy Committee (国家安全政策委员会).

[14] For a noteworthy commentary from Lt. Gen. Gao Jin, then president of the Academy of Military Science and later the inaugural commander of the PLA Strategic Support Force, see: "Academy of Military Science President: Reforms Must Resolve the Restraints Upon Systematic Assurance for a Powerful Military" [军事科学院院长:改革要解决羁绊强军的体制性障碍], *PLA Daily*, November 2, 2015, http://www.chinanews.com/mil/2015/11-02/7600724.shtml. The mechanism of winning in warfare has changed profoundly. We must be aware of our own shortcomings… We must

focus on solving the institutional obstacles, structural contradictions, and policy problems that have long plagued our military.

[15] For the definitive book on the PLA's reforms, see: Phillip C. Saunders, Arthur S. Ding, Andrew Scobell, Andrew N.D. Yang, and Joel Wuthnow (eds.), Chairman Xi Remakes the PLA: Assessing Chinese Military Reforms, ASSESSING CHINESE MILITARY REFORMS, National Defense University Press, https://inss.ndu.edu/Portals/82/Documents/books/Chairman-Xi.pdf?ver=2019-03-14-110008-073

[16] For the authoritative assessment of the PLASSF, see: John Costello and Joe McReynolds, "The Strategic Support Force: A Force for a New Era," National Defense University, October 2, 2018, http://ndupress.ndu.edu/Media/News/News-Article-View/Article/1651760/chinas-strategic-support-force-a-force-for-a-new-era/. See also: Elsa Kania and John Costello, "The Strategic Support Force and the Future of Chinese Information Operations," *Cyber Defense Review*, Spring 2018, https://cyberdefensereview.army.mil/Portals/6/Documents/CDR%20Journal%20Articles/The%20Strategic%20Support%20Force_Kania_Costello.pdf?ver=2018-07-31-093713-580. See also: Elsa Kania, "The Strategic Support Force – A Force for Innovation?," *The Diplomat*, February 23, 2017, http://thediplomat.com/2017/02/chinas-strategic-support-force-a-force-for-innovation/. For primary source documentation highlighting the PLA's role in innovation, see: "How Can the Strategic Support Force Forge New Quality Weapons" [战略支援部队如何锻造新质利器], *PLA Daily*, March 11, 2016, http://www.chinanews.com/mil/2016/03-11/7792939.shtml.

[17] "Shoulder the functional mission of strengthening the military through science and technology" [肩负起科技强军的职能使命], *PLA Daily*, April 28, 2016, http://www.mod.gov.cn/topnews/2016-04/28/content_4651316.htm

[18] "Academy of Military Science National Defense Science and Technology Innovation Research Academy – Exploring the "Matrix" Research Model to Enhance Innovation Capability" [军事科学院国防科技创新研究院—— 探索"矩阵式"科研模式提升创新能力], April 2, 2018, http://www.81.cn/jfjbmap/content/2018-04/02/content_202957.htm. See also: "Academy of Military Science National Defense Science and Technology Innovation Research Academy Has Taken Measures to Gather Top Talents" [军科院国防科技创新研究院多措并集聚顶尖人才], China Military Network, February 4, 2018, http://webcache.googleusercontent.com/search?q=cache:WDwIAWmc6agJ:www.81.cn/jwgz/2018-02/04/content_7931564.htm+&cd=8&hl=en&ct=clnk&gl=us

[19] "The Academy of Military Sciences has amassed and selected more than 120 urgently needed scientific research personnel from the whole military" [军事科学院面向全军集中选调 120 余名急需科研人才], Xinhua, January 1, 2018, http://www.xinhuanet.com/mil/2018-01/25/c_129798773.htm.

[20] See, for instance: "Four Departments Issued a Notice Regarding the ""Internet Plus" Artificial Intelligence Three-Year Action Implementation Plan" [四部门关于印发《"互联网+"人工智能三年行动实施方案》的通知], China Government Network, May 25, 2016, http://www.miit.gov.cn/n1146290/n1146392/c4808445/content.html. "State Council Notice on the Issuance of the New Generation AI Development Plan" [国务院关于印发新一代人工智能发展规划的通知], August 20, 2017, http://www.gov.cn/zhengce/content/2017-07/20/content_5211996.htm"MIIT's Notice Regarding the Release of the Three Year Action Plan to Promote the Development of New-Generation Artificial Intelligence Industry (2018-2020) [工业和信息化部关于印发《促进新一代人工智能产业发展三年行动计划（2018-2020 年）》的通], December 14, 2017, http://www.miit.gov.cn/n1146295/n1652858/n1652930/n3757016/c5960820/content.html

[21] For the full translation, see: Graham Webster, Rogier Creemers, Paul Triolo, and Elsa Kania, "Full Translation: China's 'New Generation Artificial Intelligence Development Plan' (2017)," https://www.newamerica.org/cybersecurity-initiative/digichina/blog/full-translation-chinas-new-generation-artificial-intelligence-development-plan-2017/

[22] This is an estimate and approximation on the basis of the author's awareness of the range of mechanisms for funding and investment across military, government, and private investments in artificial intelligence and related technologies.

[23] See again China's "New Generation Artificial Intelligence Development Plan."

[24] See this series in China Brief, organized by Peter Wood for early analyses on these issues: "China & the Third Offset," https://jamestown.org/programs/cb/china-third-offset/

[25] See: China Military Science Editorial Department [中国军事科学 编辑部], "A Summary of the Workshop on the Game between AlphaGo and Lee Sedol and the Intelligentization of Military Command and Decision-Making" [围棋人机大战与军事指挥决策智能化研讨会观点综述], *China Military Science* [中国军事科学], April 2, 2016. Note that the journal's own English language translation of the title of the workshop is not the direct or literal translation.

[26] The potential alternative spellings and translations of 智能化 include intelligent, intelligencization, smartification, and/or AI-ification. The notion of 'cognification' has also been used in English-language descriptions of a similar phenomenon. I have chosen to render this term "intelligentization" for consistency with some of the official translations

of the term in authoritative journals, such as *China Military Science*, but I am open to debating alternative translations and conceptualizations with those concerned. Not unlike "informatization," the notion of "intelligentization" is difficult to define with precision and appears to be used in a varying and sometimes somewhat inconsistent manner by PLA writings on these issues. My understanding of this concept has evolved since I first discussed it in published writing and testimony in February 2017, and I will discuss its multifaceted meanings later in this paper. For an early perspective on the issue: See also: Elsa B. Kania, "Testimony before the U.S.-China Economic and Security Review Commission: Chinese Advances in Unmanned Systems and the Military Applications of Artificial Intelligence—the PLA's Trajectory towards Unmanned, "Intelligentized" Warfare," U.S.-China Economic and Security Review Commission, February 23, 2017, https://www.uscc.gov/sites/default/files/Kania_Testimony.pdf

[27] CMC Joint Staff Department [中央军委联合参谋部], "Accelerate the Construction of a Joint Operations Command System with Our Nation's Characteristics—Thoroughly Study Chairman Xi's Important Sayings When Inspecting the CMC Joint Operations Command Center [加快构建具有我军特色的联合作战指挥体系—— 深入学习贯彻习主席视察军委联指中心时的重要讲话], *Seeking Truth*, August 15, 2016, http://www.qstheory.cn/dukan/qs/2016-08/15/c_1119374690.htm.

[28] "Xi Jinping's Report at the Chinese Communist Party 19th National Congress" [习近平在中国共产党第十九次全国代表大会上的报告].

[29] This concept (弯道超车), which often recurs in PLA writings, alludes to idea of two cars racing towards a corner, of which one cuts the turn more sharply and takes the inside track, thus passing by the other. I'm open to other suggestions on how to translate this term.

[30] "Lt. Gen. Liu Guozhi: the development of military intelligentization is a strategic opportunity for our military to turn sharply to surpass" [刘国治中将:军事智能化发展是我军弯道超车的战略机遇], CCTV News, October 22, 2017, http://mil.news.sina.com.cn/china/2017-10-22/doc-ifymzqpq3312566.shtml

[31] For an excellent academic evaluation of the challenges ofo catching up, see: Andrea Gilli and Mauro Gilli. "Why China Has Not Caught Up Yet: Military-Technological Superiority and the Limits of Imitation, Reverse Engineering, and Cyber Espionage." *International Security* 43, no. 3 (2019): 141-189.

[32] For an academic perspective on the notion of leapfrogging, see for instance: Takashi Hikino and Alice H. Amsden, "Staying behind, stumbling back, sneaking up, soaring ahead: late industrialization in historical perspective" *Convergence of productivity: Cross-national studies and historical evidence*(1994): 285-315.

[33] This is the author's attempt to provide the simplest possible definition of the term, and I am very open to other suggestions and interpretations.

[34] For context, see: Andrew S. Erickson and Michael S. Chase. "Informatization and the Chinese People's Liberation Army Navy." *Phillip Saunders, Christopher Yung, Michael Swaine, and Andrew Nien-Dzu Yang, The Chinese Navy: Expanding Capabilities, Evolving Roles, Washington, DC: Institute for National Strategic Studies* (2011): 247-287. Leigh Ann Ragland, Joseph McReynolds, Matthew Southerland, and James Mulvenon. *Red cloud rising: cloud computing in China*. Defense Group Incorporated, 2013.

[35] This concept (弯道超车), which often recurs in PLA writings, alludes to idea of two cars racing towards a corner, of which one cuts the turn more sharply and takes the inside track, thus passing by the other. I'm open to other suggestions on how to translate this term.

[36] "Experts: Military Intelligentization Is Not Merely Artificial Intelligence" [专家：军事智能化绝不仅仅是人工智能], *People's Daily*, December 6, 2017, http://military.people.com.cn/n1/2017/1206/c1011-29689750.html

[37] Ibid.

[38] See: China Military Science Editorial Department [中国军事科学 编辑部], "A Summary of the Workshop on the Game between AlphaGo and Lee Sedol and the Intelligentization of Military Command and Decision-Making" [围棋人机大战与军事指挥决策智能化研讨会观点综述], *China Military Science* [中国军事科学],

[39] See: "Future wars, research on future wars, thinking innovation, rational treatment of disruptive technology" [未来战争丨研究未来战争需要思维创新，理性对待颠覆性技术], The Paper, August 16, 2016,http://www.thepaper.cn/baidu.jsp?contid=1514759

[40] Ibid. Some of those prominently involved in this seminar and related initiatives have included academicians, of whom are also dual-hatted in military research institutions: Maj. Gen. Li Deyi, Yang Xuejun, Lu Xicheng, Dai Hao, Shen Changxiang, Liao Xiangke, Yu Quan, Yin Hao, and Wang Shafei, among others. Potentially, the next revised version of this paper will include a listing of those assessed to be key figures in this process in the appendix.

[41] "Theory-Technology Fusion Innovation" New Year Seminar Successfully Convened in Beijing" ["理技融合创新"新春座谈会在京成功召开], http://webcache.googleusercontent.com/search?q=cache:O8YXjXfEEdsJ:caai.cn/index.php%3Fs%3D/Home/Article/detail/id/490.html+&cd=4&hl=en&ct=clnk&gl=us

[42] For a perspective on the process of innovation, see: Tai Ming Cheung, Thomas G. Mahnken, and Andrew L. Ross. "Frameworks for analyzing Chinese defense and military innovation," 2011, https://cloudfront.escholarship.org/dist/prd/content/qt5cr8j76s/qt5cr8j76s.pdf

[43] "Xi Jinping: Strive to build a high-level military scientific research institution to provide strong support for the party's strong military objective in the new era" [习近平：努力建设高水平军事科研机构 为实现党在新时代的强军目标提供有力支撑], Xinhua, May 16, 2018, http://www.xinhuanet.com/2018-05/16/c_1122843283.htm

[44] Potentially, the 61st Research Institute, which initially appeared to have been shifted from the Informatization Department to the new Equipment Development Department, may have been linked to or re-subordinated under AMS, but that assessment would be pending further evidence and confirmation.

[45] "President Xi came to the military school for the first time" [习主席第一次到军校视察就来到这里], China Military Online, March 20, 2018, https://new.qq.com/omn/20180320/20180320A1G5SK.html .

[46] "Chief Engineer Hu Xiaofeng, General Manager of China's Bingqi Program, Delivered a Lecture: the Challenge of the Intelligentization of Command information Systems" [中国兵棋工程总师胡晓峰少将演讲：指挥信息系统的智能化挑战], July 13, 2016, 2016, http://chuansong.me/n/434595151184

[47] The PLA does not describe what it is doing as an 'offset' per se, but that oculd be the effect in practice.

[48] Ke Zhengxuan [科政轩], "How to build a military scientific research system with our military's characteristics" [我军特色军事科学研究体系如何构建形成], *PLA Daily*, August 08, 2017, http://www.81.cn/jmywyl/2017-08/04/content_7703373.htm

[49] Hu Shengning [胡延宁], Li Bingyan [李炳彦], and Wang Shengliang [王圣良], *Light Warfare: The New Trend in the Global Revolution in Military Affairs* [世界军事革命新趋势], PLA Press [*解放军出版社*], 2015, p. 65-76. See also: Li Bingyan [李炳彦], "Major Trends in the New Global Revolution in Military Transformation and the Form of Future Warfare" [世界新军事变革大势与未来战争形态], February 24, 2016.

[50] This is the department that has had direct responsibility for the PLA's formulation of its equivalent to doctrine, operational regulations.

[51] Zhang Zhanjun [张占军], "How to compete for future maritime combat initiative" [如何争夺未来海上作战主动权], *PLA Daily*, October 24, 2017, https://web.archive.org/save/http://www.xinhuanet.com/mil/2017-10/24/c_129725534.htm

[52] The prior edition of the NDU's SMS dated back to 1999, and it is unusual for a revision of the text to occur so soon.

[53] Note: Although the 2013 edition of the Science of Military Strategy is often seen as more authoritative, it is the author's contention that the 2015 and this revised 2017 versions merit greater attention. Xiao Tianliang (ed.), *The Science of Military Strategy*, National Defense University Press, 2017. This is the second edition of the edition initially released in 2015.

[54] Please note that this is the author's personal translation and paraphrasing of the text in question.

[55] For context, see: Elsa B. Kania, "When Will the PLA Finally Update Its Doctrine?," The Diplomat, June 6, 2017, https://thediplomat.com/2017/06/when-will-the-pla-finally-update-its-doctrine/

[56] Wang Yonghua [王永华], "How to get through the whole link of combat concept development?" [如何打通作战概念开发的完整链路？], China Military Network, November 29, 2018,http://www.81.cn/jwgd/2018-11/29/content_9360140.htm.

[57] Chen Hanghui [陈航辉], "Artificial Intelligence: Disruptively Changing the Rules of the Game" [人工智能：颠覆性改变"游戏规则], China Military Online, March 18, 2016, http://www.81.cn/jskj/2016-03/18/content_6966873_2.htm. Chen Hanghui is affiliated with the Nanjing Army Command College. Please note that I do not assess this to be an official or entirely authoritative perspective, though I do believe that the recurrence of similar sentiments in a range of reasonably authoritative

[58] Ibid.

[59] These concepts (i.e., of humans being in, on, or out of the loop) originate in U.S. discussions of the role of humans in decision-making, reflecting the PLA's close attention to U.S. policies and debates.

[60] "Exploring the winning joints of intelligentized operations" [探究智能化作战的制胜关节], *PLA Daily*, March 29, 2018, http://military.people.com.cn/n1/2018/0329/c1011-29896429.html

[61] Chen Dongheng [陈东恒] and Dong Julin [董俊林], "Military Intelligence Development Should Emphasize and Seize Upon Several Dialectical Relationships" [军事智能化发展应着重把握的几个辩证关系], May 14, 2019, http://www.81.cn/theory/2019-05/14/content_9502765.htm.

[62] "Exploring the winning joints of intelligentized operations" [探究智能化作战的制胜关节].

[63] "Unmanned Systems: New Opportunities the Development of Military-Civil Fusion in Artificial Intelligence" [无人系统：人工智能军民融合发展新契机].

[64] Hao Yaohong [郝耀鸿], "5G, One Step Closer to the Military Internet of Things" [5G,离军事物联网更近一步], *Confidential Work*《保密工作》 July 2017, http://www.cnki.com.cn/Article/CJFDTotal-BMGZ201707033.htm. Hao Yaohong is an expert on military communications with the PLA Special Operations Academy (特种作战学院).
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