DAIO Defense AI Observatory

“Overtaking on the Curve?”

Defense AI in China

John Lee

DAIO Study 23|13

Ein Projekt im Rahmen von

dtec.bw
Zentrum für Digitalisierungs- und Technologieforschung der Bundeswehr

Finanziert von der Europäischen Union
NextGenerationEU

About the Defense AI Observatory

The Defense AI Observatory (DAIO) at the Helmut Schmidt University in Hamburg monitors and analyzes the use of artificial intelligence by armed forces. DAIO comprises three interrelated work streams:

- Culture, concept development, and organizational transformation in the context of military innovation
- Current and future conflict pictures, conflict dynamics, and operational experience, especially related to the use of emerging technologies
- Defense industrial dynamics with a particular focus on the impact of emerging technologies on the nature and character of techno-industrial ecosystems

DAIO is an integral element of GhostPlay, a capability and technology development project for concept-driven and AI-enhanced defense decision-making in support of fast-paced defense operations. GhostPlay is funded by the Center for Digital and Technology Research of the German Bundeswehr (dtec.bw). dtec.bw is funded by the European Union – NextGenerationEU.

Ein Projekt im Rahmen von

dtec.bw
Zentrum für Digitalisierungs- und Technologieforschung der Bundeswehr

Finanziert von der Europäischen Union
NextGenerationEU

“Overtaking on the Curve?”

Defense AI in China

John Lee

DAIO Study 23|13

Ein Projekt im Rahmen von

dtec.bw
Zentrum für Digitalisierungs- und Technologieforschung der Bundeswehr

Finanziert von der Europäischen Union
NextGenerationEU

About the Author
John Lee is director of the consultancy East West Futures (https://eastwestfutures.com). He holds Masters degrees from the Australian National University in international law and King's College London in war studies. John is also affiliated with the Leiden Asia Center and consults to the International Institute for Strategic Studies (IISS). His Twitter account is @J_B_C16.

Design
Almasy Information Design Thinking

Imprint
John Lee, "Overtaking on the Curve?" Defense AI in China. DAIO Study 23/13 (Hamburg: Defense AI Observatory, 2023).

Defense AI Observatory | Chair of Political Theory | Helmut Schmidt University
Holstenhofweg 85 | 22043 Hamburg | T +49 40 6541 2776
www.defenseai.eu | contact@defenseai.eu | @Defense_AIO

ISSN (online): 2749–5337
ISSN (print): 2749–5345

Content

1 Executive Summary

China has a clear understanding of the importance of artificial intelligence (AI) to the future military balance, and a well-developed and resourced system for domestic development of AI technologies. By the judgment of seemingly most Chinese and many foreign analysts, the People's Liberation Army (PLA) remains far from implementing revolutionary uses of defense AI, and is still grappling with the institutional reforms and basic capability development needed to effectively use AI in current operations. But Chinese thinkers are working through the possibilities for AI to give the PLA both symmetric and asymmetric tools for high-end conflict with the US military and its allies, in the context of reasonably clear military strategic goals. Fear of Chinese potential was enough for the US in late 2022 to introduce severe export controls targeting China's access to high-performance semiconductors, expressly justified by the imperative to constrain Chinese advances in defense AI.

China is ruled by a Party that follows a materialist conception of human development and wields unchallenged authority over all social institutions including the PLA, with a leader who appears entrenched for the coming decade. Official judgments about AI's structural importance, and of the need to be equipped for long-term strategic competition with the US, are thus unlikely to change. To this end, China is leveraging its dynamic civilian economy to boost defense AI development, within the larger context of a national drive for the commanding heights of AI and other emerging technologies. Whether methods that have worked as part of an integrated global economy can still deliver results under growing "decoupling" pressures from the US remains to be seen. But China's internal means for AI development are now sufficiently robust that analysts of military and strategic global affairs will find it imperative to watch this space, even as it becomes increasingly opaque.

2 Thinking about Defense AI

2.1 Political Context

The PLA's subordination to the Communist Party of China (CPC) needs consideration when evaluating Chinese thinking about defense AI. The CPC exercises ideological control through the commissar system at various levels, and at the apex of the military hierarchy through the chairman of the Central Military Commission (CMC), who typically is General-Secretary of the CPC and China's head of state (currently Xi Jinping). The CMC directly makes senior PLA officer appointments, which show some correlation over time with personal ties to the CMC chairman.[1] This means that the PLA's development and use of AI is at least nominally governed by the CPC's political priorities and theoretical judgments, and in particular by the views of China's top leader.[2]

Under Xi Jinping, official rhetoric and policy has increasingly emphasised emerging technologies like AI. While this reflects the stamping of Xi's political "brand" on policies with long histories, it also signals his conviction of China's need to equip itself for a technologically transformed future: regarding the PLA, this has involved forcing major institutional reforms in command, capability development and training.[3] In his "work reports" to the last two CPC congresses, Xi highlighted the PLA's need to "accelerate development of military intelligentization" and "intelligent combat capabilities," giving top-level endorsement to a focus on defense AI. Xi's association with a "systems engineering" approach aligns with the PLA's orientation towards operational concepts based on a superior "system of systems" for warfighting that is enabled by information technologies including AI, as discussed below.[4]

The CPC's political priorities also shape official assessment of China's strategic environment and defense imperatives, identifying the Western democracies and especially the US as a source of fundamentally hostile forces.[5] This is reflected in China's Defense White Papers (DWPs), the latest 2019 iteration of which singles out the US for enhancing its military capabilities and undermining global stability, specifically in China's neighbourhood.[6] Among various threats to China's national integrity, the 2019 DWP gives prime place to Taiwanese separatism: the CPC's constitution was amended in 2022 to mandate "deterring separatists seeking 'Taiwan independence'."[7]

1 Mattingly, "How the Party Commands the Gun."
2 On the role of the CPC's theoretical process in Chinese policymaking, see: Heath, *China's New Governing Party Paradigm*.
3 Fravel/Wuthnow, "China's military strategy for a 'new era': Some change, more continuity, and tantalizing hints."
4 On Xi and systems engineering philosophy, see: Lee, "An Institutional Analysis of Xi Jinping's Centralisation of Power."
5 See for example: "Document 9: A ChinaFile Translation."
6 Ministry of National Defense, "China's National Defense in the New Era."
7 RFA Staff, "CPC amends its constitution to adopt a more aggressive Chinese policy towards Taiwan."

US intervention is the main obstacle to successful Chinese armed action against Taiwan, just as the regional US military presence is the main obstacle to Beijing's long-term effective assertion against its neighbours of claimed sovereign rights over maritime space along its littoral. Armed conflict with the US is thus necessarily the PLA's main preoccupation, regardless of what speculative judgments are made about China's potential global military ambitions. This drives Chinese efforts to close the defense capability gap with the US symmetrically, and also to search for asymmetrical means of circumventing US military advantage. Either way, exploiting emergent information-centric technologies like AI appears critical.

2.2 Towards "Intelligentized Warfare"

China's successive DWPs show progression from conceiving warfare's 'form' (形态) from being predominantly characterised by "mechanisation" towards "informatization," and since 2014 towards "intelligentization."[8] This reflects the CPC's conception of wider society's development, in which "informatization" – the widespread application of digital information and communications technology (ICT) – is a comprehensive and transformational global trend.[9] It also reflects the PLA's long practice of observing the US military, its uses of technology and its methods as demonstrated in combat operations as the leading edge for "high end" warfighting. The PLA has paid close attention to the US "Third Offset Strategy" for evolving capability, organisation and operations that emerged in the mid-2010s, with a focus on employing new technologies like AI and on China as a specific adversary.[10]

China's 2019 DWP cited the trend of "informatization" as a key feature of the global context for China's defense policy, with new technologies like AI, cloud computing and big data "being applied to the military field at an accelerated pace." However, this document still characterised "intelligentized" warfare as an emergent phenomenon, which the PLA must account for even while it strives to complete mechanisation and integrate mechanised capabilities with ICT (informatization). The 2019 DWP assessed that the gap between the PLA's capabilities and the global military technological frontier remains large, and that the PLA faces the risk of this gap widening and of being "surprised" technologically (技术突袭) by adversaries.[11]

8 Fedasiuk/Melot/Murphy, Harnessed Lightning, p. 305.
9 Lee, "Cyberspace Governance in China."
10 See generally: Gentile et al, A History of the Third Offset, 2014–2018.
11 Ministry of National Defense, "China's National Defense in the New Era."

By late 2020, the official assessment was that the PLA had "made significant progress in informatization" and would "accelerate the integrated development of a mechanized, informatized and intelligent military, with a view to taking the initiative" in global military development.[12] The current (2020) edition of the doctrinally informed *Science of Military Strategy* includes intelligentization as a capability development requirement across the PLA' services, stressing that the international environment now features "rapid development of military intelligentization."[13] As put by the director of the CMC's science and technology (S&T) commission, AI's disruptive nature offers the prospect of "overtaking (more advanced militaries) on the curve."[14]

However, this optimistic judgment about AI's potential is matched with pessimistic assessments of the PLA's state of development with defense AI compared to the US (or even the Russian) military.[15] As one example of this lag in "intelligentized" capabilities despite the PLA's rapid inventory expansion, one 2018 Chinese assessment identified a deficit of AI-enabled tools to process the volume of information provided by the PLA's then-already extensive ISR (intelligence, surveillance and reconnaissance) assets.[16] By one US expert's judgment in 2019, PLA modernization was still at the stage of strengthening the separate services' basic capabilities rather than of developing a sophisticated joint operations capability, let alone effectively integrating AI for "intelligentized" warfare.[17]

This is unsurprising given the general assessment by Chinese commentators, including Xi Jinping himself, that the PLA still lacks the organisational and human capital to conduct system-centric warfare as described below. Developing these factors is understood to require fundamental changes to the PLA's entrenched way of "doing business," and improvement to the abilities of its personnel.[18] This explains the long time horizon declared for PLA modernization, despite the PLA's rapid accumulation of material capabilities and focus on cutting-edge technologies like AI. PLA modernization and reform has been a methodical rather than revolutionary process, with the official goals remaining "full modernization" by 2035 and becoming a "world class military" – by implication, on par with that of the US – by 2050.

12 "Regular press conference of the Ministry of National Defense on 26 November 2020."
13 Wuthnow, "What I Learned From the PLA's Latest Strategy Textbook."
14 "Regular press conference of the Ministry of National Defense on 26 November 2020."
15 Dahm, "Chinese debates on the military utility of artificial intelligence."
16 See e.g., Qiao/Su/An, "Research on Maritime Intelligence Data Analysis Technologies for Massive Data."
17 Fravel/Wuthnow, "China's military strategy for a 'new era': Some change, more continuity, and tantalizing hints."
18 Cozad et al, Gaining Victory in Systems Warfare: China's Perspective on the U.S.-China Military Balance.

The sweeping US export controls targeting China's semiconductor sector that were imposed in October 2022 were officially justified by the need to restrict China's supercomputing and AI capacities, as such systems "are being used (…) to improve the speed and accuracy of (China's) military decision making, planning, and logistics, as well as of its autonomous military systems, such as those used for cognitive electronic warfare, radar, signals intelligence, and jamming", and "to improve calculations in weapons design and testing."[19] This provides further evidence suggesting that the PLA's actual state of AI development remains at the stage of enhancing information processing and optimizing existing systems, rather than implementing a whole-of-organisation systemic transformation in warfighting capacity.

In this context, Chinese thinking about AI's potential for more advanced and radical military uses can be assumed to be still largely theoretical. Describing the "end state" for PLA organisation, capability and doctrine that AI applications will fit into apparently remains a work in progress. As one recent foreign assessment puts it, Chinese literature on this subject seems to reflect a continuing effort to convince the PLA's officer corps to accept the basic requirements of a "systems warfare" approach.[20]

While this doctrinal and organisational evolution is playing out, the PLA is steadily deploying a range of increasingly capable semi-autonomous platforms.[21] In April 2022, a PLA logistics officer said on Chinese state television that "we are gradually developing a whole system of unmanned intelligent equipment."[22] In a context where military systems with varying levels of automation and remote control are being progressively introduced, discussion in China (as elsewhere) about defense AI is grappling with the gap between current capabilities and the implications of full machine autonomy.[23] One 2021 survey of Chinese state media outlets concluded that the PLA has yet to reach an official consensus on AI's fundamental attributes, absent which operational doctrine cannot be developed.[24]

19 Department of Commerce, Bureau of Industry and Security, "Implementation of Additional Export Controls."
20 Cozad et al., Gaining Victory in Systems Warfare: China's Perspective on the U.S.-China Military Balance, p. 88.
21 Lee, China-Russia cooperation in advanced technologies.
22 Liu, "China's military looks for new drones and intelligent vehicles for logistics."
23 See e.g., Fedasiuk, Chinese Perspectives on AI and Future Military Capabilities, p. 7; Kania, AI Weapons in China's Military Innovation. On the complexity of defining and classifying "autonomous" weapons, see: Jenks, "False Rubicons, Moral Panic, & Conceptual Cul-De-Sacs: Critiquing & Reframing the Call to Ban Lethal Autonomous Weapons."
24 Pollpeter/Kerrigan, The PLA and Intelligent Warfare: A Preliminary Analysis.

2.3 "System-versus-System" Operations

Nonetheless, the PLA does seem to have established an orthodox view of current and future warfare as essentially a contest between operational systems, in which more effective employment of ICT will prevail.[25] In its description of "basic operational doctrine," China's 2015 DWP refers to "prevailing in system-versus-system operations".[26] In this context, AI's information processing capacity was identified at least a decade ago by Chinese theorists as useful to achieve the "information dominance" needed to win wars under "informatized" conditions, the official description of the PLA's basic mission.

One aspect of information dominance is enhanced command and control (C2). For this purpose, one recent Chinese publication highlights AI's utility in providing strategic early warning; assisting operational decision-making; integrating operational command (within a unified information environment); and optimising resource allocation and mission management.[27] These capacities overlap with those attributed by Chinese defense media commentary to next-generation (6G) telecommunications, identified as an enabler for AI.[28] This combination of AI with other emerging technologies into an operationally and strategically superior "system of systems" is the key theme in published Chinese descriptions of "intelligentized" warfare.[29]

The advantages of enhanced C2 are often expressed by Chinese writers in terms of the OODA Loop concept, enabling the PLA to get inside the adversary's decision-making cycle and so deploy resources faster and more effectively.[30] In the context of "system-versus-system" operations, this would allow simultaneous rather than sequential attacks on an adversary system's elements, bringing rapid paralysis of the adversary's war making capacity on the model of the 1991 Gulf War. Long-range precision fires, as exhibited by the US military over the past three decades and increasingly accumulated in the PLA's inventories, remain central to this operational conception. But kinetic strikes on disaggregated and thereby vulnerable enemy force elements are just part of the objective to achieve cascading and compounding failure in the enemy's warfighting system.[31]

25 Cozad et al., Gaining Victory in Systems Warfare: China's Perspective on the U.S.-China Military Balance; Engstrom, Systems Confrontation and System Destruction Warfare.
26 Ministry of National Defense, "China's Military Strategy 2015." Although this was not repeated in China's 2019 Defence White Paper, that is likely because the newer document was part of a political rebranding and policy consolidation phase in China's defence policy. See: Fravel/Wuthnow, "China's military strategy for a 'new era': Some change, more continuity, and tantalizing hints."
27 Zhou/Chen, "Applications of AI technology in military command and control against the backdrop of intelligentized warfare."
28 See e.g., Lee/Nouwens/Tay, Strategic Settings for 6G: Pathways for China and the US, p. 5.
29 Kania, "China Artificial Intelligence Talent Training Report: Translation," p. 528.
30 Pollpeter/Kerrigan, The PLA and Intelligent Warfare: A Preliminary Analysis. For an example, see Zhou and Chen, "Applications of AI technology in military command and control against the backdrop of intelligentized warfare."
31 Dahm, "Chinese debates on the military utility of artificial intelligence."

With information acquisition and processing seen as the glue for a superior warfighting "system of systems", AI stands out as a technology enhancing the PLA's potential to realise this in practice. As described by a recent commentary in the PLA Daily, warfare's emergent form is now "information-based with intelligent features," with the mechanism for victory consisting of information-enabled conjoined operations that achieve precise use of firepower and destruction of the enemy system. "Whoever has a strong ability to acquire, process, transmit, utilize and control information, and whoever has a high degree of integration of information and firepower, will win in war. The result of information domination is the precise focus and rapid release of firepower."[32]

2.4 Future Operational and Strategic concepts

AI is thus seen in China as a means of beating the US military at its own game of precision strike warfare, seeking both to match this US capability symmetrically and to overthrow it by inducing systemic failure. Claims made by Chinese commentators for the potential of "intelligentized warfare" reflect those once made by US advocates of the Revolution in Military Affairs: for example, that small-scale precision operations will achieve effects that previously required large-scale war making.[33] This core conception of AI's utility in evolving "informatized" warfare – as true for many aspects of Chinese military practice – essentially follows, or at least responds to, the path set by the US as global military leader. As noted below, it was the US quest for first-mover advantage in military applications of next-generation technologies like AI that focused attention in China on accelerated progression towards "intelligentized warfare", an evolving external condition that the PLA must be able to meet on equal or advantageous terms if it is to credibly perform its missions.

That said, Chinese conceptions of "intelligentized warfare" are not limited to building a superior system for warfighting under "informatized" conditions: they envision new concepts of operations in response to a transformed battlespace. As one 2019 commentary put it, "The elements of warfare are changing from "information-led" to "machine-led", with machine-led warfare reshaping the operational process".[34] Substitution of unmanned platforms for humans expands the scope for military operations to new physical domains (the deep sea and outer space), while the pervasiveness of digital networks means that future war will extensively involve cyberspace. The need to develop network-based "all-domain operational capabilities" was emphasised in Xi's 2017 work report.

32 Li/Huo, "Change in operational guidance, from the viewpoint of a changing mechanism of obtaining victory."
33 Ibid.
34 Li, "Where are the changes in the mechanism for obtaining victory in intelligentized warfare?"

In recent years, the term "multi-domain precision warfare" (多域精确战, MDPW) has emerged in Chinese discourse.[35] This term was highlighted by the US Department of Defense (DoD) in its 2022 annual report on China's military power, which described MDPW as a "new core operational concept" that aims to target vulnerabilities in the US military's operational system through the PLA's own "network information system-of-systems."[36] One US expert – analogizing MDPW to the US concept (JADC2) for an AI-enabled unified cross-domain joint information system – speculates that MDPW's essence is using AI-driven information processing and decision-making support to enable effective command of joint operations at the tactical level, while noting that the PLA's structural reform process has not progressed enough to enable this.[37]

Chinese writers also take interest in AI's possibilities for exploiting the "cognitive domain" of warfare, manipulating human cognition to influence the adversary's perceptions, situational awareness and will to fight. This could be achieved by real-time analysis of adversary behaviour, data degradation and manipulation, influence over public opinion, and direct control of adversary systems.[38] Some published Chinese work on this theme shows progression from theory to specific application and assessment.[39] This aspect of Chinese thinking about AI was also highlighted in the US DoD's 2022 report, which describes the PLA as developing AI-powered "cognitive domain operations" as psychological warfare's next evolution, useful for deterrence and achieving effects against the adversary before armed conflict begins ("phase zero" operations, in US terminology).

Such a conception aligns with (debatable) characterizations of traditional Chinese strategic thinking as emphasising the creation of second-order effects by shaping underlying conditions, rather than of first-order effects through direct action: so-called "winning without fighting."[40] This would be the phase zero-equivalent of successful "system-versus-system" operations in the warfighting phase, which would paralyse the adversary force and so obviate the need for its complete destruction.[41] It also aligns with internal PLA guidance endorsed by the CMC, which has been incorporated into China's professional military education, to practice "public opinion warfare, psychological warfare and legal warfare" (the so-called "Three Warfares") as integral elements of PLA operations, "giving full play to the military operational function of political work".[42]

35 See e.g., Wang/Deng, "Dialectical understanding of single and multiple domains in joint operations."
36 2022 Report on Military and Security Developments Involving the People's Republic of China, p. 33.
37 Wuthnow, Twitter post 30 November 2022.
38 Pollpeter/Kerrigan, The PLA and Intelligent Warfare: A Preliminary Analysis; Takagi, "New Tech, New Concepts: China's Plans for AI and Cognitive Warfare."
39 See e.g., Chen, "Cyber and Influence Operations," p. 199.
40 See e.g., Jullien, A Treatise on Efficacy: Between Western and Chinese Thinking; Yuen, Deciphering Sun Tzu: How to read the "Art of War."
41 Dahm, "Chinese debates on the military utility of artificial intelligence."
42 Chang/Ou /Wang, "An exploration of the teaching curriculum for 'Introduction to Public Opinion Warfare, Psychological Warfare and Legal Warfare'."

2.5 Strategic Stability, Human Control, Ethics and Standards

Among the main themes in Chinese writings on "intelligentized" warfare is hybrid human-machine teaming, with machine intelligence seen as augmenting rather than replacing human control.[43] This is consistent with Beijing's diplomatic position on autonomy in military systems. China's position paper on regulating military applications of AI submitted to the UN Convention on Certain Conventional Weapons in 2021 states that "weapon systems must be under human control," requiring "necessary human-machine interaction across the entire life cycle of weapons."[44] It also called on nations to "refrain from seeking absolute military advantage, and prevent the deepening of strategic miscalculation." At a February 2023 international conference on responsible development and use of AI for military purposes, China's representative spoke of the need to "oppose seeking absolute military advantage and hegemony through AI" and signed the non-binding outcomes statement.[45]

This concern with strategic stability stems from Chinese self-assessments of disadvantage vis-à-vis the US not just in AI and in cyberspace capabilities generally, but in the overall balance of conventional military power.[46] Chinese focus on "intelligentized" warfare from the mid-2010s – despite the PLA then still being in the "mechanization" phase of modernization, and preparing for major structural reforms – seems to be a response to US adoption of the "Third Offset Strategy" in late 2014.[47] US officials describe the PLA's new MDPW concept as a response to the US JADC2 initiative.[48] However, PLA authors also recognise that the Third Offset – for which AI provides the "technological sauce," as one senior official put it[49] – itself responds to the PLA's development of means to target the US military's vulnerabilities, through so-called "anti-access and area denial" (A2AD) capabilities.

Specific concerns raised by Chinese authors about how US advances in AI could undermine Chinese deterrence include the potential for new US capabilities to overwhelm PLA air defense, successfully attack Chinese C2 systems (through automated vulnerability detection and exploitation) and reduce available response

43 Pollpeter/Kerrigan, The PLA and Intelligent Warfare: A Preliminary Analysis, p. 12 (fn 28).
44 Permanent Mission of the People's Republic of China to the United Nations, "Position Paper of the People's Republic of China on Regulating Military Applications of Artificial Intelligence (AI)."
45 Sterling, "U.S., China, other nations urge 'responsible' use of military AI."
46 Fedasiuk, Chinese Perspectives on AI and Future Military Capabilities; Austin, "Managing Asymmetries in Chinese and American Cyber Power."
47 Kania, "Artificial intelligence in China's revolution in military affairs," pp. 521–523; Yatsuzuka, PLA's Intelligentized Warfare: The Politics on China's Military Strategy.
48 Demarest, "China developing own version of JADC2 to counter US."
49 "Remarks by Deputy Secretary Work on Third Offset Strategy."

time.[50] Such concerns sit within a larger international debate about the escalatory potential of military AI, especially given the "black box" nature of current machine learning techniques and AI's potential to exhibit emergent behaviours.[51] Conversely, the PLA's doctrinal emphasis on "active defense" may encourage it to pursue its own "offset" of disadvantageous asymmetries vis-a-vis the US by leveraging AI for an effective first strike.

Notwithstanding professed Chinese concerns about strategic stability, the PLA has reportedly refused to admit mutual risk reduction around military uses of AI as an agenda item for official talks with the US DoD.[52] China is also the world's leading exporter of combat drones – notably to the Middle East, but even to countries in its own neighbourhood[53] – which does not suggest an excessive concern about destabilising effects outside the context of the US-China military balance, at least concerning semi-autonomous technologies.[54] The US, however, remains the leading exporter of surveillance drones.

Human control and data security appear as the salient concerns in Chinese discussion of ethics and safeguards for AI.[55] While some defense commentaries discuss a necessary progression with increasing automation from "human in the loop" to "data in the loop," such a trend can be expected to remain confined to lower levels of decision-making and command authority, especially in view of the general principle of CPC leadership in all matters.[56] Xi Jinping personally emphasised the need for AI to be "safe, reliable and controllable" in a 2018 Politburo study session.[57] The 2022 AI white paper published by CAICT, a leading state-affiliated ICT research institute, identifies "trustworthy security" as one of the definitive dimensions for AI's future development.[58] Continuing Chinese development of 6G telecoms networks aims to build in "endogenous cybersecurity," giving attention to vulnerabilities that AI algorithms may imply for the network as a whole.[59]

50 Fedasiuk, Chinese Perspectives on AI and Future Military Capabilities, pp. 2–3.
51 See e.g., Altmann/Sauer, "Autonomous Weapon Systems and Strategic Stability."
52 Allen, "One Key Challenge for Diplomacy on AI: China's Military Does Not Want to Talk."
53 Parameswaran, "What's behind Indonesia's China Drone Buy?"
54 Horowitz/Schwartz/Fuhrmann, "China Has Made Drone Warfare Global."
55 Toner, "AI Safeguards: Views inside and outside China."
56 See e.g., Li and Zhao, "Building a future superior operational chain."
57 "Xi Jinping: promote the healthy development of new generation artificial intelligence in China."
58 China Academy of Information and Communication Technology (CAICT), Artificial Intelligence White Paper 2022.
59 Lee/Zhang/Creemers, China's Standardisation System: trends, implications and case studies in emerging technologies, p. 22.

China is developing a comprehensive system of technical standards for AI, within which ethics and security standards have overriding regulatory effect.[60] In some areas, Chinese development of ethical standards for AI is ahead of the outside world.[61] In others however, China's use of AI has pushed boundaries in ways that likely violate international human rights law, with use of facial recognition technology to monitor and discriminate among citizens on the basis of ethnicity being a well-known example. It is also unclear how China's civilian AI governance frameworks will apply to the PLA, which is known to sit outside China's general data regulatory regime.[62]

The PLA's subordination to CPC control and ideological orthodoxy may also introduce idiosyncrasies to its development and use of defense AI, compared to the situation in foreign military forces.[63] For example, given the nominally central role of political commissars and CPC committees in PLA decision-making, one conceivable application of AI is limited automation of operational decisions to ensure conformity with CPC directives concerning legitimate target selection, or other choices with a salient political aspect.[64]

60 Ibid, p. 25.
61 Ibid, pp. 27–28.
62 Lee, "Cyberspace Governance in China," p. 21.
63 Kania, "Cyberspace Governance in China," p. 539.
64 See e.g., Zhu, "Adhere to the Party Committee's unified leadership on joint warfare."

3 Developing Defense AI

3.1 "Military-Civil Fusion" and the Leading Role of China's Civilian Sector

Like most computer processor-based technologies, AI development is led by the civilian sector, in China as elsewhere: one 2021 survey of China's national academic database (CNKI) found just one PLA institution among the top 20 publishers of AI-related articles.[65] China's "military-civil fusion" (MCF) policy has thus become a prominent concern, for US policymakers, cited to justify zero-risk approaches to Chinese companies outside the state-owned or defence sectors: many of the individual Chinese AI-related firms targeted by US export controls are oriented to civilian markets. Xi's leadership has seen private firms subjected to an expanded presence and influence of CPC committees, legislation and regulation requiring cooperation with authorities in national security situations, and a political climate incentivising demonstrations of loyalty to the state's policy goals.

As with many policies, MCF under Xi Jinping has involved increased top-down control and ambition, driven by a greater priority on security objectives. The aim is to push China's long-isolated and fragmented defense industry sector towards a level of interaction with the civilian economy closer to that prevailing in developed nations: by one expert's judgment, the long-term goal is to achieve 70–80 percent of the United States' "MCF" level.[66] Focused on opening China's defence industry and PLA procurement systems to civilian participation, MCF aims to promote synergistic relations between these two worlds, rather than simply subjecting the latter to PLA control. The essential idea is "synthesis of military and civilian elements to generate new hybrid outcomes."[67]

MCF is complemented by the state's movement away from a siloed, command-style approach to strategic technology development towards one that is cross-sectoral and open to market actors, officially endorsed in 2019 as a "new whole-of-nation system" (新型举国体制) for developing "key core technologies."[68] Seeking to combine China's Maoist legacy of top-down mobilization with market-conforming techniques and market-sourced funding, this approach shapes the bureaucratic environment within which directives such as the 2017 New Generation AI Development Plan (2017 Plan) operate.

Among the 2017 Plan's "basic principles" is "two-way conversion for military and civilian scientific and technological achievements, and… sharing of military

65 Fedasiuk/Weinstein, "AI in the Chinese Military," p. 181.
66 Cheung, *Innovate to Dominate: The Rise of the Chinese Techno-Security State*, p. 86.
67 Ibid, pp. 85.
68 Ibid, pp. 237–238.

and civilian resources." The 2017 Plan contains a section on MCF that calls for institutionalising coordination among research institutes, universities, enterprises and military industry units. This addresses not just Chinese defense industry's traditional operation as a walled garden, but also the relative deficiency of China's civilian economy in connecting research within universities and research institutes with real-world applications.[69] The MCF section also refers to "guid(ing) defense domain AI technology toward civilian applications," doubtless in recognition of how civilian industry has benefited from defense-oriented technological research and development (R&D) in the US.[70]

In the typical manner of Chinese industrial policy, the 2017 Plan's top-level guidance was followed by a "three-year action plan" concerned with more detailed implementation, issued and supervised by China's Ministry of Industry and Information Technology (MIIT).[71] While this document does not reference military applications, it directs a focus on developing "core foundational" technologies that include neural network chips and intelligent sensors, corresponding to the conceptual defense AI applications and fielded PLA capabilities discussed elsewhere in this report. MIIT has a close working relationship with the "Seven Sons of National Defense" universities that play a major role in China's military technological research (discussed further below).

One typology of Chinese companies involved in AI development describes five categories, with firms linked to the PLA and security services constituting one: the others are diversified digital giants (for instance, Alibaba and Huawei), large private firms focused on AI technologies, smaller private firms involved in AI inputs and applications, and state-owned enterprises (SOEs) that provide funding, backbone infrastructure and leadership in implementing AI applications.[72] Partnerships within and across these categories create synergies from different specialisations: for example, Alibaba's joint venture with defense conglomerate Norinco, the lead developer for China's satellite-based navigation system (Beidou), to provide positioning information and data mining services.[73]

Under the 2017 Plan, the state has designated individual private sector firms to lead development of AI subfields in an "open national innovation platform" model: as of mid-2019, this involved 15 firms focusing on different subfields that range from autonomous driving to cybersecurity and video sensing.[74] This approach aims for more efficient delivery of state support by avoiding duplications

69 See e.g., Zhou/Lazonick/Sun, China as an Innovation Nation.
70 Webster/Creemers/Triolo/Kania, "Full Translation: China's 'New Generation Artificial Intelligence Development Plan."
71 Ministry of Industry and Information Technology (MIIT), "Three Year Action Plan to Promote Development of the New Generation Artificial Intelligence Industry."
72 Sutter/Arnold, "China's AI Companies: Hybrid Players," pp. 20–21.
73 Gao, "Alibaba forms Norinco alliance."
74 Sutter/Arnold, "China's AI Companies: Hybrid Players," pp. 24–25.

of effort, following market signals as to which firms have already achieved economies of scale and technological leadership in their respective sectors. The "open" aspect should, in theory, promote information sharing and other non-monopolistic behaviour by these dominant firms, and so development of a wider Chinese ecosystem in the targeted AI applications.

AI development is driven by the standard suite of contemporary Chinese industrial policy: interagency national steering bodies, directive and supportive policies issued at various levels of government, "government guidance" investment funds, state-created industry alliances, state-selected pilot projects to trial new applications, dedicated industrial parks and pilot zones, work in state-linked research institutes and universities, and industry participation in national technical standardisation committees.[75] This approach has been described as "grand steerage:"[76] the state steers direction, while letting market forces operate to increase efficiencies and available resources.

In doing so, it welcomes foreign expertise and capital: for instance, China's prominent AI chip design startups have received significant investments from abroad.[77] Conversely, the amount of Chinese investment in foreign AI technology providers has become a prominent concern for foreign governments and politicians, spurring a recent expansion of US foreign investment controls. From 2015 to 2019, Chinese investors were involved in an estimated US$7 billion of disclosed investments in non-Chinese AI companies, covering venture capital, private equity and mergers and acquisitions.[78]

AI tops the list of seven technologies prioritised for development in China's current (14th) Five Year Plan, and frequent statements by Xi Jinping of its importance signal to state and market actors alike the long-term value of investing in it.[79] The rapid development of China's larger digital economy and S&T innovation system means that AI-oriented firms benefit from a surrounding ecosystem of interrelated technologies. Beijing for instance, where China's National Engineering Laboratory of Deep Learning Technology is located, has been ranked by the journal *Nature* as the world's leading science city for several years.[80] Stimulating development of strategic emerging technologies through state-organised industrial clusters has been national policy since 2019.

---

75 On this last element, see e.g., Lee, The Connection of Everything: China and the Internet of Things, p. 9.
76 Naughton, "Grand Steerage as the New Paradigm for State-Economy Relations."
77 Lee/Kleinhans, Mapping China's semiconductor ecosystem in global context: Strategic dimensions and conclusions.
78 Sutter/Arnold, "China's AI Companies: Hybrid Players," , p. 29.
79 The six other broad technology categories are quantum information sciences, integrated circuits, cloud computing, big data, internet of things, blockchain, and virtual and augmented reality. See e.g., Gruenberg/Wessling, The CCP's Next Century: Expanding economic control, digital governance and national security, p. 46.
80 "Leading science cities by the numbers."

Collaboration between different types of actors across the development cycle for emerging technologies like AI is promoted by a system of State Key Laboratories, a growing number of which are run by private companies, and National Defense Key Laboratories.[81] PLA academic institutions engaged in AI research notably include the National Defense University's Academy of Intelligent Sciences, which is conducting research into intelligent robotics, bionic robotics and swarm intelligence, and the Academy of Military Sciences, which hosts an AI Research Center that concentrates on deep learning and human-machine integration.[82] The Chinese Academy of Sciences (CAS) is involved in AI research with military applications: its Institute of Computing Technology was added to the US Entity List for targeted export controls in December 2022. CAS' Institute of Automation developed the Miaosuan wargaming platform and the AlphaWar AI gaming agent discussed in section 7 below.

China's giant state-owned conglomerates are also involved in developing military-oriented AI applications. CETC for instance appears to be a leader in swarm intelligence.[83] A research institute established by CSIC, one of China's two state-owned shipbuilding conglomerates, recently claimed to have used AI to complete within one day design work for a warship's electrical layout that with human designers had required 300 times this time investment, with 100 percent accuracy.[84]

Much R&D is carried out at civilian universities and research institutes, some of which are working on AI-related projects with direct military applications.[85] For example, Harbin Engineering University (HEU) developed the HSU001 autonomous submersible that was exhibited in China's 2019 National Day military parade, while another autonomous submersible (Sea-Whale 2000) deployed the same year for the declared purpose of deep-sea surveying in the South China Sea was developed by the Chinese Academy of Sciences.[86] Northwest Polytechnic University (NPU) hosts one of China's leading R&D centres (the No.365 Institute) for military-use unmanned aerial vehicles (UAVs).[87] Judging from published research and patents, multiple civilian universities appear to be working on UAV swarming technology, as are China's state-owned defense conglomerates.[88]

81 Weinstein/Stoff, "China's quest for AI talent," p. 102.
82 Kania. "Artificial intelligence in China's revolution in military affairs," pp. 527–528.
83 Kania, "Swarms at War: Chinese Advances in Swarm Intelligence."
84 Chen, "In China, AI warship designer did nearly a year's work in a day."
85 Fedasiuk/Weinstein, "AI in the Chinese Military," pp. 181–182.
86 Panda, "A New Chinese Autonomous Underwater Vehicle?"
87 Kania, "The PLA's Unmanned Aerial Systems: New Capabilities for a "New Era" of Chinese Military Power," p. 12.
88 Kania, "Swarms at War: Chinese Advances in Swarm Intelligence."

Most published Chinese academic research on AI-enabled cyberspace operations is produced by a small number of elite research universities, particularly the so-called "Seven Sons of National Defense" (including HEU and NPU).[89] This is an alliance of seven S&T and engineering-oriented universities that work closely with MIIT and are openly engaged in military research, including programs for AI and intelligent weapons development.[90]

China has also adopted an open "innovation challenge" model from US practice, with state authorities sponsoring contests to demonstrate AI-related technologies. For instance, the 2022 "Xingzhi Cup" National AI Innovation and Application Competition – organized by two national ministries, one municipal government and two national research institutes – ran competitions on themes of technology innovation, industry empowerment and development of the AI industrial ecosystem.[91] While the official notice made no reference to military applications, its mention of "multi-modal technologies," "network communication" and other potentially dual-use fields means that the activity could well benefit the PLA, if not through direct technology transfers than by identifying promising civilian firms and research teams or implementation techniques. Wargaming-type competitions are discussed in section 7 below.

One vulnerability of China's AI development is its reliance on foreign-developed software and machine learning software frameworks, almost exclusively provided by US companies.[92] Such "open-source open platforms," including development frameworks, algorithm libraries and toolsets, are among the "core foundational" technologies prioritised by MIIT's 2017 AI action plan.[93] Open-source approaches generally are now much promoted in China's ICT sectors as a means of mitigating upstream dominance of US firms and the supply chain chokepoints this provides the US government: much of China's recent AI processor development has utilised the open-source RISC-V architecture, which is less exposed to US export controls than proprietary architectures like ARM and X-86.

89 Chen, "Cyber and influence operations," p. 196.
90 Kania, "Artificial intelligence in China's revolution in military affairs," p. 537.
91 Ministry of Industry and Information Technology (MIIT), "Notice of Two Ministries on the 2022 inaugural 'Xingzhi Cup' National Artificial Intelligence Innovation and Application Competition."
92 Allen, Understanding China's AI Strategy, p. 12.
93 Ministry of Industry and Information Technology (MIIT), "Three Year Action Plan to Promote Development of the New Generation Artificial Intelligence Industry."

3.2 Effects of US Export Controls Targeting Chinese AI Development

Semiconductors (specifically, logic and memory chips) are a basic enabler for AI. The dominance of US firms and intellectual property in upstream segments of this complex supply chain, and China's own limited capacities in it, allow the US government to target Chinese AI development by restricting Chinese access to semiconductor technologies.[94] This was done with extensive export controls introduced in October 2022, justified in national security terms as necessary to restrict China's capacity to develop AI-powered military and espionage capabilities.

These US controls threaten the "fast follower" strategy that China has pursued to date to develop its semiconductor industry, aided by this technology's well-defined roadmaps for future development. Departures from these roadmaps – whether forced by such US decoupling measures, or by technologically endogenous factors such as the pending end of Moore's law[95] – might slow Chinese progress, but as a disruptive phenomenon they might also create opportunities for China to close the gap with foreign industry leaders. For the time being, however, many of the technologies concerned are complex to a degree that means China (despite massive import substitution efforts) will likely remain dependent for years to come on foreign suppliers, both US and non-US companies, which typically will not risk violating US law to continue selling to Chinese customers.

The new US controls are framed in ways that restrict Chinese access to the most advanced generations of logic processors and memory chips, and to the technologies required to manufacture them. However, the controls' success will depend on enforcement efforts and adaptability in response to evasion measures. Within a few weeks of their promulgation for example, the leading US vendor (Nvidia) for graphics processing units had reduced the published interconnect speed for its leading product line, allowing continued sales of these chips to Chinese customers in technical compliance with the new controls.[96]

Russia's ability to maintain a large suite of military equipment enabled by export-controlled, foreign manufactured semiconductors obtained through clandestine channels raises questions about the feasibility of policing the smuggling of advanced semiconductors into China, at least in the relatively small numbers that are likely to be required for military uses. One Chinese entity entered onto the US

94 Lee/Kleinhans, Mapping China's semiconductor ecosystem in global context: Strategic dimensions and conclusions.
95 Courtland, "Transistors Will Stop Shrinking in 2021, Moore's Law Roadmap Predicts."
96 Liao, "Nvidia touts a slower chip for China to avoid US ban."

Entity List (which imposes additional targeted export controls) in 1997 was in 2022 still obtaining chips made by vendors like Nvidia, to enable modelling of nuclear explosions.[97] The willingness of US-allied governments whose domestic firms are also critical suppliers of semiconductor-related technologies to simply copy the new US controls, let alone additional China-specific controls introduced by the US in future, is also a factor that remains to be worked out.

3.3 Human Capital

Both Chinese and foreign assessments of China's AI talent pool emphasise problems regarding both quantity and quality. One 2020 Chinese government estimate projected that domestic production of skilled AI workers in 2022 would fall 480,000 persons short of the economy's demand.[98] The deficit is especially acute for the highest grade of AI researchers: one assessment of three studies published over 2017–2018 suggests that China is second after the US in number of "AI practitioners" but far behind the US and several other countries in number of "AI experts," defined as the most innovative personnel who generate the most patents and publications.[99] One Chinese study published in January 2022 assessed that this situation had not fundamentally changed despite improvement in China's relative position, "especially (for) top basic research talents and application scenario top talents who can integrate AI technology development with the industrial system."[100]

However, Chinese contributions to AI research publications have been rising steadily, as has their quality judging from metrics such as citation rates and acceptance rates for papers presented to leading international conferences. One survey of global AI publications over 2010–20 found that if including CNKI – which accounts for an estimated two-thirds of Chinese AI papers – China accounted for half of AI publications globally.[101] For several AI subfields, China-based authors have surpassed the US-based author share of the top one percent of cited publications.[102] This trend is also observable in AI-supporting technologies: for example, Chinese institutions account for most of the accepted submissions to the 2023 iteration of a prestigious academic conference for semiconductors.[103]

97 Lin/Strumpf, "China's Top Nuclear-Weapons Lab Used American Computer Chips Decades After Ban."
98 Weinstein/Stoff, "China's quest for AI talent," p. 62.
99 Ding, "China's Current Capabilities, Policies and Industrial Ecosystem in AI."
100 "China Artificial Intelligence Talent Training Report: Translation," p. 21.
101 Chou, Counting AI Research: Exploring AI Research Output in English- and Chinese-Language Sources, pp. 5–6.
102 Zwetsloot et al., China is Fast Outpacing U.S. STEM PhD Growth, p. 6.
103 Herh, "China Distinguishing Itself at ISSCC 2023."

China's production of PhD graduates in STEM (science, technology, engineering, and mathematics) disciplines is far outstripping that of the US, with much of this growth coming from high quality universities.[104] Many of these leading Chinese institutions now provide world-class AI programs, with the highest-ranked universities now accounting for almost half of China's STEM PhD graduations.[105] However when it comes to AI-oriented doctorates, one 2019 estimate still had China's production trailing that of the US by a large margin (11% vs 44% of the global total).[106]

Education and talent cultivation for AI are central concerns of the 2017 Plan, including vocational training. In 2017 China revised its high school curriculum requirements to include AI, and in 2018 an AI talent cultivation plan was promulgated for higher education institutions, including measures such as building innovation bases to promote collaboration between universities, research institutes and enterprises.[107] However, China has had difficulty attracting foreign AI workers, a major handicap in a global talent market (by contrast, a large share of AI practitioners in the US are originally from China). By one 2019 estimate, over 90% of China's AI talent is domestically sourced.[108]

Chinese returnees who completed advanced degrees and gained industry experience in the US have made an outsized contribution to Chinese industry's development in the AI sector, as has been typical for ICT fields.[109] China has encouraged such contributions through its talent repatriation programs, with many such individuals maintaining a professional and personal presence in both the US and China. But bilateral political tensions have increasingly impacted such cross-border activity, and these are now translating into legal barriers. The restrictions on "US persons" participating in China's semiconductor sector that are included in the US export controls discussed above have already had negative impacts on Chinese industry in this key enabling technology for AI, and the Biden administration has indicated that similar restrictions will likely be extended to other strategic technology sectors, with AI being a prime candidate.

The PLA has struggled to compete with China's civilian economy for talent in general, which is another reason for the priority on MCF. Its human capital deficit appears to be particularly significant for AI development. To address these issues, by early 2019 the PLA had reportedly established talent recruitment stations at over 2500 colleges and universities nationwide, and internal reforms have aimed to

104 Zwetsloot et al, China is Fast Outpacing U.S. STEM PhD Growth.
105 Ibid, p. 1.
106 "China Artificial Intelligence Talent Training Report: Translation," pp. 22–23.
107 Weinstein/Stoff, "China's quest for AI talent," pp. 59–60.
108 "China Artificial Intelligence Talent Training Report: Translation," pp. 22–23.
109 See e.g., Lee, "The new Chinese diaspora."

raise benefits for PLA "civilian personnel" to levels comparable with those enjoyed by civil servants.[110] However, PLA-affiliated academic institutions are engaged in AI-related research and have recently increased their open-source publication in this area.[111]

3.4 Transnational Collaborations

AI has developed as a transnational collaborative field, and foreign partnerships remain important to Chinese AI development. One survey has found that in 2020, 22 percent of AI publications globally with Chinese-affiliated authors were international collaborations, with the US being the most significant partner country followed by the UK, Australia and Canada, a pattern that has remained nearly unchanged since 2015.[112] However, China's national Chinese language database CNKI is heavily represented in publications on emerging AI applications of military interest such as navigation and remote sensing, potentially implying that Chinese authors engage less in foreign collaborations in these areas.[113]

Chinese progress has benefited from much AI-related publication globally being open source and thus accessible across borders, although political pressures abroad (especially in the US) may result in open AI research being increasingly subject to national controls. The deterrent effect of political concerns about China is also increasingly discouraging collaboration with Chinese AI researchers. One study published in late 2022 found that US and Chinese AI researchers increasingly avoid mutual citation and segregate physically themselves at international conferences.[114]

The US digital technology sector been a particularly attractive target for Chinese investors, with one 2021 study finding that the Chinese stake in top US AI-oriented start-ups was double that of other foreign investors combined.[115] Conversely, Chinese markets and skilled labour for AI development have proved attractive for leading US corporate AI technology providers. A 2020 study found that China hosted 10 percent of US multinationals' (MNCs) foreign AI labs, paired with Israel in second place after Europe.[116] However, as has historically been typical of foreign MNC operations in China, much of this activity seems directed at local market optimization rather than core R&D. It is also now constrained by the "US persons"

110 Kania, "China Artificial Intelligence Talent Training Report: Translation," p. 536.
111 Murdick et al., The Public AI Research Portfolio of China's Security Forces: A High Level Analysis, p. 5.
112 Chou, Counting AI Research: Exploring AI Research Output in English- and Chinese-Language Sources, p. 10.
113 Ibid, p. 12.
114 Zhang, "China-US divide extends to AI, both in research and real life, study finds."
115 Chang/Hannas, "Foreign support, alliances, and technology transfer," pp. 42–43.
116 Heston/Zwetsloot, Mapping U.S. Multinationals' Global AI R&D Activity.

provisions in the October 2022 semiconductor-related US export controls. As of February 2023, media reports indicated that the Biden administration was preparing to introduce controls on outbound investment into China's semiconductor sector.

The potential for generic AI research collaborations with Chinese partners to feed into Chinese defense AI is opaque and represents a significant security concern for foreign governments. For instance, NPU (mentioned above) conducted a long-term collaboration with Technische Universität Berlin in applying brain–computer interfaces to drone swarming and flight control.[117] Various Chinese universities, especially the "Seven Sons," are alleged to act as fronts for technology transfer to assist military technological development.

Regarding direct foreign collaborations on military uses of AI, China's strategic relationship with Russia makes that country China's most significant potential partner. While there is little public evidence of direct China-Russia collaboration on defense AI, the number of other bilateral defense projects – which include publicly acknowledged Russian assistance to China in developing a missile attack early warning system, and integration of the two countries' satellite-based navigation systems – and Russian advances in defense AI, combined with Russia's increased dependence on China due to loss of economic and technological access to all the world's advanced economies following its 2022 invasion of Ukraine, means that such exchanges cannot be ruled out.[118] This would accelerate a trend towards increased AI research collaboration between the two countries that has been apparent since 2016, although over the decade to 2019 China-Russia collaborative AI publication output and mutual AI investments were dwarfed by the equivalent China-US numbers.[119]

China may also potentially pursue cooperation in defense AI with Iran, a country that appears to be expanding strategic cooperation with Russia. With progressive removal of UN sanctions on Iran since 2015 and US abandonment of attempts to have these reinstituted, there are currently limited disincentives to Chinese entities conducting exchanges with Iranian partners. But it is unclear whether there are any benefits from Beijing's viewpoint to cooperating in this field with Tehran that outweigh the risks, notably to China's relations with Israel and the Gulf Arab states.

117 Arcesati, Foreign collaboration continues in China's drive for technology self-reliance.
118 See generally Lee, China-Russia cooperation in advanced technologies.
119 Konaev et al., Headline or Trendline? Evaluating Chinese-Russian Collaboration in AI, pp. 2–3.

4 Organizing Defense AI

The PLA's structural reform of the mid-2010s included creating a "Strategic Support Force" (SSF), charged with integrating various "strategic" functions previously scattered across the PLA and given a "mandate to innovate."[120] Established directly under the CMC rather than affiliated with other PLA command elements, the SSF consolidates outer space, intelligence, electromagnetic and cyber warfare capabilities, all fields in which information processing and data analysis is at a premium and which would therefore benefit from AI. Foreign experts speculate that while the SSF is unlikely to be closely involved in developing the PLA's AI systems, it will have a major role in interfacing with those systems in their employment, for example by providing operational decision-making support.[121]

However, the SSF's precise relationship with PLA command elements – notably the Joint Staff Department and the Theater Commands, which under the PLA's reformed structure are responsible for conduct of joint operations – remains opaque and is probably still being worked out. It does appear that the SSF is responsible for supporting both theater-level operations and strategic level information operations.[122] "Strategic" capabilities such as China's nuclear forces are under the CMC's direct control, and the same may apply to AI-powered tools considered "strategic" in nature. Chinese media in 2016 reported the CMC's establishment of an Intelligent Unmanned Systems and Systems of Systems S&T Domain Expert Group, which is probably charged with setting strategic objectives and requirements, and exploring productive links with civilian industry: members of the group reportedly visited a testing zone for self-driving cars to explore potential for military uses.[123]

China does not yet seem to have an equivalent to the US DoD's Chief Digital and Artificial Intelligence Office (CDAO), responsible for clearing large project proposals and providing a whole-of-Defence support hub of AI expertise. However, in addition to being CMC Chairman, Xi Jinping also nominally heads other national steering bodies whose decisions may bear on development of defense AI, notably the Central Commission for Cybersecurity and Informatization (CCCI). Based on its composition when established in 2014, the CCCI's membership includes *inter alia* the head of MIIT, the chief of the PLA's Joint Staff Department, and one of the two CMC Vice-Chairmen (Xi's uniformed deputies in exercising top-level command of the PLA).[124] Xi's increasing emphasis on the top-down, CPC-led command aspect of China's "new whole-of-nation system" for developing core technologies, and establishment in March 2023 of a "Central Commission for Science and Technology" to oversee S&T policy, suggests that further centralization of direction over AI progress should be expected.

120 Nelson/Epstein, "The PLA's Strategic Support Force and AI Innovation."
121 Ibid.
122 Chen/McReynolds/Green, 'The PLA Strategic Support Force: A "Joint" Force for Information Operations', pp. 152, 163–164.
123 Kania, "Swarms at War: Chinese Advances in Swarm Intelligence."
124 Lee, "Cyberspace Governance in China" pp. 15, 21.

The current CMC Vice-Chairmen are respectively an Air Force general responsible for operations and training, and the former head of the CMC's equipment development department. Both can thus be assumed to be relatively familiar with the state of China's defense AI development, and its optimal applications to the PLA's aspirations for joint operations and "intelligentized" warfare.

The PLA's reform process includes efforts to integrate doctrinal development with technical realities of emerging technologies like AI, although equipment procurement (as in the US military) has remained a service responsibility. In 2017 the Academy of Military Sciences, which is the PLA's top institution for doctrinal theorising and reports directly to the CMC, integrated six technical research institutes that were previously subordinate to the pre-reform PLA general departments, including the Systems Engineering Institute and the National Defense S&T Innovation Institute.[125]

The known supplier profile for Chinese defense AI-related procurement reinforces the picture of the civilian economy's leading role. One study of defense AI-related contracts in 2020 identified 273 unique (sole source) vendors who are the most common suppliers of AI-related equipment, typically private firms that focus on intelligent software or sensing technologies. Of the contracts surveyed, 61 percent were awarded to private enterprises, skewed towards recently founded companies (two-thirds founded since 2010, and over one-third since 2015).[126]

China's defense SOEs are both buyers and sellers of AI-related equipment, suggesting that they may be specializing in certain AI subfields and so may avoid "crowding out" private sector investment.[127] This corresponds to the apparent role of these state-owned conglomerates in related ICT "high technologies" such as semiconductors.[128] One such conglomerate (China Aerospace Science and Technology Corporation, CASC, with subsidiaries) appeared by a large margin to dominate AI-related public procurement in 2020 by number of contracts, with the SSF second on the list.[129]

125 Wuthnow, "China's "New" Academy of Military Science: A Revolution in Theoretical Affairs?"
126 Fedasiuk/Melot/Murphy, Harnessed Lightening: How the Chinese Military is Adopting Artificial Intelligence, pp. 31–32.
127 Ibid, p. 29.
128 Lee/Kleinhans, Mapping China's semiconductor ecosystem in global context: Strategic dimensions and conclusions, p.8.
129 Fedasiuk/Melot/Murphy, Harnessed Lightening: How the Chinese Military is Adopting Artificial Intelligence, p. 30.

5 Funding Defense AI

The opacity of Chinese defense spending confounds detailed assessments about the PLA's direct funding for AI. Based on evidence including the 2019 DWP's statement that 41 percent of China's 2017 defense budget went to equipment, one 2021 foreign assessment put the PLA's annual spending on AI as US$1.6 billion-US$2.7 billion, or in any case 'in the low billions of US dollars', roughly on par with the US military's spending on AI.[130] Based on declared Chinese numbers, the equipment share of the defense budget has generally grown since 2010, though China's 2020 report to the United Nations on its military spending showed a fall to 37.19 percent.[131]

Allowance must also be made that some of the PLA's major defense acquisition programs are classified and not reflected in publicly available data. Additionally, the concentration of much relevant R&D work in China's universities, non-PLA affiliated research institutes and civilian enterprises limits the usefulness of official defense spending as a metric of total defense AI funding. By one foreign estimate, in 2019 China spent around US$25 billion on research, development, evaluation and testing for military purposes outside the nation's official defense budget.[132]

China's booming civilian digital economy generates huge resources for AI development. The much-reported "tech sector crackdown" by the Chinese state in recent years has been targeted at large commercial internet platform service providers, and does not reflect a general persecution of private enterprise.[133] To the contrary, top-level policy continues to emphasise the key role in strategic technology development of private enterprise and market forces, though the compatibility of this stance with Xi's reassertion of CPC-led centralized top-down direction remains to be seen. One market research estimate published in late 2022 projects that Chinese investment in AI may reach US$26.69 billion by 2026, accounting for about 8.9 per cent of global AI investment.[134]

While US decoupling measures will have negative impacts on development of China's ICT sector generally and AI especially, they may also have converse effects. Some investors, both Chinese and foreign, are now betting on China's semiconductor industry precisely because the new US export controls incentivize import substitution. In the most affected sectors like semiconductors, Chinese downstream firms are increasingly "buying domestic" by necessity or to risk mitigate against further expansion of US restrictions, boosting investment and revenue for Chinese vendors of enabling technologies. The readiness to date of foreign leaders (notably German and Japanese firms) in industries like chemicals, software and

130 Fedasiuk/Melot/Murphy, Harnessed Lightening: How the Chinese Military is Adopting Artificial Intelligence, pp. 10–11.
131 Permanent Mission of the People's Republic of China to the United Nations, "Report on Military Expenditure in 2020."
132 Tian/Su, "A new Estimate of Chinese military expenditure," p. 18.
133 Lee, "Cyberspace Governance in China," pp. 13–14, 22.
134 IDC, "AI Spending Will Rise Over $46 Billion by 2026 in Asia/Pacific."

electronic components to maintain and indeed expand their business in China, despite countervailing political pressures, provides further reason to doubt that China's supporting ecosystem for defense AI development will be crippled by US government efforts.

6 Fielding and Operating Defense AI

One basis for inferring the PLA's near-term priorities for deploying AI-enabled systems are defense-AI related publications. One survey of 58 such Chinese papers published over 2016–2020 identified twelve discrete applications that spanned unmanned platforms; "intelligentization" of munitions, satellites and ISR); automation of offensive and defensive cyber operations and missile launch software; and cognitive electronic warfare.[135] A review of 343 AI-related defense equipment contracts published in China in 2020 found the dominant application areas to be intelligent or autonomous vehicles (over a third of the surveyed contracts), ISR, information and electronic warfare, and predictive maintenance and logistics. Other contracts in this sample set relate to simulation and training, command and control, and automated target recognition.[136]

For years the PLA has showcased a succession of increasingly capable maritime and aerial unmanned platforms, including a series of stealthy combat models. By 2018 all four PLA services (including the Rocket Force) fielded a variety of UAVs, including a growing number of multi-mission capable models.[137] By late 2022 the PLA was integrating a drone "carrier" catamaran into experimental naval task force exercises, with apparent variants of a civilian Chinese tandem-rotor drone on board, potentially to provide transport or ISR functions.[138] Foreign media in 2022 also identified what appeared to be new and larger unmanned underwater vehicles (UUV) at the PLA's Yalong naval base facing the South China Sea, approaching the size of the US Navy's developmental Orca autonomous UUV.[139] Although deployed numbers appear limited, the PLA has a record of iteratively prototyping new equipment, eventually transitioning to rapid serial production once a given model is regarded as fit for purpose.

The current edition of *Science of Military Strategy* states that UAVs should be prioritised in unmanned systems development, although PLA theorists also stress that some "intelligentiziation" is necessary for sensing capabilities across all domains.[140] A focus on UAVs is unsurprising given that China is the world leader in civilian drones and in military drone exports, and that the aerial environment presents a relatively simpler challenge (because airspace is relatively uncluttered) for development of machine intelligence. Orientation towards UAVs and aerospace-focused defense SOEs is apparent in defense AI-related procurement tenders and contracts.[141]

135 Fedasiuk, Chinese Perspectives on AI and Future Military Capabilities, p. 7.
136 Fedasiuk/Melot/Murphy, Harnessed Lightning.
137 Kania, "The PLA's Unmanned Aerial Systems: New Capabilities for a "New Era" of Chinese Military Power," p. 11.
138 Trevithick, "China's Naval Mothership For Aerial Drones Looks To Be Operational."
139 Sutton, "China's New Extra-Large Submarine Drones Revealed."
140 Fedasiuk/Weinstein, "AI in the Chinese Military," p. 176.
141 Fedasiuk/Melot/Murphy, Harnessed Lightning, p. 30; Fedasiuk/Weinstein, "AI in the Chinese Military," p. 180.

The nature of China's maritime sovereign disputes in the East and South China Sea Seas, which incentivise persistent assertion of claimed rights over vast tracts of maritime space against foreign actors, puts a premium on effective ISR and long-range high-endurance capabilities. The PLA has been using UAVs for this purpose since the early 2010s, with these activities being characterized by foreign commentators as "gray zone operations" consistent with the "Three Warfares" approach described above. UAVs and UUVs are also useful for monitoring Taiwanese defense assets and activity in the Taiwan Strait, where Beijing currently sees an imperative to assert an increased military presence and political pressure against Taipei and Washington (to disincentivise further US movement away from the One China Policy). Unmanned platforms provide a relatively low-cost and low-risk means of collecting data on foreign military assets' electronic signatures, training, tactics and procedures (TTPs) and other information that would be useful in an armed conflict.

Sensing capabilities, as noted above, are a focus of Chinese defense AI-related publications and of MIIT's 2017 AI development plan. Defense AI development in this area likely benefits from China's long-term and world-leading development of AI-powered sensor-based networks for civilian applications, notably "smart city" management and self-driving cars.[142] Claimed Chinese research advances in hypersonic weapons over 2022 involve sophisticated sensing capabilities, potentially using AI.[143] These indicate near-term potential for deep penetrating strikes to paralyse adversary operational systems, in line with the concepts discussed in section 2 above.

A focus on using AI-powered sensing and information processing for ISR aligns with the US DoD's assessment that the PLA seeks to "establish a real-time surveillance, reconnaissance and warning system (…) to maintain situational awareness of potential flashpoints (and) monitor, track and target adversary forces."[144] In particular the PLA appears to be developing an advanced undersea monitoring system, elements of which have been deployed in the South China Sea to support China's sovereign claims over the region and defense of the local PLA bases on artificial islands. This so-called "great underwater wall" is discussed in Chinese publications, which describe its importance to protect the PLA's surface and subsurface assets, in view of US undersea warfare advantages.[145]

This raises questions about whether at least in the short term, the PLA will focus its AI development on contingencies in China's near abroad. This would align with the PLA's official basic mission of "winning local wars," and with the geographical

142 See e.g., Lee, The Connection of Everything: China and the Internet of Things.
143 Lee, China-Russia cooperation in advanced technologies.
144 2022 Report on Military and Security Developments Involving the People's Republic of China, p. 72.
145 Goldstein, "China Is Building a 'Undersea Great Wall' To Take on America in a War."

restrictions of its most potent warfighting capabilities, at least those it would need to employ to be competitive against the US military. Physical limitations on the use of cheap and numerically abundant but small sized drones also raise doubts as to how effectively AI could augment the PLA's combat power projection at long distances, in a context where the PLA still operates only one military base abroad (Djibouti, excluding the South China Sea artificial islands).[146] Conversely, published Chinese writings on an undersea observation system make clear that this should be implementable where needed worldwide, rather than confined to China's "near seas."[147]

Another AI application that the PLA seems to be deploying in practice is logistics optimization, which is unsurprising given China's stable of private sector internet platform firms providing AI-driven services comparable to those of US logistics and transportation giants like Amazon and Uber. The PLA is developing a "strategic delivery" system of integrated transport services and military bases to enable efficient force projection into zones of current operations, utilising AI to enhance the speed of real-time requirements analysis and services delivery.[148]

146 Shmuel, "The coming swarm might be dead on arrival."
147 Goldstein, "China Is Building a "Undersea Great Wall" To Take on America in a War."
148 Chieh/Yang, "Crossing the Strait: Recent Trends in PLA 'Strategic Delivery' Capabilities," p. 62.

7 Training for Defense AI

UAVs are leading the PLA's deployment of AI-related capabilities and so are supported by a system of specialised military education: a 2016 study identified at least eight PLA academic institutions with UAV-related programs for training specialists (officers and enlisted personnel).[149] AI-enabled virtual and augmented reality systems are also used to train pilots of manned aircraft, with reports in 2021 of an AI agent developed by PLA institutes defeating a fighter pilot in a simulated dogfight, comparable to achievements by an AI agent developed by the US Defense Advanced Research Projects Agency.

UAVs have appeared in multi-service PLA training activities and alongside multiple types of manned aircraft, while dedicated UAV-equipped units have progressively increased the sophistication of their training exercises, including kinetic attacks under adverse environmental conditions.[150] The PLA may also be learning from use of Chinese-supplied military UAVs in foreign conflicts, notably in the Middle East and Africa. Reported use of Chinese civilian drones by Russian forces in Ukraine potentially provides further intelligence collection and evaluation opportunities, in a high intensity conflict involving extensive use of US equipment.

One obvious application of AI's simulation capabilities is to train for current operations and simulate the effects of future operational concepts and C2 approaches.[151] The above-mentioned Chinese interest in cognitive warfare has also doubtless spurred a focus on AI's application for this purpose, especially since the 2015–16 victories of "deep learning" software AlphaGo over professional human Go players. AI-powered simulated learning is an attractive option for the PLA to address its own negative assessments of its officers' decision-making capabilities, in the context of the whole institution's dearth of recent operational experience.[152]

The PLA has been applying AI to wargaming since at least 2017, led by the National Defense University. Some of these activities have involved universities, research institutes and civilian firms, and pitted machine intelligence against machine intelligence as well as against humans, generating data to support further machine self-learning as demonstrated by AlphaGo. One US analyst in 2019 characterized these Chinese exercises as exceeding comparable US activities in scope and scale.[153] The PLA has awarded contracts to develop AI wargaming software for use in professional military education.

AI agents and wargaming platforms for testing them are being developed by both civilian and PLA institutions. For example, the Chinese Academy of Science's

149 Kania/Allen, "The Human and Organizational Dimensions of the PLA's Unmanned Aerial Vehicle Systems."
150 Kania, "The PLA's Unmanned Aerial Systems: New Capabilities for a "New Era" of Chinese Military Power," p. 19.
151 Kania, "China Artificial Intelligence Talent Training Report: Translation," pp. 537–538.
152 Blasko, "The Chinese Military speaks to itself, revealing doubts."
153 Kania, "Learning Without Fighting: New Developments in PLA Artificial Intelligence War-Gaming."

Institute of Automation (CAS IoA) has developed the Miaosuan (庙算) wargaming platform and the AI gaming agent AlphaWar, comparable to the AlphaStar gaming agent developed by UK-based DeepMind. AlphaWar is claimed to have passed the Turing test – exhibiting behaviour indistinguishable from a human's – in 2020, and to have confirmed this result in the 2021 iteration of the "Miaosuan Cup" tournament.[154]

This competition, organised by the Chinese Society of Artificial Intelligence and the CAS IoA, pits human and AI players in adversarial and collaborative games on the Miaosuan platform, with human finalists required to guess whether anonymous opponents were human or AI. The competition's 2021 iteration included four AI agents, two of which were developed by PLA institutions.[155] The competition's 2022 iteration was described as involving human-machine collaborative teaming and confrontation, and as geared towards the needs of manned and unmanned human-machine hybrid intelligence.[156]

However, the extent to which AI-driven simulation and learning can compensate for real-world military operational experience remains to be seen. The PLA certainly does not to be relying primarily on AI in this context. For example, some foreign analysts perceive a recently increased emphasis on provoking incidents with the US military to evaluate US response and capabilities, so-called "using the enemy to train the troops" (拿敌练兵).[157] Such high-risk methods do not suggest confidence in AI as a self-sufficient learning basis to prepare for real combat, at least against the most capable adversaries.

154 Yin et al, "Intelligent decision making techniques and challenges for wargaming."
155 Institute of Automation, Chinese Academy of Sciences, "The 2021 'Miaosuan Cup' human-computer confrontational test competition was successfully held."
156 Institute of Automation, Chinese Academy of Sciences, "2022 Miaosuan Cup Human-Machine Hybrid confrontational competition is about to open."
157 Martinson/Kennedy, "Using the Enemy to Train the Troops — Beijing's New Approach to Prepare its Navy for War."

8 Conclusion

The official explanation of the drivers behind China's latest Defense White Paper – and of the internal strategic guidance that accompanied it[158] – described S&T-driven evolution in patterns of warfare as "the main motivation" for developing China's military strategy.[159] While the PLA's overall state of development suggests that it is some way from becoming a global leader in "intelligentized" warfare, it is already deploying numerous and capable semi-autonomous military systems, while Chinese thinkers are covering the ground in applying AI's potential to both current military operations and future operational concepts. China has a comprehensive, well-resourced and increasingly well-organized national system for AI development in general, and a focus at the top of its political system on bending this "whole-of-nation system" to the service of defense AI applications.

The final report of the US National Security Commission on Artificial Intelligence (NSCAI), published in 2021, argued that China already led the US in three of six layers of the AI technological "stack:" data availability, fielding applications at scale, and integration across the whole stack.[160] A debate can be had over whether such judgments overstate Chinese capabilities, especially given the NSCAI's chair's (foreign Google CEO Eric Schmidt) potential conflicts of interest.[161] However, the US government as a whole appears convinced that China's emergent defense AI capabilities represent a "pacing threat" that requires severe measures, reflected in the October 2022 US export controls targeting China's access to the semiconductor technologies needed to support defense AI applications. While their effectiveness remains to be seen, these controls will at least create major challenges for future Chinese progress in AI generally, though probably not to the point where the PLA abandons efforts to compete in a technology perceived as critical to future outcomes in war.

The available evidence does not suggest that China is on the point of snatching a decisive and widening lead over the US and its allies in military uses of AI. But the Chinese system does have a clear and entrenched view of AI's structural importance, and reasonably clear military strategic goals that defense AI development can be directed towards, even if most potential applications remain a work in progress. Foreign analysts tracking Chinese AI development face an increasingly tight information environment, as more data sources are progressively closed off due to their sensitivity. Assessing China's progress with defense AI will be a challenging task, but one that is indispensable to analysis on the international military balance of power.

158 That is, the military strategic guidelines (军事战略方针). See generally Fravel/Wuthnow, "China's military strategy for a 'new era': Some change, more continuity, and tantalizing hints."
159 "Briefing on the interpretation of the white paper "China's National Defense in the New Era" and other matters."
160 Freedberg Jr., "China Leads US In 3 Of 6 AI Areas: Bob Work."
161 Wolff, "Ex-Google CEO Criticized After Release of China Report." For a more critical assessment of China's position vis-à-vis the US, see e.g., Ding, Deciphering China's AI Dream: The context, components, capabilities, and consequences of China's strategy to lead the world in AI.

Literature

"Briefing on the interpretation of the white paper 'China's National Defense in the New Era' and other matters," State Council Information Office, 24 July 2019, http://www.gov.cn/xinwen/2019–07/24/content_5414317.htm (last accessed 8 March 2023).

"China Artificial Intelligence Talent Training Report: Translation" (Washington, DC: Center for Security and Emerging Technology, 2022), https://cset.georgetown.edu/publication/china-artificial-intelligence-talent-training-report/ (last accessed 8 March 2023).

"Regular Press Conference of the Ministry of National Defense on November 26," China Military Online, 29 November 2020, http://eng.mod.gov.cn/news/2020–11/29/content_4874839.htm (last accessed 8 March 2023).

"Remarks by Deputy Secretary Work on Third Offset Strategy," Department of Defense, 28 April 2016 https://www.defense.gov/News/Speeches/Speech/Article/753482/remarks-by-deputy-secretary-work-on-third-offset-strategy/ (last accessed 8 March 2023).

"Document 9: A ChinaFile Translation," ChinaFile, 8 November 2013, https://www.chinafile.com/document-9-chinafile-translation (last accessed 8 March 2023).

"Leading science cities by the numbers," Nature, 25 November 2022 https://www.nature.com/articles/d41586–022–02881–8 (last accessed 8 March 2023).

"Xi Jinping: promote the healthy development of new generation artificial intelligence in China" (习近平：推动我国新一代人工智能健康发展), Xinhua, 31 October 2018 http://www.xinhuanet.com/politics/2018–10/31/c_1123643321.htm (last accessed 8 March 2023).

2022 Report on Military and Security Developments Involving the People's Republic of China (Washington, DC: Department of Defense, 2022), https://www.defense.gov/News/Releases/Release/Article/3230516/2022-report-on-military-and-security-developments-involving-the-peoples-republi/ (last accessed 8 March 2023).

Allen, Gregory, "One Key Challenge for Diplomacy on AI: China's Military Does Not Want to Talk," Center for Strategic & International Studies, 20 May 2022, https://www.csis.org/analysis/one-key-challenge-diplomacy-ai-chinas-military-does-not-want-talk (last accessed 8 March 2023).

Allen, Gregory, Understanding China's AI Strategy (Arlington: Center for Naval Analyses, 2019) https://www.cnas.org/publications/reports/understanding-chinas-ai-strategy (last accessed 8 March 2023).

Altmann, Juergen, and Frank Sauer, "Autonomous Weapon Systems and Strategic Stability," Survival, 59:5 (September/October 2017), pp. 117–142.

Arcesati, Rebecca, "Foreign collaboration continues in China's drive for technology self-reliance," The Strategist, 14 September 2022 https://www.aspistrategist.org.au/foreign-collaboration-continues-in-chinas-drive-for-technology-self-reliance/ (last accessed 8 March 2023).

Austin, Greg, "Managing Asymmetries in Chinese and American Cyber Power," Georgetown Journal of International Affairs: International Engagement on Cyber IV (2014), pp. 141–151, https://www.jstor.org/stable/43773657 (last accessed 8 March 2023).

Blasko, Dennis, "The Chinese military speaks to itself, revealing doubts," War on the Rocks, 18 February 2019, https://warontherocks.com/2019/02/the-chinese-military-speaks-to-itself-revealing-doubts/ (last accessed 8 March 2023).

Chang, Huey-Meei and William C. Hannas, "Foreign support, alliances, and technology transfer', in William C. Hannas and Huey-Meei Chang (eds), Chinese Power and Artificial Intelligence: Perspectives and Challenges (Abingdon; New York: Routledge, 2023), pp. 36–53.

Chang, Yan'e, Ou Lishou and Wang Furong, "An exploration of the teaching curriculum for 'Introduction to Public Opinion Warfare, Psychological Warfare and Legal Warfare,"舆论战心理战法律战概论"课程教学探析 Journal of Higher Education Research 高等教育研究学报 30(4) 2007, pp. 63–65.

Chen, John, Joe McReynolds and Kieran Green, "The PLA Strategic Support Force: A 'Joint' Force for Information Operations," in Joel Wuthnow et al. (eds), The PLA Beyond Borders: Chinese Military Operations in Regional and Global Context (Washington, DC: National Defense University Press, 2021), pp. 151–179, https://ndupress.ndu.edu/Publications/Books/PLA-Beyond-Borders/ (last accessed 8 March 2023).

Chen, John, "Cyber and Influence Operations," William C. Hannas and Huey-Meei Chang (eds), Chinese Power and Artificial Intelligence: Perspectives and Challenges (Abingdon; New York: Routledge, 2023), pp. 189–204.

Chen, Stephen, "In China, AI warship designer did nearly a year's work in a day," South China Morning Post, 10 March 2023, https://www.scmp.com/news/china/science/article/3213056/china-ai-warship-designer-did-nearly-years-work-day (last accessed 10 March 2023).

Cheung, Tai Ming, Innovate to Dominate: The Rise of the Chinese Techno-Security State (Ithaca/London: Cornell University Press, 2022).

Chieh, Chung, and Andrew N. D. Yang, "Crossing the Strait: Recent Trends in PLA 'Strategic Delivery' Capabilities," in Joel Wuthnow, Arthur S. Ding, Phillip C. Saunders, Andrew Scobell and Andrew N.D. Yang (eds), The PLA Beyond Borders: Chinese Military Operations in Regional and Global Context (Washington, DC: National Defense University Press, 2021), pp. 51–72, https://ndupress.ndu.edu/Publications/Books/PLA-Beyond-Borders/ (last accessed 8 March 2023).

China Academy of Information and Communication Technology (CAICT), Artificial Intelligence White Paper 2022 (Haidian: CAICT 2022), http://www.caict.ac.cn/kxyj/qwfb/bps/202204/P020220412613255124271.pdf (last accessed 8 March 2023).

Chou, Daniel, Counting AI Research: Exploring AI Research Output in English- and Chinese-Language Sources, (Washington, DC: Center for Security and Emerging Technology, 2022), https://cset.georgetown.edu/publication/counting-ai-research/ (last accessed 8 March 2023).

Courtland, Rachel, "Transistors Will Stop Shrinking in 2021, Moore's Law Roadmap Predicts," IEEE Spectrum, 22 July 2016 https://spectrum.ieee.org/transistors-will-stop-shrinking-in-2021-moores-law-roadmap-predicts (last accessed 8 March 2023).

Cozad, Mark et al., Gaining Victory in Systems Warfare: China's Perspective on the U.S.-China Military Balance (Santa Monica: RAND, 2023), Dahm, Michael, "Chinese debates on the military utility of artificial intelligence," War on the Rocks 5 June 2020 https://warontherocks.com/2020/06/chinese-debates-on-the-military-utility-of-artificial-intelligence/ (last accessed 8 March 2023).

Demarest, Colin, "China developing own version of JADC2 to counter US," C4ISRNET, 5 January 2022, https://www.c4isrnet.com/battlefield-tech/it-networks/2023/01/05/china-developing-own-version-of-jadc2-to-counter-us/ (last accessed 8 March 2023).

Department of Commerce, Bureau of Industry and Security, RIN 0694-AI94 "Implementation of Additional Export Controls: Certain Advanced Computing and Semiconductor Manufacturing Items; Supercomputer and Semiconductor End Use; Entity List Modification" https://public-inspection.federalregister.gov/2022–21658.pdf (last accessed 8 March 2023).

Ding, Jeffrey, "China's Current Capabilities, Policies and Industrial Ecosystem in AI," Testimony before the U.S.-China Economic and Security Review Commission, 7 June 2019, https://cset.georgetown.edu/publication/chinas-current-capabilities-policies-and-industrial-ecosystem-in-ai/ (last accessed 8 March 2023).

Ding, Jeffrey, Deciphering China's AI Dream: The context, components, capabilities, and consequences of China's strategy to lead the world in AI (Oxford: Future of Humanity Institute/University of Oxford, 2018), https://www.fhi.ox.ac.uk/wp-content/uploads/Deciphering_Chinas_AI-Dream.pdf (last accessed 8 March 2023).

Engstrom, Jeffrey, Systems Confrontation and System Destruction Warfare: How the Chinese People's Liberation Army Seeks to Wage Modern Warfare (Santa Montica: RAND, 2018), https://www.rand.org/pubs/research_reports/RR1708.html (last accessed 8 March 2023).

Fedasiuk, Ryan and Emily Weinstein, "AI in the Chinese Military", in William C. Hannas and Huey-Meei Chang (eds), Chinese Power and Artificial Intelligence: Perspectives and Challenges (Abingdon; New York: Routledge, 2023), pp. 175–188.

Fedasiuk, Ryan, Chinese Perspectives on AI and Future Military Capabilities, (Washington, DC: Center for Security and Emerging Technology, 2020), https://cset.georgetown.edu/publication/chinese-perspectives-on-ai-and-future-military-capabilities/ (last accessed 8 March 2023).

Fedasiuk, Ryan, Jennifer Melot, and Ben Murphy, Harnessed Lightning: How the Chinese Military is Adopting Artificial Intelligence (Washington, DC: Center for Security and Emerging Technology, 2021), https://cset.georgetown.edu/publication/harnessed-lightning/ (last accessed 8 March 2023).

Fravel, Taylor and Joel Wuthnow, "China's military strategy for a 'new era': Some change, more continuity, and tantalizing hints," Journal of Strategic Studies (March 2022), DOI:10.1080/01402390.2022.2043850 (last accessed 8 March 2023).

Freedberg Jr., Sydney, "China Leads US In 3 Of 6 AI Areas: Bob Work," Breaking Defense, 9 April 2021 https://breakingdefense.com/2021/04/china-leads-us-in-3-of-6-ai-areas-bob-work/ (last accessed 8 March 2023).

Gao Yuan, "Alibaba forms Norinco alliance," China Daily, 20 August 2015 https://www.chinadaily.com.cn/business/2015–08/20/content_21656788.htm (last accessed 8 March 2023).

Gentile, Gian et al., A History of the Third Offset, 2014–2018 (Santa Monica: RAND, 2020), https://www.rand.org/pubs/research_reports/RRA454–1.html (last accessed 8 March 2023).

Goldstein, Lyle, "China Is Building a "Undersea Great Wall" To Take on America in a War," The National Interest, 27 October 2019 https://nationalinterest.org/blog/buzz/china-building-undersea-great-wall-take-america-war-90601 (last accessed 8 March 2023).

Gruenberg, Nis and Claudia Wessling (eds.), The CCP's Next Century: Expanding economic control, digital governance and national security (Berlin: Mercator Institute for China Studies, 2021), https://merics.org/en/report/ccps-next-century-expanding-economic-control-digital-governance-and-national-security (last accessed 8 March 2023).

Heath, Timothy, China's New Governing Party Paradigm: Political Renewal and the Pursuit of National Rejuvenation (Farnham: Ashgate, 2014).

Herh, Michael, "China Distinguishing Itself at ISSCC 2023," BusinessKorea, 17 November 2022 http://www.businesskorea.co.kr/news/articleView.html?idxno=104260 (last accessed 8 March 2023).

Heston, Roxanne and Remco Zwetsloot, Mapping U.S. Multinationals' Global AI R&D Activity (Washington, DC: Center for Security and Emerging Technology, 2020), https://cset.georgetown.edu/publication/mapping-u-s-multinationals-global-ai-rd-activity/ (last accessed 8 March 2023).

Horowitz, Michael C., Joshua A. Schwartz and Matthew Fuhrmann, "China Has Made Drone Warfare Global: The United States Must Join the Market or Be Left Behind," Foreign Affairs, 20 November 2020, https://www.foreignaffairs.com/articles/china/2020–11–20/china-has-made-drone-warfare-global (last accessed 8 March 2023).

https://www.rand.org/pubs/research_reports/RRA1535–1.html (last accessed 8 March 2023).

IDC, "AI Spending Will Rise Over $46 Billion by 2026 in Asia/Pacific," 27 September 2022 https://www.idc.com/getdoc.jsp?containerId=prAP49721022 (last accessed 8 March 2023).

Institute of Automation, Chinese Academy of Sciences, "The 2021 'Miaosuan Cup' human-computer confrontational test competition was successfully held" (2021届"庙算杯"人机对抗测试赛成功举行), 9 August 2021, http://www.ia.cas.cn/xwzx/kydt/202108/t20210809_6153415.html (last accessed 8 March 2023).

Institute of Automation, Chinese Academy of Sciences,"2022 Miaosuan Cup Human-Machine Hybrid confrontational competition is about to open" (2022庙算杯人机混合对抗赛即将开启), 28 September 2022 http://www.ia.cas.cn/xwzx/xshd/202209/t20220928_6518314.html (last accessed 8 March 2023).

Jenks, C., "False Rubicons, Moral Panic, & Conceptual Cul-De-Sacs: Critiquing & Reframing the Call to Ban Lethal Autonomous Weapons", 44:1 (December 2016) Pepperdine Law Review, pp. 1–70.

Jullien, Francois, A Treatise on Efficacy: Between Western and Chinese Thinking (Honolulu: University of Hawai'i Press, 2004).

Kania, Elsa and Kenneth Allen, "The Human and Organizational Dimensions of the PLA's Unmanned Aerial Vehicle Systems," China Brief 16:8 (11 May 2016), https://jamestown.org/program/the-human-and-organizational-dimensions-of-the-plas-unmanned-aerial-vehicle-systems/ (last accessed 8 March 2023).

Kania, Elsa, "Learning Without Fighting: New Developments in PLA Artificial Intelligence War-Gaming," China Brief 19:7 (9 April 2019), https://jamestown.org/program/learning-without-fighting-new-developments-in-pla-artificial-intelligence-war-gaming/ (last accessed 8 March 2023).

Kania, Elsa, "Artificial intelligence in China's revolution in military affairs" Journal of Strategic Studies, 44:4 (2021), pp. 515–554, https://doi.org/10.1080/01402390.2021.1894136

Kania, Elsa, "Swarms at War: Chinese Advances in Swarm Intelligence," China Brief 17:9 (6 July 2017), https://jamestown.org/program/swarms-war-chinese-advances-swarm-intelligence/ (last accessed 8 March 2023).

Kania, Elsa, AI Weapons in China's Military Innovation (Washington, DC: Brookings, 2020), https://www.brookings.edu/wp-content/uploads/2020/04/FP_20200427_ai_weapons_kania_v2.pdf (last accessed 8 March 2023).

Kania, Elsa, The PLA's Unmanned Aerial Systems: New Capabilities for a "New Era" of Chinese Military Power (Montgomery: China Aerospace Studies Institute, 2018) https://apps.dtic.mil/sti/citations/AD1082743 (last accessed 8 March 2023).

Konaev, Margarita et al., Headline or Trendline? Evaluating Chinese-Russian Collaboration in AI (Washington, DC: Center for Security and Emerging Technology, 2021), https://cset.georgetown.edu/publication/headline-or-trend-line/ (last accessed 8 March 2023).

Lee, John, "The new Chinese diaspora," The Interpreter, 31 March 2017 https://www.lowyinstitute.org/the-interpreter/new-chinese-diaspora (last accessed 8 March 2023).

Lee, John, "Cyberspace Governance in China: Evolution, Features and Future Trends" French Institute of International Relations (IFRI), Asie.Visions, No. 129, July 2022 https://www.ifri.org/en/publications/notes-de-lifri/asie-visions/cyberspace-governance-china-evolution-features-and-future (last accessed 8 March 2023).

Lee, John, and Jan-Peter Kleinhans, Mapping China's semiconductor ecosystem in global context: Strategic dimensions and conclusions (Berlin: Mercator Institute for China Studies/Stiftung Neue Verantwortung, 2021), https://merics.org/en/report/mapping-chinas-semiconductor-ecosystem-global-context-strategic-dimensions-and-conclusions (last accessed 8 March 2023).

Lee, John, Mei Nouwens and Kai Lin Tay, Strategic Settings for 6G: Pathways for China and the US (London: IISS, 2022), https://www.iiss.org/blogs/research-paper/2022/08/strategic-settings-for-6g-pathways-for-china-and-the-us (last accessed 8 March 2023).

Lee, John, China-Russia cooperation in advanced technologies: The future global balance of power and the limits of 'unlimited' partnership (Ultimo: Australian China Relations Institute/University of Technology Sydney, 2022), https://www.australiachinarelations.org/content/china-russia-cooperation-advanced-technologies-future-global-balance-power-and-limits (last accessed 8 March 2023).

Lee, John, Eric Zhang, and Rogier Creemers, China's Standardisation System: trends, implications and case studies in emerging technologies (Leiden: Leiden Asia Centre, 2022) https://leidenasiacentre.nl/chinas-standardisation-system-trends-implications-and-case-studies-in-emerging-technologies/ (last accessed 8 March 2023).

Lee, John, The Connection of Everything: China and the Internet of Things (Berlin: Mercator Institute for China Studies, 2021), https://merics.org/en/report/connection-everything-china-and-internet-things (last accessed 8 March 2023).

Lee, Sangkuk, "An Institutional Analysis of Xi Jinping's Centralisation of Power", 26:105 (May/June2017), Journal of Contemporary China, pp. 325–336, https://doi.org/10.1080/10670564.2016.1245505 (last accessed 8 March 2023)

Li, Binhai and Huo Yunchao, "Change in operational guidance, from the viewpoint of an evolving mechanism for obtaining victory" (从制胜机理演变看作战指导之"变"), People's Liberation Army Daily, 2 February 2023 http://www.mod.gov.cn/jmsd/2023–02/02/content_4931741.htm (last accessed 8 March 2023).

Li, Minghai, "Where are the changes in the mechanism for obtaining victory in intelligentized warfare?" (智能化战争的制胜机理变在哪里), People's Liberation Army Daily, 15 January 2019 http://www.81.cn/jfjbmap/content/2019–01/15/content_225335.htm (last accessed 8 March 2023).

Li, Wei and Zhao Zipeng, "Building a future superior operational chain" (打造未来作战优势链路), People's Liberation Army Daily, 11 February 2020 https://www.81.cn/jfjbmap/content/2020–02/11/content_253748.htm (last accessed 8 March 2023).

Liao, Rita, "Nvidia touts a slower chip for China to avoid US ban," TechCrunch, 8 November 2022, https://techcrunch.com/2022/11/07/nvidia-us-china-ban-alternative/ (last accessed 8 March 2023).

Lin, Liza and Dan Strumpf, "China's Top Nuclear-Weapons Lab Used American Computer Chips

Decades After Ban," Wall Street Journal, 29 January 2023 https://www.wsj.com/articles/chinas-top-nuclear-weapons-lab-used-american-computer-chips-decades-after-ban-11674990320 (last accessed 8 March 2023).

Liu Zhen, "China's military looks for new drones and intelligent vehicles for logistics," South China Morning Post, 12 April 2020, www.scmp.com/news/china/military/article/3174026/chinas-military-looks-new-drones-andintelligent-Vehicles (last accessed 8 March 2023).

Martinson, Ryan D. and Conor Kennedy, "Using the Enemy to Train the Troops —Beijing's New Approach to Prepare its Navy for War," China Brief 22:6 (25 March 2022), https://jamestown.org/program/using-the-enemy-to-train-the-troops-beijings-new-approach-to-prepare-its-navy-for-war/ (last accessed 8 March 2023).

Mattingly, Daniel C., "How the Party Commands the Gun: The Foreign–Domestic Threat Dilemma in China," American Journal of Political Science (21 October 2022), pp. 1–16, https://doi.org/10.1111/ajps.12739.

Ministry of Industry and Information Technology (MIIT), "Notice of Two Ministries on the 2022 inaugural 'Xingzhi Cup' National Artificial Intelligence Innovation and Application Competition" (两部委关于举办2022年首届"兴智杯"全国人工智能创新应用大赛的通知), MIIT No.170, 2022 https://www.miit.gov.cn/zwgk/zcwj/wjfb/tz/art/2022/art_f5ccabd9350b4bb7ad49fe5baec60b25.html (last accessed 8 March 2023).

Ministry of Industry and Information Technology (MIIT), "Three Year Action Plan to Promote Development of the New Generation Artificial Intelligence Industry" (促进新一代人工智能产业发展三年行动计划) MIIT, 15 December 2017 https://app.www.gov.cn/govdata/gov/201712/15/416663/article.html (last accessed 8 March 2023).

Ministry of National Defense, "China's Military Strategy 2015" (中国国防白皮书《中国的军事战略》2015), http://www.chinadaily.com.cn/interface/toutiao/1138561/2015–5-26/cd_20821000.html (Chinese); http://eng.mod.gov.cn/publications/2021–06/23/content_4887928.htm (English) (last accessed 8 March 2023).

Ministry of National Defense, "China's National Defense in the New Era" (新时代的中国国防), http://www.gov.cn/zhengce/2019–07/24/content_5414325.htm (Chinese), http://eng.mod.gov.cn/publications/2019–07/24/content_4846452.htm, July 2019 (English) (last accessed 8 March 2023).

Murdick, Dewey et al., The Public AI Research Portfolio of China's Security Forces: A High Level Analysis (Washington, DC: Center for Security and Emerging Technology, 2021), https://cset.georgetown.edu/publication/the-public-ai-research-portfolio-of-chinas-security-forces/ (last accessed 8 March 2023).

Naughton, Barry, "Grand Steerage as the New Paradigm for State-Economy Relations," in Frank Pieke and Bert Hofman (eds), CPC Futures: The New Era of Socialism with Chinese Characteristics (Singapore: NUS Press, 2022), pp. 105–112.

Nelson, Amy J. and Gerald L. Epstein, "The PLA's Strategic Support Force and AI Innovation', Brookings Tech Stream, 23 December 2022, https://www.brookings.edu/techstream/the-plas-strategic-support-force-and-ai-innovation-china-military-tech/ (last accessed 8 March 2023).

Panda, Ankit, "A New Chinese Autonomous Underwater Vehicle?" The Diplomat, 11 November 2019 https://thediplomat.com/2019/11/a-new-chinese-autonomous-underwater-vehicle/ (last accessed 8 March 2023).

Parameswaran, Prashanth, "What's Behind Indonesia's China Drone Buy?," The Diplomat, 7 February 2018, https://thediplomat.com/2018/02/whats-behind-indonesias-china-drone-buy/ (last accessed 8 March 2023).

Permanent Mission of the People's Republic of China to the United Nations, "Report on Military Expenditure in 2020," 11 February 2022 https://front.un-arm.org/wp-content/uploads/2022/03/20220211-note-verbale-from-china-mission.pdf (last accessed 8 March 2023).

Permanent Mission of the People's Republic of China to the United Nations, "Position Paper of the People's Republic of China on Regulating Military Applications of Artificial Intelligence (AI)," 13 December 2021 http://geneva.china-mission.gov.cn/eng/dbdt/202112/t20211213_10467517.htm (last accessed 8 March 2023).

Pollpeter, Kevin and Amanda Kerrigan, with contributions by Andrew Ilachinski, The PLA and Intelligent Warfare: A Preliminary Analysis (Arlington: Center for Naval Analyses), 2021 https://www.cna.org/reports/2021/10/the-pla-and-intelligent-warfare-preliminary-analysis (last accessed 8 March 2023).

Qiao, Hui, Su Yun and An Jin, "Research on Maritime Intelligence Data Analysis Technologies for Massive Data" "面向海量数据的海情数据分析技术研究,"

Command Control and Simulation (指挥控制与仿具), 40(2), 2018.

RFA Staff, "CPC amends its constitution to adopt a more aggressive Chinese policy towards Taiwan" Radio Free Asia, 24 October 2022 https://www.rfa.org/english/news/southchinasea/taiwan-china-plans-10242022032256.html (last accessed 8 March 2023).

Shmuel Shmuel, "The coming swarm might be dead on arrival," War on the Rocks, 10 September 2018, https://warontherocks.com/2018/09/the-coming-swarm-might-be-dead-on-arrival/ (last accessed 8 March 2023).

Sterling, Toby, "U.S., China, other nations urge 'responsible' use of military AI," Reuters, 16 February 2023, https://www.reuters.com/business/aerospace-defense/us-china-other-nations-urge-responsible-use-military-ai-2023–02–16/ (last accessed 8 March 2023).

Sutter, Karen M. and Zachary Arnold, "China's AI Companies: Hybrid Players," in William C. Hannas and Huey-Meei Chang (eds), Chinese Power and Artificial Intelligence: Perspectives and Challenges (Abingdon; New York: Routledge, 2023), pp. 19–35.

Sutton, H. I., "China's New Extra-Large Submarine Drones Revealed," Naval News, 16 September 2022, https://www.navalnews.com/naval-news/2022/09/chinas-secret-extra-large-submarine-drone-program-revealed/ (last accessed 8 March 2023).

Takagi, Koichiro, "New Tech, New Concepts: China's Plans for AI and Cognitive Warfare," War on the Rocks, 13 April 2022 https://warontherocks.com/2022/04/new-tech-new-concepts-chinas-plans-for-ai-and-cognitive-warfare/ (last accessed 8 March 2023).

Tian, Nan and Fei Su, A New Estimate of China's Military Expenditure (Stockholm: SIPRI, 2021), https://www.sipri.org/sites/default/files/2021–01/2101_sipri_report_a_new_estimate_of_chinas_military_expenditure.pdf (last accessed 8 March 2023).

Toner, Helen, "AI Safeguards: Views inside and outside China", in William C. Hannas and Huey-Meei Chang (eds), Chinese Power and Artificial Intelligence: Perspectives and Challenges (Abingdon; New York: Routledge, 2023), pp. 244–459.

Trevithick, Joseph, "China's Naval Mothership For Aerial Drones Looks To Be Operational," The War Zone, 22 December 2022, https://www.thedrive.com/the-war-zone/chinas-drone-carrier-mothership-looks-to-be-in-service (last accessed 8 March 2023).

Wang, Ronghui and Deng Shifeng, "Dialectical understanding of single and multiple domains in joint operations" (辩证认识联合作战的单域与多域), People's Liberation Army Daily, 20 January 2022 http://www.81.cn/jfjbmap/content/2022–01/20/content_307852.htm (last accessed 8 March 2023).

Webster, Graham, Rogier Creemers, Paul Triolo and Elsa Kania, "Full Translation: China's 'New Generation Artificial Intelligence Development Plan' (2017)" DigiChina, New America 1 August 2017, https://www.newamerica.org/cybersecurity-initiative/digichina/blog/full-translation-chinas-new-generation-artificial-intelligence-development-plan-2017/ (last accessed 8 March 2023).

Weinstein, Emily, and Jeffrey Stoff, "China's Quest for AI Talent," in William C. Hannas and Huey-Meei Chang (eds), Chinese Power and Artificial Intelligence: Perspectives and Challenges (Abingdon; New York: Routledge, 2023), pp. 57–72.

Wolff, Ilene, "Ex-Google CEO Criticized After Release of China Report," EETimes, 13 December 2022, https://www.eetimes.com/ex-google-ceo-criticized-after-release-of-china-report/ (last accessed 8 March 2023).

Wuthnow, Joel, "China's 'New' Academy of Military Science: A Revolution in Theoretical Affairs?," China Brief, 19:2 (18 January 2019), Jamestown Foundation, https://jamestown.org/program/chinas-new-academy-of-military-science-a-revolution-in-theoretical-affairs/ (last accessed 8 March 2023).

Wuthnow, Joel, "What I Learned From the PLA's Latest Strategy Textbook," China Brief 21(11), 25 May 2021, https://jamestown.org/program/what-i-learned-from-the-plas-latest-strategy-textbook/ (last accessed 8 March 2023).

Wuthnow, Joel, Twitter post 30 November 2022, https://twitter.com/jwuthnow/status/1597949841778540545 (last accessed 8 March 2023).

Yatsuzuka, Massaki, PLA's Intelligentized Warfare: The Politics on China's Military Strategy (Tokyo: National Institute for Defense Studies, 2020), http://www.nids.mod.go.jp/english/publication/security/pdf/2022/01/05.pdf (last accessed 8 March 2023).

Yin, Qiyue, Zhao Meijing, Ni Wancheng, Zhang Junge and Huang Kaiqi, "Intelligent decision making techniques and challenges for wargaming" 兵棋推演的智

能决策技术与挑战 Acta Automatica Sinica（自动化学报), 48(9) 2022, pp. 1–15 http://www.aas.net.cn/article/doi/10.16383/j.aas.c210547 (accessed 8 March 2023).

Yuen, Derek, Deciphering Sun Tzu: How to read the "Art of War" (Oxford: Oxford University Press, 2014).

Zhang Tong, "China-US divide extends to AI, both in research and real life, study finds," South China Morning Post, 6 December 2022 https://www.scmp.com/news/china/science/article/3202292/china-us-divide-extends-ai-both-research-and-real-life-study-finds (accessed 8 March 2023).

Zhou Yu, William Lazonick and Yifei Sun, (eds.), China as an Innovation Nation (Oxford: Oxford University Press, 2016).

Zhou, Wei and Chen Yaning, "Applications of AI technology in military command and control against the backdrop of intelligentized warfare" (智能化战争背景下人工智能技术在军事指挥控制中的应用) Military Digest (军事文摘) 2022(15), pp. 27–30.

Zhu Haiwen, "Adhere to the Party Committee's unified leadership on joint warfare" (坚持党委对联合作战的统一领导), People's Liberation Army Daily, 9 June 2021 http://www.81.cn/ll/2021–06/09/content_10047132.htm (last accessed 8 March 2023).

Zwetsloot, Remco et al., China is Fast Outpacing U.S. STEM PhD Growth (Washington, DC: Center for Security and Emerging Technology, 2021) https://cset.georgetown.edu/publication/china-is-fast-outpacing-u-s-stem-phd-growth/ (last accessed 8 March 2023).

Defense AI Observatory Studies

23|13 John Lee, "Overtaking on the Curve?" Defense AI in China

23|12 Heiko Borchert, Torben Schütz, and Joseph Verbovszky, Master and Servant. Defense AI in Germany

23|11 Katarzyna Zysk, High Hopes Amid Hard Realities. Defense AI in Russia

23|10 Yvonne Hofstetter and Joseph Verbovzsky, How AI Learns the Bundeswehr's "Innere Führung." Value-Based Engineering with IEEE7000™-2021

23|09 Robert C Engen, When the Teeth Eat the Tail: A Review of Canada's Defence Artificial Intelligence

23|08 Çağlar Kurç, Enabling Technology of Future Warfare. Defense AI in Turkey

23|07 Lauren A. Kahn, Risky Incrementalism. Defense AI in the United States

22|06 Yvonne Hofstetter, Wie KI Innere Führung lernt. Wertbasierte Technik mit IEEE7000™-2021

22|05 Andrea Gilli, Mauro Gilli, and Ivan Zaccagnini, Exploring the Benefits of a New Force Enabler: Defense AI in Italy

22|04 Kenneth Payne, Bright Prospects – Big Challenges. Defense AI in the United Kingdom

22|03 Heiko Borchert, Christian Brandlhuber, Armin Brandstetter, and Gary S. Schaal, Free Jazz on the Battlefield. How GhostPlay's AI Approach Enhances Air Defense

22|02 Peter Layton, Evolution not Revolution. Australia's Defence AI Pathway

21|01 Heiko Borchert, Torben Schütz, Joseph Verbovszky, Beware the Hype. What Military Conflicts in Ukraine, Syria, Libya, and Nagorno-Karabakh (Don't) Tell Us About the Future of War

Defense AI Observatory

www.defenseai.eu