

SHANSHAN MEI

The People's Liberation Army's Approach to Manned-Unmanned Teaming

Theory and Practice



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About This Report

Over the past decade, the People's Liberation Army (PLA) has been monitoring the evolution of U.S. approaches to strengthening combat effectiveness through enhanced collaborations between manned and unmanned combat systems, known as manned-unmanned teaming (MUM-T). The PLA has analyzed key milestones in U.S. MUM-T development to identify U.S. military vulnerabilities, fine-tune its own defense acquisition strategies, and develop countermeasures. As MUM-T further integrates into the Department of the Air Force's (DAF's) Collaborative Combat Aircraft and related programs, the PLA appears to be experimenting with similar strategies, with modifications to fit its own combat requirements. As of 2025, the PLA assesses that, to optimize combat effects, a defining feature of future warfare will be integrating artificial intelligence-enhanced unmanned systems with combat networks that are dominated by manned platforms. The PLA is also likely planning to position itself more advantageously in the event of future combat.

For this study, the author used primarily publicly available information to investigate Chinese perspectives on MUM-T in air combat. This information helped identify key stakeholders and advocates for MUM-T within China's military-industrial complex and analyze whether—and potentially how—the PLA plans to integrate MUM-T into military operations. The author also conducted an analysis of the PLA's potential challenges with political control under MUM-T conditions. This report presents preliminary recommendations for DAF leaders and strategists to consider while the DAF continues to develop advanced MUM-T warfighting concepts.

The intended audience for this report includes DAF senior leaders, strategists and acquisition professionals, and military researchers who are interested in understanding the PLA's future air combat capabilities and concepts. This research is also intended to provide insights on PLA doctrine and strategy development.

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Summary

Issue

As the Department of the Air Force (DAF) accelerates its testing of manned-unmanned teaming (MUM-T) concepts and further integrates the Collaborative Combat Aircraft (CCA) program into operations against highly capable adversaries, it is critical for U.S. Department of Defense (DoD) and DAF planners, strategists, and analysts to better understand Chinese perspectives and similar lines of effort to integrate autonomous systems into air operations. Insights into China's MUM-T capabilities can inform the DAF's operational planning, enhance interoperability with allied forces, and guide investment in relevant technologies. Additionally, understanding China's approach to MUM-T can help the DAF anticipate and counter adversarial tactics, ensuring that U.S. forces maintain a strategic advantage in the foreseeable future.

Approach

For this study, the author relied on open-source Chinese-language publications to analyze the Chinese defense community's perspectives regarding technologies in air combat. This information helped identify key stakeholders and advocates for MUM-T within China's military-industrial complex. The following research questions were investigated:

- Is the People's Liberation Army (PLA) planning to integrate MUM-T and counterstrategies into its own development of concepts of operations? How does it plan to do that?
- How does the PLA perceive the DAF's emphasis on MUM-T as a defining feature of future combat capability?
- More broadly, what do we know about the PLA's perspective on the man-machine relationship and the role of autonomous systems in warfare?

Key Findings

- The PLA assesses that MUM-T will be a defining feature of future combat activities involving intelligent systems and is in the nascent stages of developing operational concepts to integrate MUM-T into its existing doctrine.
- Since 2015, the PLA has monitored developments in U.S. MUM-T concepts and technologies to identify U.S. vulnerabilities and develop countermeasures.
- As of early 2025, the PLA appears to be taking a different approach to MUM-T than the U.S. Air Force, focusing more on enhancing software and algorithms to enable unmanned systems to support and augment manned platforms. While both militaries prioritize cost-effective

CCA-type capabilities, the PLA emphasizes augmentation over advanced teaming, which demands greater autonomy for unmanned systems.

- The PLA is in the nascent stages of developing operational concepts to integrate MUM-T.
- PLA writings emphasize the importance of reinforcing the wartime party committee's role under manned-unmanned collaborative combat conditions. Finding the right balance between automation and political control likely will remain a challenge in the near future.

Recommendations

Although the U.S. integration of MUM-T into the development of future operational concepts remains at a preliminary stage, it is the right time for the United States to adopt a competitive strategy to ensure that the DAF maintains its technological and conceptual advantages. To that end, the following policy recommendations are based on the initial findings in this report:

- Leverage red-teaming analysis to develop tailored strategic messaging around the U.S. research, development, and acquisition of MUM-T capabilities.
- Use MUM-T and CCA development as a case to inject “conceal and reveal” strategies into capability development.
- The PLA is poised to accelerate its adoption and integration of more autonomous systems into military operations in the next decade. Accordingly, in addition to platform capabilities, direct or designate relevant intelligence components to focus on the analysis of PLA organization, doctrine, and training in assessments of PLA MUM-T capabilities.
- Make a concerted and targeted effort to significantly boost the protection of the electromagnetic spectrum. Electromagnetic warfare collaboration with allied and partner militaries and defense industrial bases should be expanded.
- As the DAF stands up the Integrated Capabilities Command, it should ensure that its intelligence cell—augmented by China specialists—actively monitors, analyzes, and informs the command's acquisition activities on the PLA's electromagnetic warfare and information warfare capabilities.
- Gain a better understanding of the PLA's insecurity about political control under complex combat conditions, which are increasingly shaped by artificial intelligence and unmanned systems, to develop tailored concepts of employment for CCA.

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Introduction

The Department of the Air Force (DAF) is, at the time of this writing, undertaking several changes to its organizational principles and doctrine that are aimed at securing U.S. military advantages in the coming decades. The Next Generation Air Dominance (NGAD) program's family of systems is a critical component of the DAF's effort to advance air superiority in contested combat environments. Its Collaborative Combat Aircraft (CCA) program is a subsystem of NGAD that may include a crewed fighter platform, sensors, and weapons in the future.¹ NGAD and CCA reflect an increasing emphasis on concepts of operations (CONOPS) driven by manned-unmanned teaming (MUM-T) technologies in potential conflicts with the People's Liberation Army (PLA). Chinese defense researchers and the PLA's military services have closely monitored the technological trends of MUM-T and its military applications. As of 2025, the PLA appears to share the DAF's view that advances in artificial intelligence (AI) and autonomous systems are ushering in a new era of human-machine collaboration and combat-teaming to advance air superiority.²

For this report, the author used open-source Chinese-language primary sources to investigate prevalent Chinese perspectives on MUM-T in air combat. Those sources helped identify key stakeholders and supporters for MUM-T within China's military-industrial complex. The author also analyzed if, and potentially how, the PLA plans to integrate MUM-T into future operations performed. The following key questions prompted this study:

- Is the PLA planning to integrate MUM-T and counterstrategies into its own development of CONOPS? How does it plan to do that?
- How does the PLA perceive the DAF's emphasis on MUM-T as a defining feature of future combat capability?
- More broadly, what do we know about PLA's perspective on the man-machine relationship and the role of autonomous systems in warfare?

This report contains five chapters. Following this chapter, Chinese Communist Party perspectives on the human-machine relationship at foundational and technical levels are discussed in Chapter 2. There is also a brief comparison of PLA perceptions of the man-machine relationship with prevalent Western military perspectives and an effort to shed light on the political factors that may affect the PLA's future integration of MUM-T capabilities into its doctrine and operations. Chapter 3 contains

¹ Jennifer DiMascio, "U.S. Air Force Collaborative Combat Aircraft (CCA)," Congressional Research Service, IF12740, version 4, updated January 22, 2025.

² *Collaboration* is defined by Robert Work, a former undersecretary of defense and a key architect of the U.S. Third Offset Strategy, as "using the tactical acuity of a computer to help a human make better decisions and human-machine combat teaming is using manned and unmanned platforms" (Mark Pomerleau, "DoD's Third Offset Strategy: What Man and Machine Can Do Together," *Defense One*, May 4, 2016).

a summary of Chinese military assessments of U.S. doctrinal concepts that are based on and enabled by breakthrough MUM-T capabilities. Chapter 4 presents an analysis of the PLA's self-assessment of the prospect of adopting MUM-T into its own CONOPS and the potential applications of MUM-T in future combat. Chapter 5 provides conclusions and recommendations for the DAF to consider.

The aim of this report is to improve public understanding of PLA perceptions and practices regarding MUM-T. By providing insight into adversary perceptions of the U.S. research, development, and acquisition of U.S. MUM-T capabilities, the analysis presented in this report can inform the DAF and U.S. Department of Defense (DoD) program assessments. The insights gleaned through this examination of PLA concepts related to teaming in future warfare can also inform evaluations of broader PLA modernization efforts that include increasing the integration of autonomous systems in the long term.

Research Approach

Source Material

For this report, the author used more than 50 open-source Chinese-language publications to analyze the Chinese defense community's perspectives regarding MUM-T topics. The search was limited to publications since 2016, when the U.S. Third Offset Strategy—with an emphasis on MUM-T—was officially launched, but older publications that prominently feature in those texts were also reviewed. Given China's unique media environment, in which the state has almost total control over media content and how information flows, there are occasional references to nonofficial Chinese netizen and social media discussions to help gauge general sentiments. The sources the author references in this report include the following:

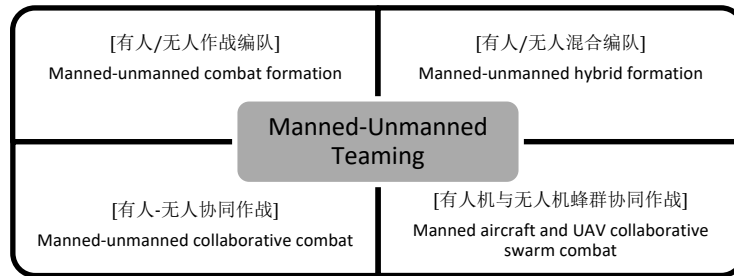
- speeches and writings from Chinese Communist Party General Secretary and Chairman of the Central Military Commission (CMC) Xi Jinping and statements from other Chinese Communist Party leaders, senior PLA officers, and government officials
- media products—such as text, videos, and social media entries—published by *PLA Daily* (解放军报) (the official mouthpiece of the CMC), China Central Television (CCTV), and other notable state-sponsored media outlets, including Xinhua news, *People's Daily* (人民日报), and Chinese provincial government websites and sponsored newspapers
- book chapters, journal articles, and academic conference papers published by authors who are either serving in or affiliated with the PLA and Chinese research institutions with close ties to the PLA
- authoritative Chinese military texts, including versions of China's Defense White Papers and such military education texts as the *Science of Military Strategy*.

Terminology

The concept of *manned-unmanned teaming*, or MUM-T, is a borrowed term in PLA parlance; therefore, multiple Chinese-language variations of the concept exist that describe the English concept of MUM-T. After reviewing numerous Chinese-language uses and the contexts in which such uses

appear, the author determined that China’s preferred translation of *teaming* into Chinese is *xietong* (协同), which implies *coordination* and *synchronizing*. For this report, all the Chinese terms that are depicted in Figure 1.1 were taken into consideration.

Figure 1.1. Key Chinese Terms Equivalent to Manned-Unmanned Teaming



NOTE: UAV = unmanned aerial vehicle.

Scoping

For this report, the author focused on Chinese writings about the *teaming* or *collaborative* aspects of unmanned warfare and not the PLA’s views of fully autonomous systems and drone warfare.³ Human-machine brain interface–related issues are not discussed. The author did consider Chinese-language descriptions of UAVs, such as the Chinese “Loyal Wingman” platform FH-97A, but the analysis was limited to official discussions about how the PLA intends to integrate such platforms in operational constructs and not the capabilities of the platforms. Moreover, the author’s main consideration was the PLA’s thinking about how to employ MUM-T–type operations in the air domain, and only land- and sea-based operations that are intended to supplement air operations are referenced.

³ For a comprehensive study on China’s unmanned systems, see Michael S. Chase, Kristen Gunness, Lyle J. Morris, Samuel K. Berkowitz, and Benjamin Purser, *Emerging Trends in China’s Development of Unmanned Systems*, RAND Corporation, RR-990-OSD, 2015.

Is One Plus One Greater Than Two? People's Liberation Army Thinking on Human-Machine Interactions

Discussions within China's defense community and from PLA authors about MUM-T shed light on broader Chinese perspectives about autonomous systems in future warfare and the relationship between man and machines. China's military technologists generally share Western military authors' optimism about the potential benefits of integrating MUM-T into combat to create information and decision advantages. However, differing perspectives likely exist within China's defense community, and questions remain about how the military intends to implement MUM-T, particularly given the rapid pace of technological advancements underpinning this concept. This chapter presents previously understudied literature on PLA understandings of optimized MUM-T operations and more-general views on autonomy and man-machine integration. First, PLA discourse on defining an appropriate ratio of manned and unmanned elements to best achieve desired MUM-T effects is unpacked. Next comes a summary and preliminary analysis of PLA views on how to develop trust between human and AI-enabled unmanned systems. Finally, this is followed by the PLA's dilemma of asserting political control over military operations that are increasingly defined by the ubiquitous presence of stand-alone, unmanned systems and MUM-T.

It Is People, Not Things, That Are Decisive

PLA authors' views about modern warfare and human-machine relationships continue to be shaped by Marxist war theories and Chairman Mao Zedong's interpretations of those theories.⁴ In

⁴Jian Zihan [简子涵], "Examining Modern Wars with the Marxist View of War" ["用马克思主义战争观检视现代战争"], *PLA Daily* [解放军报], June 7, 2016; Yang Wenzhe [杨文哲], "Exploring the Way to Win Intelligent Warfare Amidst Change and Immutability" ["在变与不变中探寻智能化战争制胜之道"], *PLA Daily* [解放军报], October 22, 2019; Xu Zhongbo [徐忠波], "The Key Factor That Determines the Outcome of a War Is People" ["决定战争胜负的关键因素是人"], *PLA Daily* [解放军报], October 25, 2015; Huang Yingxu [黄迎旭], "To Win the Information War, People Are the Decisive Factor" ["要打赢信息化战争, 人是决定因素"], *PLA Daily* [解放军报], January 9, 2017; Zhao Wanxu [赵万须] and Zhai Qinghua [翟清华], "On Mao Zedong's Views on the Main Determinants of Victory or Defeat in War" ["论毛泽东关于战争胜负的主要决定因素观点"], *Mao Zedong and the Great Rejuvenation of the Chinese Nation: Proceedings of an Academic Seminar Commemorating the 120th Anniversary of the Birth of Comrade Mao Zedong (Part 2)* [毛泽东与中华民族伟大复兴: 纪念毛泽东同志诞辰120周年学术研讨会论文集(下)], Central Compilation Press [中央文献出版社], 2014; Li Jiyong [李计勇] and Zou Li [邹力], "Grasping the Integration Point of Theory and Technology for Innovative Tactics" ["找准战法创新的理技融合点"], *PLA Daily* [解放军报], May 9, 2023; Liang Yongqiang [梁永强], Wang Wei [王威], and Jiang Zhen [姜振], "Understanding Human-Machine Relationships in Future Wars" ["厘清未来战争中的人机关系"], *PLA Daily* [解放军报], June 11, 2020.

discussions about modern warfare, PLA theorists frequently reference the following well-known statement in Mao's 1938 book, *On Protracted War*: "Weapons are an important factor in war, but not the decisive factor; it is people, not things, that are decisive."⁵ President Xi Jinping's theory about man-equipment and man-machine factors in war is essentially an interpretation of Mao's statement, except that he went a step further to claim that people are a decisive factor to "winning a war."⁶ In his address to a PLA equipment conference in 2014, Xi noted,

When it comes to winning a war, people are the decisive factor. At the same time, we must also see that with the continuous development of military technology, the importance of equipment factors is rising. The human factors and weapon factors are becoming more and more closely integrated. Human and equipment have become highly integrated. Paying attention to weapon factors also means paying attention to human factors.⁷

Mao and Xi's statements provide a critical yet understudied context for understanding the fundamental principles that shape PLA and China's defense community's thinking about MUM-T and military AI. Xi's "theory of victory" allows the PLA to accelerate the development and integration of more modern weapon systems into the total force, but it also leaves room for interpretation and internal debate to define what exactly the desired ratio between human factors and weapon factors should be.⁸

To date, the PLA has not provided an exact answer to the question of ratio, but many writers have laid out key ingredients (i.e., factors and considerations) that should be taken into consideration while searching for the Goldilocks solution (see Figure 2.1). The top concern revolves around the issue of making unmanned and manned platforms truly compatible. For instance, in the air, various types of UAVs need "similar flight performance characteristics to different types of manned aircraft, especially speed, altitude, [and] maneuvering overload, and . . . the weapon load and performance must also adapt to the needs of collaborative operations."⁹

⁵ Mao Zedong [毛泽东], *Selected Military Writings of Mao Zedong* [毛泽东军事文集], Vol. 2, Academy of Military Science Press [军事科学出版社] and Central Party Literature Publishing House [中央文献出版社], 1993, p. 297.

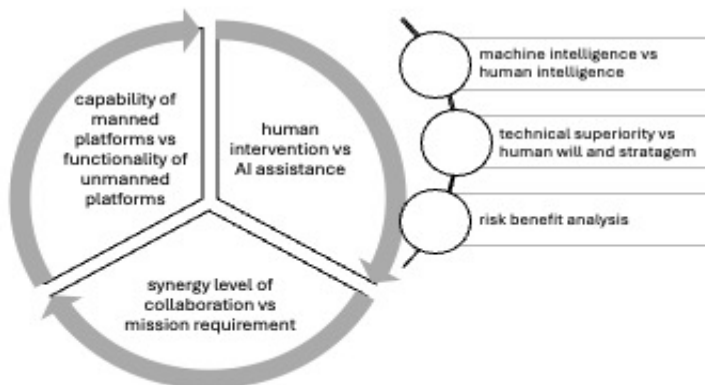
⁶ "Xi Jinping Emphasized at the Meeting on Equipment Work of the Whole Army: Accelerate the Construction of an Equipment System That Meets the Requirements of Fulfilling Missions" ["在出席全军装备工作会议时强调: 加快构建适应履行使命要求的装备体系"], *People's Daily* [人民日报], December 5, 2014; italics added.

⁷ "Xi Jinping Emphasized," 2014.

⁸ "Xi Jinping Emphasized," 2014.

⁹ Zhao Xiangang [赵先刚] and Lu Cong [吕聪], "Accurately Grasp the Balance Point of Manned/Unmanned Collaborative Operations—Opening the Door to Victory in Unmanned Operations" ["准确把握有人/无人协同作战的平衡点—叩开无人作战制胜之门"], *PLA Daily* [解放军报], April 20, 2023, p. 7.

Figure 2.1. Key Considerations to Determine the Goldilocks Solution



The reality is that, despite the official PLA media’s rhetorical embrace of military AI and intelligent warfare, debates within the defense community and the PLA likely exist. It is possible that China’s defense industry and PLA technologists are pitted against more-conservative forces within the military often affiliated with PLA research institutes that focus on Marxism, Leninism, and Xi Jinping thought studies.¹⁰ It is also likely that debates about the direction of doctrinal development and, perhaps more importantly, how the PLA will be allocating resources to realize the benefits of putting MUM-T into future battlefields remain largely undecided.¹¹

Although they do not often provide direct criticisms or total rejections, numerous *PLA Daily* commentaries on the topics of modern warfare and MUM-T–related issues highlight the importance of “seeking balance” between humans and the adoption of machines. This is mainly because the level of intelligence that machines can achieve remains low at the time of this writing.¹² For instance, in a 2023 *PLA Daily* article, authors who are affiliated with the PLA’s National Defense University, College of Joint Operations, wrote that the overall level of autonomous weapons remains low. When operating under

¹⁰ Zhao and Zhai, 2014.

¹¹ This statement also applies to the PLA’s doctrinal development writ large. The PLA is still grappling with how to develop and improve its *joint doctrine system-of-systems* [联合作战体系] under the *core operational concept*—namely, *multi-domain precision warfare*, which is supported by service-specific doctrine and concepts. For an informed discussion of this topic in English, see David M. Finkelstein, *The PLA’s New Joint Doctrine: The Capstone of the New Era Operations Regulations System*, Center for Naval Analyses, September 2021. For a discussion of this topic in Chinese, see “Xi Jinping: Hold High the Great Banner of Socialism with Chinese Characteristics and Work Together to Build a Modern Socialist Country in All Respects—Report to the 20th Party Congress of the Chinese Communist Party” [“高举中国特色社会主义伟大旗帜，为全面建设社会主义现代化国家而团结奋斗—在中国共产党第二十次全国代表大会上的报告”], *Xinhua* [新华社], October 25, 2022; Han Lin [韩林], Wei Bing [魏兵], and Liu Jianwei [刘建伟], “Promoting Joint Operations Training to Achieve Higher Standards—A One-Year Review of the Implementation of the *Guidelines of Joint Operations of the People’s Liberation Army of China (Trial)*,” *PLA Daily* [解放军报], January 5, 2022, p. 8; and Li Wenqing [李文清] and Zhou Dewang [周德旺], “Optimizing Joint Operations Command System of Systems” [“优化联合作战指挥体系”], *PLA Daily* [解放军报], January 5, 2023, p. 7.

¹² Zhao and Lu, 2023, p. 7; Zeng Zilin [曾子林], “How to ‘Intelligently Mix and Match’ Humans and Machines” [“人机如何‘智能化混搭’”], *PLA Daily* [解放军报], July 22, 2021, p. 7; Sam Bresnick, *China’s Military AI Roadblocks: PRC Perspectives on Technological Challenges to Intelligentized Warfare*, Center for Security and Emerging Technology, June 2024.

highly complex, highly volatile, and uncertain situations that come with intense confrontations . . . if the operations will be entirely dependent on the human operators on manned platforms . . . it is going to be difficult to adapt to the fast pace of war and deliver any desired MUM-T effects.¹³

To achieve this objective, the autonomy of unmanned combat platforms and manned combat platforms must be improved to adapt to collaborative operations on the basis of different collaborative combat levels and combat grouping types.¹⁴

Another key factor concerns the level of assistance AI provides to human operators in a collaborative relationship without causing human cognitive overload.¹⁵ As the systems become more complex, ensuring that operators can effectively manage and respond to information and control systems is critical. Although it is unclear whether efforts are already underway to improve training and interface design to ensure that MUM-T can be used effectively and safely in future air combat, potential solutions to such challenges, PLA researchers argue, include reconstructing the PLA's command and control (C2) structure to allow UAVs to serve as key C2 hubs when space-based communication and navigation capabilities are destroyed.¹⁶

Finally, these PLA authors argue that mission requirements should be used as the benchmark for determining the synergy level of present collaboration.¹⁷ The bottom line is that not all missions require MUM-T, and certain missions may be better suited to traditional platforms rather than adding complexities that are less efficient. For instance, in terms of cooperation between long-range intelligence, surveillance, and reconnaissance UAVs and land-based fire strike units for ground attacks, direct communication and information exchange between these units allow for the effective use of UAV-collected data for decisionmaking, fire planning, target guidance, and damage assessment without the need to control the UAVs' flight.¹⁸ But the UAVs' maneuvering should remain under the control of a rear control station to avoid overloading the fire strike units and distracting them from their primary tasks, which reduces efficiency.¹⁹

Trust but Supervise?

At the core of MUM-T lies the critical issue of building trust in human-machine teams.²⁰ PLA researchers and commentators have written about this issue at the philosophical and technical levels,

¹³ Zhao and Lu, 2023, p. 7.

¹⁴ Zhao and Lu, 2023.

¹⁵ Livio Rossetti, "Manned-Unmanned Teaming: A Great Opportunity or Mission Overload?" *Journal of JAPCC*, Vol. 29, January 2020.

¹⁶ Zhao and Lu, 2023; Chen Yugong [陈育功], "Research on the Realization Methods of Autonomous Collaborative Operations of Swarm Intelligent Unmanned Systems" ["群体智能无人系统自主协同作战实现方法研究"], *China Military Science* [中国军事科学], Vol. 4, No. 172, 2022, p. 15.

¹⁷ Zhao and Lu, 2023.

¹⁸ Zhao and Lu, 2023.

¹⁹ Zhao and Lu, 2023.

²⁰ Margarita Konaev and Husanjot Chahal, "Building Trust in Human-Machine Teams," Brookings Institution, February 18, 2021.

as will be discussed in this section, but publicly available information on this topic does not reveal whether the PLA has developed effective measures to address trust concerns between human operators and unmanned platform systems in technical training and military exercises. The PLA exists in an Orwellian society, in which the Chinese Communist Party is the Big Brother watching over everyone and everything. In such a low-trust political environment, subordinates executing a mission are often concerned about superiors watching over their shoulders as they conduct operations with unmanned platforms. More importantly, a challenge that is perhaps unique to the PLA is how a military that is built on the principle of top-down control reconciles the concept of *autonomy* with the need for PLA senior leaders to trust autonomous platforms and algorithms to conduct operations at a speed that prevents absolute human (i.e., senior leader) control. Does the PLA plan to apply political work requirements—long touted as the “magic weapon” to ensure human political loyalty to the Chinese Communist Party—to autonomous systems and MUM-T? If so, how?²¹

At the philosophical and foundational levels, the man-machine-environment system engineering (MMESE) principle developed by Qian Xuesen continues to be influential.²² MMESE focuses on the interaction and integration among humans, machines, and their surrounding environment in complex systems. The MMESE principle emphasizes understanding how these three elements influence each other to optimize performance and efficiency in various applications, particularly in engineering, aerospace, and systems design.²³

At the technical level, although there is consensus that building trust between human operators and machines is critical for future intelligent air combat, most of the Chinese discussions examined for this analysis are descriptive. For instance, researchers from the Jiuquan-based PLA Air Force (PLAAF) Unit 93210 (Test and Training Base) and the Beijing Institute of Technology acknowledged that the development of AI in the field of air combat requires more research to “formulate standards for human-machine interaction models to achieve integrated human-machine interaction and mutual trust to help improve overall mission effectiveness.”²⁴ They further broke down the *how* into the subcategories of “human-machine function allocation, mutual trust training, and collaborative operations” without providing further details.²⁵ PLA authors also discussed the necessity of developing a brain-machine interface to use machine learning to analyze, train, and decode human

²¹ The PLA’s political work system ensures that the Chinese Communist Party has absolute control over the military through such mechanisms as political commissars, party committees, and ideological education. It integrates political oversight into all aspects of military operations, recruitment, and decisionmaking, emphasizing loyalty to the party rather than the state.

²² Qian Xuesen [钱学森], a U.S.-educated scientist, is widely regarded as the “father of China’s missile and space programme” and nuclear weapons (“Qian Xuesen: The Man the U.S. Deported—Who Then Helped China into Space,” BBC, October 26, 2020).

²³ Long Zhengzhao, “Overview of Man-Machine-Environment System Engineering,” Beijing KeCui Man-Machine-Environment System Engineering Technology Research Institute, April 1, 2020; “The Great Scientist Qian Xuesen Highly Praised the Man-Machine-Environment System Engineering” [“伟大科学家钱学森对人-机-环境系统工程的高度评价”], Beijing KeCui Man-Machine-Environment System Engineering Technology Research Institute, April 1, 2020; Systems Engineering Society of China, “Introduction to the Human-Machine-Environmental Systems Engineering Committee” [“人-机-环境系统工程专委会简介”], August 29, 2024; Qi Jiayin [齐佳音], “Reflections on Human-Machine Teaming Intelligence Decision-Making” [“人机混合智能决策的一点思考”], Science Network, April 20, 2023.

²⁴ Ye Kunwu [叶坤武], Niu Chao [牛超], Liu Zehua (刘泽华), Luo Diqin [罗堤钦], and Yang Wenjia [杨文佳], “Human-Machine Relationship in Intelligent Air Combat” [“智能空战中的人机关系”], *Proceedings of the 11th China Conference on Command and Control*, Ordnance Industry Press [兵器工业出版社], October 2023, p. 38.

²⁵ Ye et al., 2023, p. 38.

operators' brain waves to accurately comprehend human intent in the future.²⁶ But trust has to be mutual, and the PLA will need to “ensure [that] human operators fully understand the underlying logic of machines' decision-making and the inner workings of algorithms.”²⁷

What is left unsaid in the PLA literature about building trust in MUM-T pertains to the issue of political control under modern warfare conditions. This lack of information may reflect the topic's sensitive nature. However, at least two strands of thinking are apparent in discussions that call for the PLA's political work system to keep pace with the times and “adapt to the military era of intelligent machines.”²⁸ PLA authors who are affiliated with the Army Medical University reiterated that the “human factor [is] the most decisive” in the military AI age and argued that enhanced political indoctrination must be built into the training of human operators to reduce the political risks of MUM-T gone awry.²⁹ The authors, perhaps reflecting on certain military programs that are being carried out at the medical institution, also put a particular emphasis on improving censorship, psychological defense, and counterattack measures to protect PLA personnel from adversary psychological attacks that seek to exert mind control under AI-enabled combat conditions.³⁰

However, as noted above, discussions about maintaining balance between man and machine in military operations suggest that the PLA may be struggling with sustaining the Chinese Communist Party's total political control while seeking to maximize the benefits of man-machine collaborations.³¹ There are discussions about improving wartime party committees at various echelons of leadership under modern warfare conditions.³² Influential PLA journals have published articles that argue for increasing data-driven decisionmaking processes as a way to mitigate human error, and an intense emphasis has been placed on using data—and math and operations research—to precisely understand mission requirements and the intent of higher echelon leadership. It is as if the PLA trusts machines and algorithms more than human operators, given that properly programmed autonomous systems may be more controllable and predictable than human operators. Notably, PLA authors also warn of an adversary (possibly referencing the United States) accelerating from “effect-centric” to “decision-centric” warfare to impose “high intensity cognitive disruption” on the PLA. These authors urge unit party committees to adapt distributed decisionmaking on the basis of information networks, assume a “key node decision role,” and allow “anticipatory decision-making.”³³

²⁶ Zeng, 2021, p. 7.

²⁷ Zeng, 2021, p. 7.

²⁸ Kang Huaihai [康怀海], “Integrate Emerging Fields, Innovate Thinking and Concepts, and Promote the Intelligent Development of Political Work” [“融合新兴领域, 创新思维理念, 推动政治工作向智慧化发展”], *PLA Daily* [解放军报], May 30, 2024; Zhang Fengpo [张凤坡], “Intelligent Warfare Also Requires Good Political Work” [“智能作战也要做好政治工作”], *Study Times* [学习时报], January 14, 2019.

²⁹ China Social Sciences Network [中国社会科学网澎湃账户], “Strengthening the Political Work of the Military in the Era of Military Intelligence” [“加强军事智能化时代的军队政治工作”], *The Paper* [澎湃新闻], November 21, 2019.

³⁰ China Social Sciences Network, 2019.

³¹ “Lifeline Is Revitalized in Intelligent Warfare” [“生命线在智能化作战中焕发新活力”], *China Social Sciences Journal* [中国社会科学报], February 4, 2021; Chue Xiangqian [啜向前], Sun Wei [孙炜], and Li Yongbing [栗勇兵], “Attach Importance to Carrying Out Intelligent Command Training” [“重视开展智能化指挥训练”], *PLA Daily* [解放军报], April 27, 2023, p. 7.

³² Wu Dingping [吴定平], Cao Ergang [曹二刚], and Su Shengdi [苏生迪], “Preliminary Discussion of Military Party Leadership and Construction Under Intelligentized Conditions” [“刍议智能化条件下军队党的领导和党的建设”], *China Military Science* [中国军事科学], No. 187, 2023, p. 29.

³³ Wu, Cao, and Su, 2023, p. 29.

Conclusion

This chapter presented Chinese perspectives on MUM-T and its broad implications, beginning by delving into the philosophical and foundational beliefs of the Chinese Communist Party leadership's thinking about the relationship between human and machine. This was followed by an analysis of China's defense community's ongoing efforts to define the Goldilocks solution that best mixes and matches manned platforms and AI-enabled unmanned capabilities in future combat designs. The findings highlight the optimism shared by China's military technologists regarding the integration of MUM-T to enhance operational effectiveness but also suggest that internal debates within China likely exist because of the Chinese Communist Party's anxiety about maintaining absolute political control under intelligent warfare conditions.

People's Liberation Army Assessments of U.S. Manned- Unmanned Teaming Theory and Practice

Since 2015, the PLA has monitored the evolution of U.S. approaches to MUM-T and analyzed key milestones in this evolution to identify perceived U.S. military operational vulnerabilities, fine-tune its own defense acquisition strategies, and develop countermeasures. The PLA assesses that MUM-T is becoming a critical feature of all future combat involving intelligent systems, and it will become a standard component of U.S. future combat. The evolution of U.S. operational concepts and capabilities likely have influenced, but not determined, the PLA's adoption and integration of unmanned systems into Chinese doctrines.

From Network-Centric to Mosaic Warfare

PLA scholars have closely monitored the evolution of U.S. thinking about how to deepen human-machine collaboration to advance combat effectiveness in an age of information revolution and the proliferation of machine intelligence. Since the mid-2000s, Chinese defense researchers and military analysts have published numerous research papers, commentaries, and books to introduce such topics as network-centric warfare and mosaic warfare to Chinese readers.³⁴ Figure 3.1 provides an overview of a selected list of MUM-T-related U.S. military programs that have been referenced by Chinese defense researchers. Chinese writers appear to think that future warfare between technologically

³⁴ Zhao Renxing [赵仁星], Wang Ling [王玲], Feng Mingyue [冯明月], and Jia Wentong [贾文通], "Analysis of the Combat Concept 'Mosaic Warfare' and Countermeasures" ["马赛克战'作战概念构想及对策分析"], *Aerospace Defense* [空天防御], Vol. 4, No. 3, 2021; Li Qing [李清], "Discussion on U.S. Military's 'Mosaic Warfare'" ["说说美军'马赛克战'"], *China Aviation News* [中国航空报], December 24, 2020; Yang Cunyin [杨存银], "From 'Cyber Warfare' to 'Mosaic Warfare'" ["从'赛博战'到'马赛克战'"], *PLA Daily* [解放军报], September 14, 2021; Deng Peng [邓鹏], Ding Hao [丁浩], Zhang Yong [张永], and Wang Xinhua [王新华], "Discussion on the Use of Underwater Manned and Unmanned Combat Based on 'Mosaic Warfare'" ["基于'马赛克战'的水下有人-无人作战使用探讨"], *Ship Science and Technology* [舰船科学技术], Vol. 46, No. 1, 2024, pp. 186–189; Yang Fan [杨帆] and Dong Zhenghong [董正宏], "Research on Cooperation Technologies and Combat Patterns of Manned/Unmanned Platforms" ["有人/无人平台协同技术与行动模式研究"], *Defense Technology Review* [国防科技], Vol. 39, No. 4, August 2018; Tang Yi-feng [汤一峰], "Analysis of the History and Progress of the US Air Force's Distributed Operations from the Perspective of System Integration Technology and Experimental Projects" ["从体系综合技术与试验项目分析美空军分布式作战历程与进展"], *Avionics Technology* [航空电子技术], Vol. 54, No. 4, December 2023; Fu Bingzhong [傅秉忠], "Research on the Concept of Integrated Unmanned Warfare" ["天地一体无人战概念研究"], *Military Art* [军事学术], Vol. 1, No. 554, 2022.

advanced powers is increasingly a competition of decisionmaking quality and speed on the battlefield.³⁵ To that end, integrating AI-enabled autonomous systems to enhance or replace human-driven decisionmaking processes is perceived as both a necessity and an inevitability.³⁶

Figure 3.1. Selected List of Key U.S. Programs Related to Manned-Unmanned Teaming Referenced in Chinese Defense Writings

体系综合技术和试验 [System of Systems Integration Technology and Experimentation, SoSite]	跨域海上监视与目标定位 [Cross-Domain Maritime Surveillance and Targeting, CDMaST]	复杂适应性系统组合与设计环境 [Complex Adaptive System Composition and Design Environment, CASCADE]	进攻性蜂群使能战术 [OFFensive Swarm-enabled tactics, OFFSITE]	“拒止环境中协同作战项目” [Collaborative Operations in Denied Environment, CODE]
“分布式战场管理” [Distributed Battle Management, DBM]	“无人机操作最佳角色分配管理控制系统” [Systematizing Confidence in Open Research and Evidence, SCORCH]	马赛克战 [Mosaic Warfare]	“中平台间的通信能力对抗环境中的通信” [Communications in Contested Environments, C2E]	“满足任务最优化的动态适应网络” [Dynamic Network Adaptation for Mission Optimization, DyNAMO]
	未来机载能力环境 [Future Airborne Capability Environment, FACE]	开放式任务系统 [Open Mission Systems, OMS]	天空博格 [Skyborg]	

Mosaic warfare is an operational vision originally proposed by the U.S. Defense Advanced Research Projects Agency’s (DARPA’s) Strategic Technology Office in 2019 to turn the complexity of weapon and sensor platforms into an asymmetric advantage.³⁷ The U.S. architect behind mosaic warfare, Timothy Grayson, said that the driving factors behind changing U.S. perceptions about future warfare are varying force projection requirements and employment in contested environments to deliver speed, lethality, and surprises.³⁸ Mosaic warfare aims to enhance America’s military competitiveness in peer-to-peer conflicts by harnessing information networks, advanced data processing, and distributed capabilities.³⁹ Influential PLA thinkers appear to perceive mosaic warfare—and its key component of employing MUM-T for warfighting—as a natural progression

³⁵ Yu Quan [于全], “From ‘Network Center’ to ‘Decision-Making Center’: Deciphering the U.S. Mosaic Warfare” [“从‘网络中心’到‘决策中心’: 解读美军马赛克战”], *PLA Daily* [解放军报], December 23, 2023; Xue Ya [薛亚], Tan Xiaolong [谭小龙], and Li Qinan [李奇男], “Exploring the Development Rules of Building New Quality Combat Effectiveness” [“探寻新质战斗力建设发展规律”], *PLA Daily* [解放军报], March 23, 2021.

³⁵ Edmund J. Burke, Kristen Gunness, Cortez A. Cooper III, and Mark Cozad, *People’s Liberation Army Operational Concepts*, RAND Corporation, RR-A394-1, 2020.

³⁶ Yu, 2023; Xue, Tan, and Li, 2021; Liu Haijiang [刘海江], “Accelerate the Innovation and Transformation of Operational Concepts—Generating New Combat Capabilities Through Operational Concept Innovation Is an Inevitable Choice to Achieve Strategic Initiative” [“加速推进作战概念创新转化—通过作战概念创新生成新质作战能力是达成战略主动的必然选择”], *PLA Daily* [解放军报], June 23, 2022.

³⁷ DARPA, “Strategic Technology Office Outlines Vision for ‘Mosaic Warfare,’” August 4, 2017.

³⁸ DARPA tv, “Mosaic Warfare and Multi-Domain Battle,” video, September 24, 2018.

³⁹ David A. Deptula and Heather Penney, “Mosaic Warfare,” *Air & Space Forces Magazine*, November 1, 2019.

from network-centric warfare.⁴⁰ Network-centric warfare is “an information superiority–enabled concept of operations that generates increased combat power by networking sensors, decision makers, and shooters to achieve shared awareness, increased speed of command, higher tempo of operations, greater lethality, increased survivability, and a degree of self-synchronization.”⁴¹ Yu Quan, an authoritative PLA expert on military communication technology affiliated with the Academy of Military Science’s Institute of Systems Engineering (系统工程研究院),⁴² reflected on the nature of mosaic warfare in 2023:

As a new combat concept, mosaic warfare is not a complete denial of Network-centric Warfare. It is mainly a new way of combat implemented at the tactical endpoints under the conditions of confronting strong enemies. The basic concept is to introduce unmanned and intelligent technologies into the command and control process, adopt decentralized and self-organizing military design principles, give full play to the advantages of autonomous systems and AI technology, and enhance the system’s battlefield adaptability and flexibility, while at the same time bring decision-making dilemmas to the enemy. . . . mosaic warfare will have a significant impact on traditional command and control processes and tactical communication networking technology.⁴³

Perhaps on the basis of careful studies of Grayson’s remarks and DARPA’s publicly available information, PLA analysts have emphasized that the key decisionmaking advantage of mosaic warfare is the emphasis on “unmanned swarms” (“无人集群”) to execute combat missions.⁴⁴ In intelligent warfare, by dispersing reconnaissance and surveillance, information communication, C2, fire strike, and other functions to a large number of unmanned combat units with a single function, a highly robust and elastic “kill web” (“杀伤网”) is constructed that creates numerous uncertainties for the adversary.⁴⁵ The winning mechanism of kill web–centric mosaic warfare requires three fundamental pathway shifts to generate combat capabilities. As summarized by one PLA writer,

⁴⁰ Arthur K. Cebrowski and John H. Garstka, “Network-Centric Warfare—Its Origin and Future,” *Proceedings*, Vol. 124, No. 1, January 1998.

⁴¹ David S. Alberts, John J. Garstka, and Frederick P. Stein, *Network Centric Warfare: Developing and Leveraging Information Superiority*, CCRP, 2nd ed. (revised), 1999, p. 2.

⁴² The Systems Engineering Academy at the Academy of Military Science is arguably one of the PLA’s most important brain trusts, responsible for system design and standards validation. For an introduction to the academy, see Tianjin University, “Academy of Military Science Introduction to the Institute of Systems Engineering,” undated; and Marcus Clay, “To Rule the Invisible Battlefield: The Electromagnetic Spectrum and Chinese Military Power,” *War on the Rocks*, January 22, 2021. Yu is a key member of the Systems Engineering Academy’s Key Lab for Information Security [信息安全重点实验室] and, as of 2024, likely serves as the vice chairman of the steering committee of the influential Chinese Institute of Command and Control [中国指控学会]. Yu’s key public accomplishments include the PLA’s first multiband, multimodal, programmable software radio station; the PLA’s first-generation tactical communications network, shared by the PLA, PLA Navy, and PLA AF; and the PLA’s first-generation shortwave integrated communications network. Yu was elected to be an academician of the Chinese Academy of Engineering (Shanghai Jiao Tong University Graduate School, “Researcher Yu Quan, Academician of the Chinese Academy of Engineering, Was a Guest Speaker at the 165th Master Forum” [“中国工程院院士于全研究员第 165 期大师讲坛”], April 20, 2021).

⁴³ Yu, 2023, p. 7.

⁴⁴ Xie Kai [谢恺], Zhang Dongrun [张东润], and Liang Xiaoping [梁小平], “Insights into the Evolution of the Winning Mechanism of Intelligent Warfare” [“透视智能化战争制胜机理嬗变”], *PLA Daily* [解放军报], April 26, 2022, p. 7.

⁴⁵ Xie, Zhang, and Liang, 2022.

First, utilizing and optimizing existing weapon systems to reduce reliance on [the research and development] of new equipment . . . second, building a combat system based on global interoperability; and third, designing “fast weapons” to defeat peer opponents. . . . [T]his will shorten the traditional acquisition process from years and months to days and hours, if not minutes.⁴⁶

China’s defense community writes admiringly about the mosaic warfare concept—sometimes with even more enthusiasm than its U.S. counterparts. One report from the Chinese Institute of Command and Control described the concept as sophisticated, beautiful, and lethal, even going so far as to compare mosaic warfare with Mohammed Ali’s famous fighting style, “float like a butterfly and sting like a bee.”⁴⁷ Chinese writers have praised the concept as a way to significantly reduce costs and ease the tasks of building and integrating new equipment into combat systems, arguing that proper implementation will save time and improve efficiency.⁴⁸

However, such Chinese enthusiasm for mosaic warfare and MUM-T capabilities is not without limits. China’s defense writers stress that turning the vision into reality poses enormous challenges for the U.S. military and creates new risks for military operations. For instance, some Chinese defense analysts point out that China could potentially exploit the challenges posed by the complex collaboration among numerous platforms of manned and unmanned systems.⁴⁹ “The Achilles heel of mosaic warfare,” according to another PLA author, lies in the data: the lack of data standardization, the quality of the data, and the safe transmission of the data.⁵⁰

In a 2021 article published in *PLA Daily*, Yang Cunyin, an author affiliated with the PLA Information and Communications Base (Unit 61001), wrote that “the seemingly ‘impeccable’ decentralized structure of ‘mosaic warfare’ can still be effectively cracked.”⁵¹ He further identified a few key vulnerabilities and provided limited but informative insights into how the PLA could exploit those vulnerabilities:

- Grasp the complex characteristics of the system, use its correlation and dependence, highlight the functional suppression of the communication networks, build pathways to carry out integrated cyber and electronic warfare attacks, and disassemble and isolate each unit of the combat system.
- Take advantage of the dissipative characteristics of its structure, make use of its [distributed warfare] dependence on external information to camouflage and corrupt data and prompt the combat system to transform into abnormal states, such as information closure and information overload.

⁴⁶ Li Yi [李义], “U.S. Military’s ‘Mosaic Warfare’—Make the Organization of Combat Units More Efficient” [“美军‘马赛克战’—让作战单元组合更高效”], *PLA Daily* [解放军报], January 16, 2020, p. 11.

⁴⁷ Chinese Institute of Command and Control [中国指挥与控制学会], “Mosaic Warfare: Redefining the Battlefield” [“马赛克战: 重新定义战场”], December 7, 2023.

⁴⁸ Li, 2020; Chinese Institute of Command and Control, 2023.

⁴⁹ Chinese Institute of Command and Control, 2023.

⁵⁰ Notably, this also appears to be a challenge the PLA faces (Liu Peng [刘鹏], “The Achilles Heel of U.S. Mosaic Warfare” [“美军马赛克战的阿喀琉斯之踵”], *PLA Daily* [解放军报], March 1, 2021, p. 4).

⁵¹ This unit, previously under the PLA Strategic Support Force until April 2024, is likely subordinate to the newly created PLA Information Support Force as of early 2025. It is responsible for managing and maintaining PLA critical military command, control, and communications infrastructure (Yang, 2021, p. 7).

- Understand its group autonomy, exploit its dependence on key technologies to highlight the confrontation against intelligent algorithms. . . . Reduce efficiency and inhibit the intelligent driving force of each combat unit.
- Exploit its functional non-linear characteristics, take advantage of its unknown vulnerabilities, highlight differentiated strike assessment on the battlefield, and explore and discover imbalance points in the combat system with higher efficiency and faster speed, looking for key weaknesses in the system to break.⁵²

Given Yang's affiliation with the former PLA Strategic Support Force's information support wing, which protects and supports the PLA's critical information infrastructure, it is plausible that he is reasonably aware of the PLA's key network offensive and defensive capabilities.⁵³ His insider knowledge may have informed his analysis, making it more credible. In a nutshell, this PLA communication specialist's view is that integrated cyber and electromagnetic warfare waged in all domains (e.g., space, air, land, and sea) holds the key to defeating the mosaic warfare construct. Other PLA writers, although not directly referencing any of China's capabilities, cite examples from Russia (e.g., the use of the Murmansk-BN electronic warfare system to attack U.S. military shortwave communications) and Iran (e.g., the capture of a U.S. RQ-170 in 2011) to highlight how electronic or electromagnetic warfare could be used to defeat U.S. mosaic warfare. Notable countermeasures against U.S. military's "nerves" include data deception warfare, depleting data links, and controlling and manipulating adversary data links.⁵⁴

Other Chinese defense researchers have pointed out that, despite its apparent advantages, current limitations in autonomous decisionmaking capabilities may continue to constrain MUM-T and CCA employment.⁵⁵ These deficiencies create more mission overload on the human operators of manned aircraft. Also, "once the manned aircraft is shot down by the opponent, the effectiveness of the entire combat group will be seriously compromised."⁵⁶

Can the Department of the Air Force Pull It Off?

The DAF's CCA program aims to develop UAVs that can team up with manned fighter jets, enhancing combat capabilities through collaboration. These collaborative aircraft are designed to perform various roles, including surveillance, electronic warfare, and direct attack. The CCA embody the principles of mosaic warfare by implementing MUM-T—enabling the U.S. Air Force to effectively increase its combat power without proportionately increasing the number of pilots or manned aircraft. This aligns with the mosaic warfare principle of maximizing the effectiveness of

⁵² Yang, 2021, p. 7.

⁵³ Yang's affiliation with the Strategic Support Force likely also makes his views biased toward electronic warfare.

⁵⁴ Liu, 2021, p. 4.

⁵⁵ Chai Shuiping [柴水萍] and Yang Hongxia [杨红霞], "Cooperative Combat Aircraft Accelerates to the Battlefield" ["协同作战飞机加速飞向战场"], *PLA Daily* [解放军报], September 13, 2024.

⁵⁶ Liu Bo [刘波], Wei Xiaolong [魏潇龙], Qu Hong [屈虹], Gan Xusheng [甘旭升], and Liu Fei [刘飞], "Research on Maneuvering Decision-Making in Manned-Unmanned Aerial Combat" ["有人-无人协同空战机动决策研究"], *Advancement in Aeronautical Science and Engineering* [航空工程进展], Vol. 14, No. 6, 2023, p. 64.

available resources through collaboration and integration. CCA also support the adaptability required in mosaic warfare by allowing for the rapid deployment and reconfiguration of assets in response to evolving threats.

Official Chinese sources offer limited information about how the PLA or China's defense community evaluates the DAF's ongoing effort to operationalize MUM-T and pursue the development of CCA. However, former Secretary of the Air Force Frank Kendall's flight on an AI-enabled F-16 in May 2024 certainly caught the Chinese media's attention and generated useful discussions on semiofficial and unofficial Chinese social media platforms that may serve as a baseline for analyzing China's sentiments toward CCA and the DAF's ongoing programs.⁵⁷ The key takeaway from Chinese observers appears to be that such a high-profile show of confidence in the application of AI to air combat signals the DAF's resolve to scale AI-enabled drones (e.g., CCA) to become a standard component of future air operations.⁵⁸ Such an assessment, although unofficial, reflects long-term observation by China's defense research community of the DAF's successful Skyborg (天空博格) program—an autonomous aircraft-teaming architecture designed by the Air Force Research Laboratory to produce and sustain combat mass in contested environments.⁵⁹

However, there are voices of doubt, too. Chinese commentators often question if AI-enabled systems, when challenged by complex adversaries who are “adept at deceptions and stratagems,” are truly reliable.⁶⁰ Others appear unconvinced that the DAF will be able to implement its CCA program given several potential technical and administrative difficulties.⁶¹ These same Chinese propagandists openly argue that, in the short run, the DAF is unlikely to resolve the real-time communication problems between manned aircraft and UAVs.⁶² Besides writings that directly comment on CCA, PLA writings on to how to counter mosaic warfare and network-centric warfare also shed light on how the PLA analyzes the challenges CCA continue to face.

Technology integration across diverse air platforms will face compatibility issues because of varying standards and a lack of high-level interoperability.⁶³ PLA analysts also note that the DAF will

⁵⁷ “US Air Force Secretary Takes AI-Controlled Fighter Jet for Test Ride” [“美空军部长试乘 AI 控制战机”], *Reference News* [参考消息], May 6, 2024; Zhang Xuri [张旭日] and Kang Zhengce [康政策], “Will AI Pilots Step into More Fighter Cockpits?” [“AI 飞行员将进入更多战机座舱?”], *PLA Daily* [解放军报], September 20, 2024; “The United States Conducts a Test Flight of an AI-Controlled Fighter Jet, and the Air Force Minister Personally Experienced It” [“美国进行 AI 控制战斗机试飞, 空军部长亲自体验”], Phoenix New Media, May 6, 2024.

⁵⁸ “Weapons in All Aspects: What Signal Does the US Air Force Secretary Personally Advertising for AI Fighter Jets Send?” [“兵器面面观: 美国空军部长亲自为 AI 战斗机打广告 释放什么信号”], video, CCTV-7, May 23, 2024.

⁵⁹ Air Force Research Laboratory, “Skyborg,” webpage, undated-a. The PLA has almost certainly been observing and studying the progress of Skyborg since the program was first made public (Zhang Ke [张珂], “The U.S. Air Force Continues to Advance the Development of Artificial Intelligence Wingman” [“美空军持续推进人工智能僚机的研发”], Sohu.com, March 25, 2019. Zhang is affiliated with the Academy of Military Sciences's Military Science Information Research Center [军事科学院军事科学信息研究中心]). See also Li Long [李龙] and Zheng Tianhui [郑天慧], “Analysis of Low Cost, Attributable UAV and Its Power Development” [“低成本可消耗飞行器及其动力发展分析”], *Aerospace Power* [航空动力], No. 3, 2021. Li is an engineer at the Sichuan Gas Turbine Research Institute, part of the Aero Engine Corporation of China [中国航发燃气涡轮院], and specializes in aircraft engine design and intelligence for new technology testing.

⁶⁰ Privy Council No. 10 [枢密院十号], “Far Ahead of China and Other Countries! Is This Breakthrough of the US Air Force Really So Amazing?” [“遥遥领先中国等国! 美国空军这次突破, 当真如此牛?”], Huanqiu.com [环球网], May 7, 2024.

⁶¹ Privy Council No. 10, 2024.

⁶² Privy Council No. 10, 2024.

⁶³ Privy Council No. 10, 2024.

likely have to reevaluate its procurement volume when expected production costs and research and development expenses run higher than predicted.⁶⁴

The authors of a 2024 report published by the Chinese Institute of Command and Control appear to be keenly aware of the DAF's more-practical considerations for developing the CCA program.⁶⁵ The report notes that

After years of drawdown, today's U.S. Air Force lacks the capabilities, lethality, and survivability to win decisive victory in a peer conflict with a major power. To address these shortcomings, U.S. Air Force leaders today are making major decisions about the future force. They are placing their hope in autonomous CCA to improve the Air Force's combat capabilities and create a more affordable force that can endure attrition and become more resilient. It enables the [U.S. Air Force] to provide theater commanders with strategic reserves for rapid reinforcement operations and enables complex operations to complicate adversary defenses.⁶⁶

Conclusion

This chapter presented the PLA's assessments of U.S. MUM-T theory and practice, highlighting the PLA's close monitoring of U.S. military developments since 2015. PLA authors and defense commentators seek to understand the underlying logic of the evolution from network-centric warfare to mosaic warfare concepts in U.S. doctrine. They appear to be convinced that decentralized C2 and distributed warfighting enabled by MUM-T and the further integration of autonomous technologies will be a defining feature of future warfare. Given the limited amount of publicly available data, it is difficult to fully assess the validity of the counterstrategies that are possibly under development by the PLA doctrinal community. But this chapter provides a preliminary analysis of existing Chinese perspectives on both the vision of mosaic warfare and the DAF's ongoing pursuit of MUM-T and CCA to operationalize mosaic warfare. Although PLA analysts admire the adaptability and agility of mosaic warfare, they have identified vulnerabilities and lingering technical issues, such as data standardization issues and the complexities of coordinating numerous platforms. As the ratio of MUM-T and autonomous systems increases in future combat, PLA analysts and strategists may suggest and pursue enhanced electronic warfare and cyber capabilities to exploit U.S. weaknesses.

⁶⁴ Liang Chunhui [梁春晖] and Zhang Jingrui [张景瑞], "The U.S. Air Force Is Accelerating the Development of 'Cooperative Combat Aircraft'" ["美空军加快发展'协同作战飞机'"], *China National Defense Newspaper* [中国国防报], February 21, 2024.

⁶⁵ The Chinese Institute of Command and Control is an influential organization that likely plays a role in shaping PLA perspectives about adversary technological advancement in C2 capabilities (Chinese Institute of Command and Control [中国指挥与控制学会], "Manned-Unmanned Teaming: Five Keys to Achieving Highly Collaborative Combat Aircraft" ["有人-无人编队协同:实现高度协同作战飞机的5个关键"], March 31, 2024).

⁶⁶ Chinese Institute of Command and Control, 2024.

People's Liberation Army Self-Assessment of Adopting and Implementing Manned-Unmanned Teaming

Discussions within China's defense community about MUM-T largely focus on technical aspects and specific proposals for adopting and implementing MUM-T concepts by developing combat methods. The lack of substantive discussions is unsurprising given the sensitivities surrounding PLA planning and operational concepts and the fact that critical technologies are still in development. Nonetheless, discussions in PLA journals can provide insight into emerging ideas that can serve as a baseline to monitor and analyze changes in PLA concepts, capabilities, or doctrine.

This chapter presents how the nascent MUM-T discussion fits into existing PLA views on future warfare. What drives the PLA's pursuit and assessment of developing and integrating MUM-T in its operations? Under what combat conditions is the PLA planning to integrate autonomous systems to amplify manned platforms? Although PLA discussions of MUM-T often mirror general themes in U.S. discussions on the topic, Chinese thinkers place significantly more emphasis on potential algorithmic advantages rather than the capabilities provided by specific platforms.

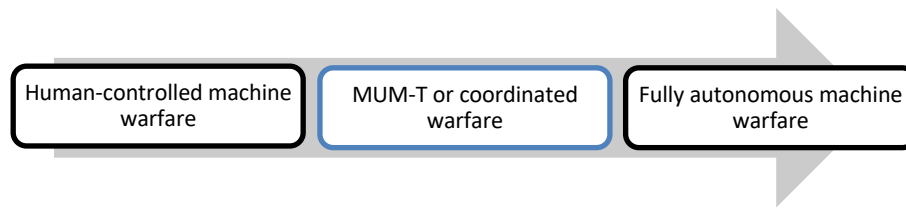
Manned-Unmanned Teaming in People's Liberation Army Discourse of Intelligent Warfare

China's military planners, likely shaped by a Marxist worldview, generally embrace an evolutionary view of the development of warfare in the information age. For instance, PLA theorists affiliated with the War Studies Institute of the Academy of Military Sciences suggest that the transition from *informatized warfare* (associated with the prevalent use of computers and information systems) to *intelligentized warfare* (defined by the increasing adoption of autonomy in military operations) is made up of three phases: human-controlled machine warfare, MUM-T or coordinated warfare, and fully autonomous machine warfare (see Figure 4.1).⁶⁷ This line of thinking is consistent with the PLA's doctrinal emphasis on the “three -izations” (“三化”)—“mechanization, informatization, and

⁶⁷ Hua Ji [花吉], “A Study of the Laws in Winning Informatized and Intelligentized Warfighting” [“信息化智能化作战制胜规律浅探”], *China Military Science* [中国军事科学], Vol. 187, No. 1, 2023, p. 57.

intelligentization”—as a holistic concept centered on the fusion of the three elements.⁶⁸ Despite the advancement in military applications of AI, the PLA foresees that MUM-T will remain the main form of warfare in the near future because of “weak AI”—a continued lack of fully reliable and autonomous capabilities of unmanned systems.⁶⁹ MUM-T requires humans to continue to be responsible for analysis and assessment, command and decisionmaking, and operational control. But MUM-T will facilitate the integration of “human-strategic thinking and the strong algorithmic power of machines.”⁷⁰

Figure 4.1. General People’s Liberation Army Thinking About the Evolution of Warfare



SOURCE: Adapted from Hua 2023, p. 57.

Publicly available PLA research papers suggest that, as early as the 2010s, there was an academic interest in understanding the key technical requirements of MUM-T and the development of MUM-T operational concepts.⁷¹ As shown in Figure 4.2, in 2018 and 2019, publications by Chinese defense authors on MUM-T topics significantly increased, which coincides with DARPA’s unveiling of the mosaic warfare concept. In a 2016 study, the PLA’s Air Force Engineering University researchers attempted to build an evaluation model for the combat effectiveness of manned-unmanned aerial vehicles on the basis of complex network analysis.⁷² In 2018, a pair of researchers from the PLA’s Space Engineering University provided an urban warfare and anti-terrorism combat scenario to validate key requirements and technical indicators for evaluating the combat effectiveness of MUM-T operations.⁷³ (See Figure 4.3 for those key indicators.)

⁶⁸ Marcus Clay and Roderick Lee, “Unmasking the Devil in the Chinese Details: A Study Note on the Science of Military Strategy 2020,” China Aerospace Studies Institute, January 2022, pp. 3, 13.

⁶⁹ Hua, 2023, p. 57.

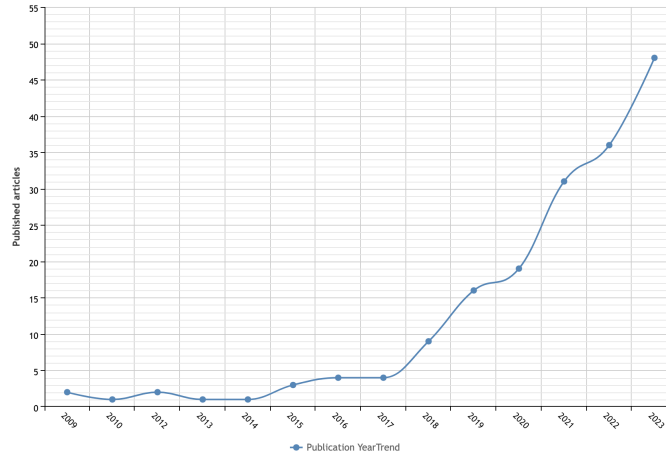
⁷⁰ Hua, 2023.

⁷¹ Ma Xiangling [马向玲], Lei Yuyao [雷宇曜], and Sun Yongqin [孙永芹], “Summary of Key Technologies for Manned/Unmanned Aerial Vehicle Collaborative Air-Ground Combat” [“有人/无人机协同空地作战关键技术综述”], *Electrooptical and Control* [电光与控制], Vol. 18, No. 3, 2011; Yin Xiaohui [阴小晖], *Research on the Effectiveness Evaluation of Manned and Unmanned Aerial Vehicle Collaborative Operations* [有人机/无人机协同作战效能评估研究], thesis, Nanchang Hangkong University [南昌航空大学], June 2013; Yang Huijun [杨慧君] and Liu Jia [刘佳], “X-47B Completed Aircraft Carrier Collaborative Flight Demonstration Verification with F/A-18 for the First Time” [“X-47B 首次与 F/A-18 完成航母合作飞行演示验证”], *Aerodynamic Missile Journal* [飞航导弹], No. 11, 2014; Wang Xun [王勋], Yao Peiyang [姚佩阳], and Shui Dongdong [税冬东], “Discussions About Manned-Unmanned Aerial Vehicle Formation Collaborative Combat Decision-Making” [“关于有人机/无人机编队协同作战决策”], *Computer Simulation* [计算机仿真], Vol. 32, No. 9, 2015.

⁷² Jiang Yucheng [姜禹呈] and Guo Jilian [郭基联], “Modeling Manned-Unmanned Collaboration” [“有人机/无人机协同效果评估模型设计”], *Military Operations Research and Systems Engineering* [军事运筹与系统工程], Vol. 30, No. 3, 2016.

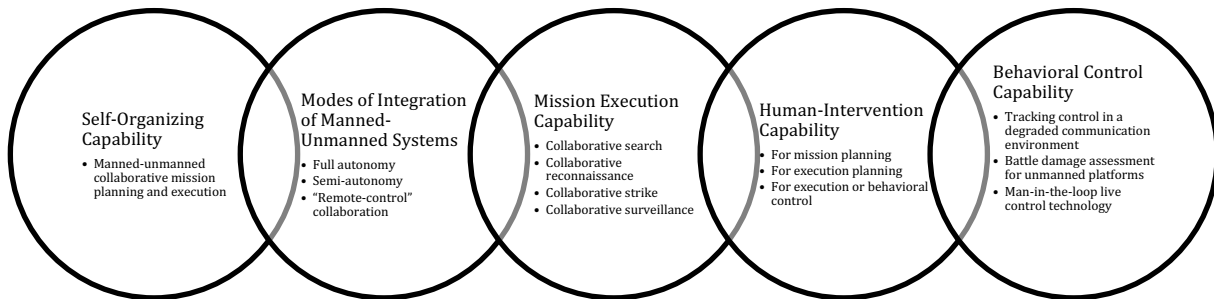
⁷³ Yang and Dong, 2018.

Figure 4.2. Trends in Publications on Manned-Unmanned Teaming by Chinese Defense Authors



SOURCE: Features data from China National Knowledge Infrastructure, database, undated.

Figure 4.3. Key Technical Indicators for Manned-Unmanned Teaming Operations



SOURCE: Adapted from Yang and Dong, 2018.

As the PLA deepens its integration of intelligent platforms, the authors of a *PLA Daily* (解放军报) commentary from 2024 foresaw MUM-T warfighting capabilities taking on a more central and critical role in PLA force employment.⁷⁴ They laid out at least four key emerging modes of operation in MUM-T warfare: First, they emphasized the use of a significant number of unmanned intelligent systems that combine reconnaissance, jamming, deception, and strike capabilities with the aim of replacing traditional long-range precision strike weapons with first-strike capabilities. Additionally, the authors advocated for the covert deployment of numerous unmanned devices during peacetime, which can be activated in wartime, thereby superseding the current practice of rapidly mobilizing

⁷⁴ Xu Yatao [徐亚涛] and Liu Jingyi [刘静怡], "Insights into the Phased Characteristics of the Evolution of Intelligent Warfare" ["透视智能化战争演进的阶段性特征"], *PLA Daily* [解放军报], August 21, 2024.

forces to combat zones at the start of a conflict. The strategy also incorporates autonomous swarm operations, through which coordinated attacks by swarms of unmanned systems can target high-value assets at a lower cost through saturation tactics. Finally, the authors advocated for the seamless integration of manned and unmanned units to facilitate multidomain collaborative operations in complex battlefield scenarios.⁷⁵

Discussions about MUM-T in future warfare suggest that PLA academics are observing U.S. and Western military force design principles closely. When asked about future trends in warfare, Zhao Xiangang from the Joint Operations Academy at the PLA's National Defense University referenced the U.S. Army's ongoing effort to integrate more unmanned aerial systems (UASs) into mechanized companies for reconnaissance, strikes, and transport to maximize the effects of MUM-T.⁷⁶ Zhao said that such a development is a necessary step to further integrating unmanned systems into the force structure, which requires "integrated training in peacetime and integrated applications in wartime."⁷⁷

Loyal Wingman with Chinese Characteristics?

With the official designation of two CCA prototypes to become fighter drones in early 2025, the DAF is poised to accelerate its development of CCA and Loyal Wingman concepts.⁷⁸ Although CCA represent a broader and more flexible vision for future air warfare, the Loyal Wingman—an early manifestation of CCA and a specific implementation of MUM-T—is smaller in scope and focuses on direct support to manned aircraft.⁷⁹ The PLA appears to be taking on a parallel effort to build out its own versions of the Loyal Wingman. The official introduction of J-35A aircraft at the 2024 Zhuhai air show generated Western speculation about the PLA's future plans to integrate its own CCA to fight alongside this newest addition to the PLA's air superiority tactical aircraft arsenal.⁸⁰ Is this developmental trend a convergent evolution of the PLA mimicking the U.S. Air Force?

The PLA previously debuted a number of unmanned systems, such as the FH-97A, GJ-11, and the long-endurance CH-7, which could also potentially serve Loyal Wingman functions. China's official media gave the FH-97A a high-profile public debut in 2022 at the Zhuhai air show (see Figure 4.4).⁸¹ The FH-97A features a redesigned aerodynamic layout and is reportedly one of various Chinese Loyal Wingman projects under development or being tested.⁸² In 2024, an official statement

⁷⁵ Xu and Liu, 2024, p. 7.

⁷⁶ Zhang Dan [张丹], "Unmanned Combat Forces Accelerate to the Battlefield" ["无人作战力量走向战场"], *PLA Daily* [解放军报], January 17, 2025, p. 2.

⁷⁷ Zhang, 2025, p. 2.

⁷⁸ Chris Gordon, "America's First Unmanned Fighters Are Here: YFQ-42 and YFQ-44," *Air & Space Forces Magazine*, March 3, 2025.

⁷⁹ The Loyal Wingman program, spearheaded by Boeing Defence Australia and supported by the Royal Australian Air Force, is considered an early example of a CCA (Samara Kitchener, "First Flight for Loyal Wingman," Defence, Australian Government, March 3, 2021).

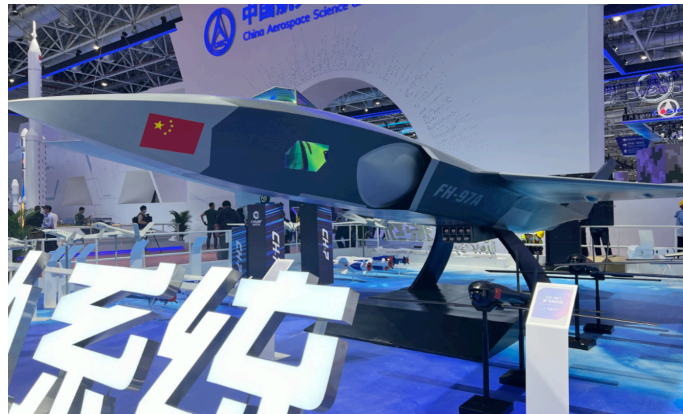
⁸⁰ Rick Joe, "Assessing the J-35A: The Chinese Air Force's New Stealth Fighter," *The Diplomat*, November 20, 2024.

⁸¹ China Association for Science and Technology [科普中国], "The Weapon of a Great Power Makes Its First Public Debut! 'Loyal Wingman' Appears at Zhuhai Air Show" ["大国利器, 首次公开亮相! '忠诚僚机'现身珠海航展"], *The Paper* [澎湃新闻], November 9, 2022.

⁸² Other publicly known programs that likely are underway include Darksword, GJ-11, CH-7, and Star Shadow.

accompanying the debut of China's most-advanced fifth-generation fighter jet—the J-20S—at the Zhuhai air show confirmed that “the J-20S can team up with unmanned planes in air combat” (see Figure 4.5).⁸³

Figure 4.4. FH-97A on Display at Zhuhai Air Show



SOURCE: Reproduced from Liu Xuanzun, Cao Siqi, and Fan Wei, “China’s New Loyal Wingman Drone to Greatly Change Air Combat: Designer,” *Global Times*, November 8, 2022.

Figure 4.5. J-20S on Display at Zhuhai Air Show



SOURCE: Reproduced from Zhao Lei, 2024.

On the basis of the limited available information in the public domain, it is likely that the FH-97A was originally developed as a response to the U.S. Loyal Wingman program.⁸⁴ The shape and design

⁸³ Zhao Lei, “Twin-Seat J-20S Stealth Fighter to be Unveiled,” *China Daily*, November 11, 2024.

⁸⁴ For instance, in a 2021 article, PLA researchers affiliated with the Shenyang Aircraft Design Institute [沈阳飞机设计研究所] analyzed the capabilities of the XQ-58A and acknowledged that it may help “expand Chinese thinking about combat tactics and methods for unmanned combat vehicles” (Lu Yuanjie [卢元杰] and Chen Xingyi [陈星伊], “Analysis of the Overall Scheme of the XQ-58A UAV” [“XQ-58A 无人机总体方案分析”], *Aircraft Design* [飞机设计], Vol. 41, No. 3, 2021).

of the FH-97A is similar to the Kratos Valkyrie XQ-58A, the U.S. Loyal Wingman aircraft. But the FH-97A's intended purpose remains largely unclear.⁸⁵ Chinese media describes the FH-97A as “a sensor, ammunition depot, as well as a human pilot's intelligent assistant.”⁸⁶ Echoing U.S. discussions about CCA missions, the FH-97A is reportedly going to

- conduct collaborative reconnaissance with special-mission aircraft (e.g., Airborne Warning and Control System aircraft)
- collaborate with fighter jets to suppress enemy air defense missions
- carry out collaborative targeting with fighter jets.⁸⁷

However, it is unclear whether the FH-97A is a stand-alone project or whether the PLA plans to build out its own CCA to keep up with U.S. development. Unofficial military commentators have presented conflicting views on China's plans. One commentator noted that FH-97A cost concerns may be a determining factor and a key indicator to understanding the PLAAF's future procurement plans.⁸⁸ Because the FH-97A has a bigger payload but an inferior stealth capability compared with the GJ-11, it may be more suitable for foreign military sales.⁸⁹ Another unofficial military commentator pointed out that Chinese and U.S. perspectives about future air warfare may be fundamentally different.⁹⁰ The DAF's preference for CCA suggests that the United States is more confident in the underlying technologies supporting its MUM-T operations and that it intends to put more emphasis on the centrality of manned aircraft in the foreseeable future. But the PLA's strategy is different and will most likely continue to focus on expanding its highly autonomous unmanned aircraft (e.g., the GJ-11 and W5000) independent of manned aircraft (see Figure 4.6).⁹¹ The cost of the PLA's unmanned platforms will be higher than the DAF's CCA, but some platforms may be taking on roles to replace strategic bombers.⁹²

⁸⁵ Air Force Research Laboratory, “XQ-58A Valkyrie,” webpage, undated-b.

⁸⁶ Tang Suyan [唐苏妍], Tang Xueqin [唐雪琴], and Wang Jiongqi [王炯琦], “Behind the First Public Appearance of ‘Loyal Wingman’: Entering the World of Algorithms” [“忠诚僚机”首次公开亮相背后: 走进算法的世界], *PLA Daily* [解放军报], November 18, 2022.

⁸⁷ Tang, Tang, and Wang, 2022.

⁸⁸ Liaowang Yunxiao [瞭望云霄], “The Advanced Design Concept of Feihong 97 Does Not Mean That It Is a Loyal Wingman of the Chinese Air Force. It Is the Key to Success or Failure” [“飞鸿 97 设计理念先进, 不等于是中国空军忠诚僚机, 决定成败的关键”], *QQ News*, November 29, 2024b.

⁸⁹ Liaowang, 2024b.

⁹⁰ Liaowang Yunxiao [瞭望云霄], “The U.S. Air Force Turns to Loyal Wingmen, China Develops Fixed-Wing Drones. Which of the Two Countries Made the Wrong Choice in the Technology Tree?” [“美空军转向忠诚僚机, 中国发展飞翼无人机, 中美谁点错科技树?”], *QQ News*, October 5, 2024a.

⁹¹ Liaowang, 2024a.

⁹² Li Lu [李路] and Chen Xinling [陈歆铃], “Anchor Takes You to the Air Show | Large Stealth Drone, Cloud Shadow 5000T!” [“主播带您看航展 | 大型隐身无人机, 云影5000T!”], video, *Beijing Daily* [北京日报], November 13, 2024.

Figure 4.6. Notional People’s Liberation Army Manned-Unmanned Teaming Employment (possible J-20 and GJ-11 pairing)



SOURCE: Reproduced from “Assuming That the Two-Seat Version of the J-20 Can Control an Unmanned Wingman, What Advantages Will It Have In Combat?” Guangming Online, December 23, 2022.

Interestingly, *PLA Daily* authors suggest that the FH-97A’s true value lies in the algorithm that powers its “highly efficient collaborative/teaming” capability to assist with coordinated reconnaissance, air superiority operations, and suppression of enemy air defense missions.⁹³ This official commentary went into detail about algorithmic warfare rather than the technical details of the platform, noting that the nature of “asymmetric warfare” is shifting from the “assassin’s mace”-style, platform-centric capabilities powered by highly sophisticated technology to big data and AI-enabled advantages.

Another general PLA observation in the literature on MUM-T suggests that the PLA is likely keenly aware of the importance of standardization to facilitate interoperability among various manned and unmanned platforms.⁹⁴ PLA propagandists’ critique of the lack of standardized protocol for tactical communications in the DAF’s CCA program likely reflects China’s own anxieties.⁹⁵ As of the early 2020s, Chinese researchers continued to focus on communication standardization among various models of unmanned systems, but discussions about improving manned and unmanned platform interoperability remain scarce.⁹⁶ Authoritative PLA experts of military communications, such as Yin

⁹³ Tang, Tang, and Wang, 2022.

⁹⁴ Wang Wenfeng [王文峰], Yu Xuemei [余雪梅], and Xu Dongmei [徐冬梅], “Overview of Unmanned Systems Interoperability Standardization” [“无人系统互操作性标准化综述”], *China Electronic Standardization Institute* [中国电子技术标准化研究院], Vol. 572, No. 12, 2020.

⁹⁵ Shen Lincheng [沈林成], Niu Yifeng [牛轶峰], and Zhu Huayong [朱华勇], *Theories and Methods of Autonomous Cooperative Control for Multiple UAVs* [多无人机自主协同控制理论与方法], 2nd ed., National Defense Industry Press [国防工业出版社], 2018, p. IV; Yin Hao [尹浩], Wei Jibo [魏急波], Zhao Haitao [赵海涛], Zhang Jiao [张姣], Wang Haijun [王海军], and Ren Baoquan [任保全], “Key Technologies of Intelligent Communication and Networking for Manned/Unmanned Collaboration: Current Status and Trends” [“面向有人/无人协同的智能通信与组网关键技术:现状与趋势”], *Journal on Communications* [通信学报], Vol. 45, No. 1, 2024.

⁹⁶ Wang, Yu, and Xu, 2020; Emilie B. Stewart, *Survey of PRC Drone Swarm Inventions*, China Aerospace Studies Institute, October 2023.

Hao, a Chinese academician and director of the Institute of Systems Engineering at the PLA's Academy of Military Sciences, openly have discussed the daunting technical challenges of realizing the full potential of MUM-T.⁹⁷ In a 2024 overview article analyzing the state of intelligent networking technologies supporting the performance of MUM-T, Yin and his co-authors from the National University of Defense Technology wrote that “the complex, changeable, and highly contested electromagnetic environment limits the sensing, communications, and computing capabilities of heterogeneous platforms” and that it is “difficult to achieve global situation awareness [for all platforms] to help make optimized decisions. This is limiting the realization of the true performance of MUM-T.”⁹⁸

Developing a Concept of Employment: Key Scenarios

By 2022, the PLAAF may have carried out several proof-of-concept simulations to analyze and develop its MUM-T concept of employment.⁹⁹ In a 2023 CCTV military program, a PLAAF UAS regiment based in northwest China appeared to be using an unmanned GJ-2 (also known as Wing Loong 2) to conduct collaborative training with a manned J-16 to develop tactics, techniques, and procedures.¹⁰⁰ Public writings by Chinese defense analysts suggest that the PLA likely is exploring at least three potential use cases: suppression of enemy air defenses, support to airborne operations, and defensive counter-air operations. Below are three scenarios discussed by Chinese authors that apply MUM-T in operations.

⁹⁷ Yin Hao [尹浩] is often credited in Chinese media as the mastermind of the PLA's first indigenously designed military communications systems. He also played a key role in the development of the PLA's second- and third- generation key communications networks. For more information on his background and PLA affiliations, see Yin Hao's Xi'an University of Post and Telecommunications profile (Xi'an University of Post and Telecommunications, “Yin Hao,” webpage, undated).

⁹⁸ Yin et al., 2024, p. 10.

⁹⁹ Dong Yanfei [董彦非], Cui Wei [崔巍], and Zhang Wang [张旺], “Comprehensive Index Model for Evaluating Manned/Unmanned Aircraft Collaborative Air Combat Effectiveness” [“有人机/无人机协同空战效能评估的综合指数模型”], *Flight Dynamics* [飞行力学], Vol. 32, No. 5, 2014; Wang Guangyuan [王光源], Sun Tao [孙涛], Mao Shichao [毛世超], and Zhang Yaoqing [章尧卿], “Research on Evaluation of Manned/Unmanned Aircraft Sea Attack Combat Effectiveness Based on Task Collaboration” [“基于任务协同的有人机/无人机对海攻击作战效能评估研究”], *Journal of Naval Aeronautical and Astronautical University* [海军航空工程学院学报], Vol. 32, No. 5, 2017; Xu Yurou [徐宇茹], Gong Wei [龚伟], and Jiang Wenzhi [姜文志], “CGF Model of Island Reef Air Defense Based on OODA Process” [“基于 OODA 过程的岛礁防空 CGF 模型”], *Journal of Naval Aeronautical and Astronautical University* [海军航空工程学院学报], Vol. 30, No. 1, 2015; Liu Shuguang [刘树光] and Wang Huan [王欢], “Review of Research on Manned/Unmanned Aircraft Collaborative Formation Control” [“有人/无人机协同编队控制研究综述”], *Flight Dynamics* [飞行力学] Vol. 40, No. 5, 2022; Sun Shengzhi [孙盛智], Meng Chunming [孟春宁], Hou Yan [侯妍], and Cai Xiao [蔡晓], “Research on Manned/Unmanned Aircraft Collaborative Combat Mode and Key Technologies” [“有人机/无人机协同作战模式及关键技术研究”], *Aero Weaponry* [航空兵器], No. 5, 2021; Zhong Yun [钟贇], Zhang Jieyong [张杰勇], and Deng Changlai [邓长来], “Issues in Manned/Unmanned Aircraft Collaborative Combat” [“有人/无人机协同作战问题”], *Command Information Systems and Technology* [指挥信息系统与技术], Vol. 8, No. 4, 2017.

¹⁰⁰ Military Fans World [军迷天下], “Gongji-2 and J-16 Engage in Joint Operations! An Exclusive Look into the PLA's First Integrated Reconnaissance-and-Strike Drone Unit: A 'Post-90s' Squadron Commander Provides an In-Depth Analysis of the Latest Combat Models for Domestic Drones!” [“攻击-2 与歼-16 联合作战! 独家探访解放军首支察打一体无人机部队: '90后'大队长详细解读国产无人机最新作战模式”], video, August 31, 2023. For Chinese commentaries on this unit's possible MUM-T missions, see “Drones and J-16 Fighters Rarely Appear in the Same Frame. Experts: The PLA Is Exploring and Practicing Coordinated Combat Tactics” [“无人机与歼 16 战斗机罕见同框, 专家: 解放军摸索演练协同作战战术”], *Global Times* [环球时报], August 11, 2023.

Scenario 1: Collaborative Strike Against Enemy Air Defense Position

In an academic paper on the findings of a new combat model under development, a team of PLA researchers affiliated with the PLAAF's Shijiazhuang Flight Academy designed the following air defense position attack scenario:

Construct a simulation mission based on the reconnaissance and attack on an air defense position, using manned/unmanned aerial vehicle swarm hard-kill strike to damage all combat equipment in the air defense missile weapon system position, causing it to lose its combat capabilities. The main goal is **to assault its command and information combat systems and air defense combat forces**. . . . The cluster coverage area is 5 km × 5 km, the number of target types is greater than or equal to 3, the number [of what] is greater than or equal to 5, and the number of manned/unmanned aerial vehicles in the cluster is not less than 15. Manned/UAV collaborative combat plan: one Type A manned aircraft and 16 Type B UAVs form a manned/UAV formation to complete combat missions, conduct 100 simulation tests, and evaluate the results based on the obtained simulation test data.¹⁰¹

After the UAV discovers the air defense missile position control area, according to the PLA researchers, the UAV will feed the information back to the manned aircraft and the ground command center. After receiving instructions, the crewed aircraft will strike in the “phased array radar vehicle-C2 vehicle-battery vehicle-missile launch vehicle” sequence; these targets are absolutely the most vulnerable nodes in an enemy's air defense systems.¹⁰² The PLA researchers concluded that among a series of 20 simulation tests, 15 met the requirements for completing the task, and most of those were well completed. MUM-T combat achieved the desired result.¹⁰³

Scenario 2: Airborne Corps Operations

Former PLAAF Airborne Corps General Jing Tao advocated for integrating the MUM-T concept into future airborne operations.¹⁰⁴ He authored a revealing 2022 piece that discussed the necessity of developing novel operational concepts to keep up with the U.S. and Russian militaries. Jing argued that the Airborne Corps, which serves as the PLA's future global rapid response force, is uniquely positioned to deliver MUM-T combat capabilities.¹⁰⁵ Jing lamented the “backwardness” of PLA operational concept development and suggested that the PLA must develop scenarios that are

¹⁰¹ Han Yueming [韩月明], Liu Tielin [刘铁林], and Xue Hui [薛辉], “Evaluation of Manned/Unmanned Aircraft Collaborative Combat Effectiveness Based on Grey Theory” [“基于灰色理论的有人/无人机协同作战效能评估”], *Military Operations Research Assessment* [军事运筹与评估], Vol. 38, No. 1, February 2023, p. 23.

¹⁰² Han, Liu, and Xue, 2023, p. 23.

¹⁰³ Han, Liu, and Xue, 2023, p. 23.

¹⁰⁴ Unlike in the U.S. military, the Airborne Corps falls under the PLAAF and not the Army.

¹⁰⁵ Jing was a general in the PLAAF Airborne Corps and has extensive participation experience in all PLA strategic training events and in multiple iterations of Air Sword [空剑] and Red Sword [红剑] exercises. *Military Art* is a key PLA journal that is endorsed by the CMC as a platform for innovative military theories and operational ideas. It is published by the Institute of War Studies at the Academy of Military Sciences, the Chinese Communist Party's military brain trust (Jing Tao [景涛], “In-Depth Study of Manned-Unmanned Collaborative Combat” [“基于联合作战体系的‘有人+无人’协同空降作战深化研究”], *Military Art* [军事学术], No. 1, 2022, p. 6).

applicable to manned-unmanned collaborative airborne strikes, including “island landing attack, border defense, cross-domain key node seizure (跨域制要), and overseas limited punishment and deterrence operations (海外有限惩戒).”¹⁰⁶ To accelerate and optimize the integration of UAVs in airborne operations, Jing argued for combining manned-unmanned collaborative combat training with PLA “actual combat readiness training” and “special activities.”¹⁰⁷ In terms of force design in mid- to long-range planning, Jing made the case for expanding UAS elements in the Airborne Corps and making adjustments to the force design. For instance, the PLA should “create UAS regiments at the corps-level and expand existing UAS squads at the brigade level to battalions . . . [and] add unmanned armored squads (*fendui*) for ground operations.”¹⁰⁸

Scenario 3: Air-to-Air Combat

PLA writers have proposed that technological advancements in systems architecture and communication protocols, particularly sensor and data-fusion technologies, have driven the United States’ pursuit of MUM-T military applications. AI and machine learning are further enhancing such capabilities to make autonomous systems more effective and reduce the cognitive load of human operators.¹⁰⁹ Essentially, in the view of PLA authors, the desire to adapt the platform-centric kill-chain design of traditional air combat to a more-contested combat environment is what drives U.S. thinking about the application of MUM-T to air combat. The U.S. military wants to rely more on low-cost UAVs and manned-unmanned collaborations to realize distributed functionalities.¹¹⁰

A group of writers from Xidian University with close ties to the PLA acknowledged that the DAF’s traditional platform-centric air combat model is increasingly challenged by the potential for high-damage costs imposed by adversaries and the long development cycle for new air platforms.¹¹¹ An edited graduate-level textbook on new combat concepts for the PLA explained that, in mosaic warfare, “low cost drones with dispersed functions are used to form a distributed combat network . . . and manned aircraft and drones will jointly perform combat missions, which not only have high battlefield survivability but also greatly improve the efficiency of mission completion.”¹¹²

How do those writers envision mosaic warfare and, more specifically, MUM-T will play out in air combat? The example they offered resembles DARPA’s descriptions.¹¹³ These authors describe a

¹⁰⁶ Jing, 2022, p. 6.

¹⁰⁷ Jing, 2022, p. 6.

¹⁰⁸ Jing, 2022, p. 6.

¹⁰⁹ Liu et al., 2023.

¹¹⁰ Chen Shitao [陈士涛], Sun Peng [孙鹏], and Li Daxi [李大喜], *Analysis of New Combat Concepts* [新型作战概念剖析], Xidian University Press [西安电子科技大学出版社], 2021.

¹¹¹ Chen, Sun, and Li, 2021.

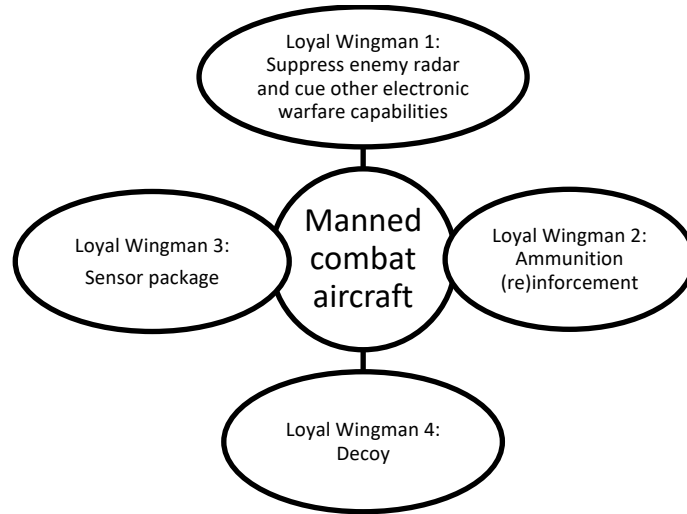
¹¹² Chen, Sun, and Li, 2021, p. 132.

¹¹³ DARPA’s discussion of air combat via mosaic warfare is as follows:

In the air domain, four F-16s might be going head-to-head with four rival jet fighters. However, in a Mosaic Warfare context, the U.S. Air Force might also deploy four relatively inexpensive, somewhat expendable unmanned aerial systems ahead, each with different weapons or sensor systems. The combatant commander can treat these assets like a football coach who chooses team members and then positions them on the field to

scenario in which a series of UAVs serve as wingmen—similar to the DAF’s Loyal Wingman idea—to accompany fighter jets performing missions. One of the drones is responsible for jamming enemy radars or summoning other electronic warfare capabilities, and another drone is equipped with weapons. A third drone carries sensor packages, and the fourth drone acts as a decoy (see Figure 4.7).

Figure 4.7. Notional Chinese Understanding of Loyal Wingman Employment



SOURCE: Adapted from Chen, Sun, and Li, 2021.

run plays. The added aircraft make the situation much more complex and can overwhelm the opponent’s decision-making. (DARPA, “DARPA Tiles Together a Vision of Mosaic Warfare,” undated)

The key advantage of mosaic warfare in air combat is that

[i]nstead of four flashing dots on the radar screen, the enemy may be seeing eight dots . . . and they won't be able to differentiate the capabilities and missions of each aircraft nor can they tell what the enemy is up to next.¹¹⁴

Putting It Together in Island Landing Campaigns

As with other doctrinal concepts, the PLA's depictions of operational concepts that integrate MUM-T frequently appear to be similar to publicly available diagrams about CCA created by U.S. military and defense industry partners. In an article about employing MUM-T in an island landing scenario, the PLA authors envision the deployment of MUM-T capabilities to carry out missions to penetrate enemy air defense systems and conduct air strikes inside enemy defense zones.¹¹⁵ Multiple UAVs accompany manned fighter jets via data links to suppress enemy air defenses and strike sensitive enemy targets.

In two other MUM-T iterations for island landing operations, the authors depict scenarios in which UAVs accompanying manned aircraft take on collaborative jamming missions to provide coverage for manned aircraft while carrying out penetration strikes on enemy C2 nodes. For collaborative reconnaissance missions, UAVs transmit the sensing data of the enemy fleet, topography, and infrastructure information to carrier-based manned aircraft.

Conclusion

This chapter presented discussions in China's defense community about MUM-T and evaluated emerging Chinese concepts of employment for Loyal Wingman and CCA in future PLA air combat planning. It remains unclear whether the PLA's CCA program is a stand-alone effort—a response to the DAF's and other Western militaries' advancement in MUM-T—or whether the PLA has already embarked on its own operational concept development to position itself more advantageously in future air combat. Nevertheless, discussions by Chinese official and unofficial sources provide insight into emerging ideas that can serve as a baseline to monitor and analyze changes in PLA concepts, capabilities, or doctrine.

¹¹⁴ Chen, Sun, and Li, 2021, p. 132.

¹¹⁵ Although it is not specified, such a scenario resembles an island landing campaign against Taiwan or other disputed islands in the East China Sea and South China Sea (Wang Wenhao [王文豪], Zhang Yan [张言], Dong Lei [董磊], Li Zhipeng [李志鹏], and Hu Shenghua [胡盛华], "Research on Typical Applications of Manned and Unmanned Aircraft Collaboration in Landing Operations" ["登陆行动中有人机协同典型应用研究"], *Proceedings of the Sixth China Command and Control Conference*, Vol. 1, 2018, pp. 364–365.

Conclusion and Policy Recommendations

China's defense community is carefully monitoring U.S. technological advances that could enable more-effective MUM-T performance. It is also paying close attention to public statements by DoD, the DAF, and industry leaders regarding the progress of the NGAD program's family of systems and CCA and seeks to understand the policy implications for future acquisitions. Leading Chinese defense researchers are dedicating their time and effort to study the key technologies that are facilitating more-optimized MUM-T performance on the battlefield with state funding.¹¹⁶ But to what end?

The Gap Between Theory and Practice

The publicly available Chinese discussions about MUM-T presented in this report show that the PLA views the deepening relationship between manned and unmanned systems as a defining feature of future warfare. What remains unclear, however, is whether and how the PLA has allocated resources to develop its own CCA program to meet its mission of bridging the current state of development with a fully autonomous warfighting environment in the future. Although there are occasional teases in the Chinese media about potential candidate platforms (e.g., the FH-58A or GJ-11) being employed as China's Loyal Wingman, official PLA sources have not confirmed that China is actively developing any such program at the time of writing this report.

This is not to say that the PLA *will not* pursue its own CCA in the future, and we do not know for certain whether a nonpublic program is already underway. PLA strategists often write about future warfare with a special emphasis on innovating CONOPS via MUM-T to better leverage C2 of intelligent systems to generate multidomain collaborative capabilities.¹¹⁷ As PLAAF General Jing Tao argued in 2022, both the U.S. and Russian militaries are engaging in early-stage development of intelligent warfare, and China should seize this window of opportunity to convert MUM-T from theory to practice to "leapfrog ahead."¹¹⁸

There is no doubt that China's defense technology community has made significant progress in AI-enabled unmanned technologies under the banner of building Xi Jinping's "strong military." But

¹¹⁶ Yin et al., 2024; Chen Jie [陈杰] and Xin Bin [辛斌], "Key Scientific Problems in the Autonomous Cooperation of Manned-Unmanned Systems" ["有人/无人系统自主协同的关键科学问题"], *Scientia Sinica: Informationis* [中国科学: 信息科学], Vol. 48, No. 9, 2018.

¹¹⁷ Liu, 2022.

¹¹⁸ Jing, 2022, p. 6. However, it is worth noting that General Jing is an operational commander and not a national-level policy decisionmaker. His opinion may represent certain factions within the PLA but not the entire military.

significant technological and political hurdles remain for China's pursuit of CCA and semi- or fully autonomous warfare. The gap between MUM-T theory and practice remains large. Reaping the full benefits of teaming manned and unmanned platforms requires sophisticated standardization and the interoperability of different generations and types of platforms. Unlike the U.S. military, which is divesting from legacy platforms developed before the information age (e.g., the A-10s, F-18s, and RQ-4 Global Hawks), the PLA may have a latecomer's advantage; its defense modernization programs took off in the late 1990s and early 2000s, and many of its unmanned platforms were brought online in the 2010s with relatively unified network standards already baked in.¹¹⁹ However, to deliver the optimized effects of synchronized MUM-T under high-tempo combat conditions in highly complex and contested electromagnetic environments remains a daunting challenge. The calculation within the PLA may be that, at present, investing in swarming technology and counter-CCA (and counter-UAS) capabilities is more technologically feasible and economically beneficial, with a higher return on investment in the short run.¹²⁰

Moreover, although the PLA may share the DAF's concerns about costs when designing acquisition strategies, the combat requirements associated with an anti-access and area denial operational environment that justify the DAF's CCA program are not applicable to the PLA. To defeat the DAF's CCA and the distributed warfare concept, the PLA does not need its own CCA program. What makes more operational sense is the continued expansion of the PLA's diversified arsenal of unmanned systems, from high-end and multifunctional autonomous combat vehicles to low-cost attritable drones. The diversification strategy provides the PLA with more flexibility to configure for the different contingency scenarios it may be called on to respond to. From Beijing's point of view, building up the quantitative advantage of unmanned vehicles will certainly help in any future combat scenarios in China's neighborhood (e.g., the Taiwan Strait, East China Sea, and South China Sea) when facing any invading forces. CCA may be a "nice to have" item, but it is not a necessity. And any publicly acknowledged program to develop Chinese CCA could divert attention from higher priority projects that are also under development.

Politically, despite the PLA's ongoing effort to modernize its political work apparatus to be more adaptable to the fast pace of modern warfare, the fundamental contradiction between absolute political control and highly decentralized, complex, decision-centric, and automated military operations has not been resolved. Such a dilemma is more pronounced under air combat conditions, which often occur at rapid speeds far from home base. The PLAAF has always been cognizant of the unique challenges its career political work cadres face largely because of the technical nature of the air force.¹²¹ In a way, ensuring political control of ground-based C2 centers that operate military drones may help alleviate the burden of political work for the air force. But MUM-T may potentially pose a different set of challenges. The teaming of manned and unmanned systems may require that more independence is awarded to human pilots in the air, who enjoy varying degrees of control over multiple

¹¹⁹ Peter Levine, "If You Want More Defense Innovation, Spend Less on Legacy Platforms," *War on the Rocks*, August 20, 2018.

¹²⁰ Hayley Wong and Amber Wang, "Swarming Drones and Counter-Drone Systems Dazzle at China's Zhuhai Air Show," *South China Morning Post*, November 14, 2024.

¹²¹ Cheng Fuming [程福明] and Qian Renyuan [钱人源], "I Have a Better Understanding of Political Work During Training" ["做训练中政治工作更有底了"], *PLA Daily* [解放军报], July 21, 2013.

unmanned platforms—there is simply no room for political work while on a mission. Will the PLA be willing to increase the importance of political indoctrination in its pilot training programs at the expense of technical proficiency?

The reality is that, despite the PLA's rhetorical embrace of military AI and intelligent warfare in its official media, debates within the defense community and the PLA likely exist. It is possible that China's defense industry and technologists are pitted against some of the more-conservative forces within the military that are often affiliated with Marxism, Leninism, Xi Jinping thought research institutes, and PLA services.¹²² It is also likely that debates about the direction of doctrinal development and, perhaps more importantly, how the PLA will be allocating resources to realize the benefits of putting MUM-T into future battlefields remains largely undecided. Although it is certainly possible that the PLA is emulating the U.S. approach to air warfare to develop its own CCA program, as of 2025, the PLA's study of the U.S. theory and practice of MUM-T mainly serves to identify U.S. weaknesses in order to develop counterstrategies.

Findings

The findings are as follows:

- **The PLA assesses that MUM-T will be a defining feature of future combat activities involving intelligent systems.** It also foresees AI-enhanced MUM-T capabilities becoming a standard component of future U.S. forces.
- **Since 2015, the PLA has monitored developments in U.S. MUM-T concepts and technologies to identify U.S. vulnerabilities and develop countermeasures.** Chinese observers argue that, in the near term, the DAF is unlikely to surmount obstacles to realize the Loyal Wingman program's full potential, including real-time communication problems and limited autonomous decisionmaking capabilities.
- **As of early 2025, the PLA appears to be taking a different approach to MUM-T than the U.S. Air Force.** Although costs remain a key driving factor for both militaries in their pursuit of CCA-type capabilities, **the PLA places more emphasis on enhancing software and algorithms to enable unmanned systems to support and augment the capabilities of its manned platforms rather than pursuing more advanced teaming capabilities**, which require a higher degree of autonomy awarded to CCA. The technical challenges that drone swarm technologies face, such as secure data transmission under high-mobility conditions and weak AI in military applications, will prohibit the PLA's large-scale adoption of MUM-T in the near term.
- **The PLA is in the nascent stages of developing operational concepts to integrate MUM-T.** There are general discussions about missions in which MUM-T may be employed, such as strikes on air defenses in an island invasion scenario (potentially applicable to a Taiwan scenario). However, the operational challenges that would have to be addressed are unclear. Public-facing Chinese discussions suggest that the PLA lacks concrete standardization plans

¹²² Zhao and Zhai, 2014.

to integrate manned and unmanned assets, and it remains unclear whether the PLA is integrating MUM-T concepts into pilot training programs.

- **PLA writings emphasize the importance of reinforcing the wartime party committee's role under manned-unmanned collaborative combat conditions.** Finding the right balance between automation and political control likely will remain a challenge in the near future.

Recommendations

Although the integration of MUM-T into the development of future operational concepts remains at a preliminary stage, it is the right time for the United States to adopt a competitive strategy to ensure that the DAF maintains its technological and conceptual advantages. On the basis of the initial findings in this report, the following policy recommendations are provided:

- **Leverage red-teaming analysis to develop tailored strategic messaging around the U.S. research, development, and acquisition of MUM-T capabilities.** PLA analysts' keen interest in U.S. MUM-T concepts, capabilities, and doctrinal development provides an opportunity to shape China's perceptions of U.S. capability and intent. Although intelligence analyses of adversary capabilities are often incorporated into U.S. programs, less attention is paid to potential adversary perceptions and adaptations. Red teaming draft DoD and DAF leader statements on technological or conceptual progress or setbacks can help maintain consistent messaging, anticipate unwanted Chinese reactions, and help the DAF gain an edge in shaping—rather than reacting to—the PLA's media campaigns.
- **Use MUM-T and CCA development as a case to inject “conceal and reveal” strategies to capability development.**¹²³ Although it remains unclear to what degree the PLA has integrated its own CCA into operational planning, China is monitoring and mimicking U.S. capabilities to improve its AI and unmanned technologies. MUM-T development may also serve as a catalyst for innovative thinking in operational concepts and force employment.
- **Direct or designate relevant intelligence components to focus on the analysis of PLA organization, doctrine, and training in assessments of PLA MUM-T capabilities.** For instance, the DAF should closely evaluate changes in PLA training methods in its pilot training programs. The PLA research community acknowledges human cognitive overload challenges and may be developing new measures to improve training and exercises for human operators. Any changes in PLA pilot training programs may provide insights into the PLA's thinking about future operational concepts.
- **Make a concerted and targeted effort to significantly boost the protection of the electromagnetic spectrum.** PLA researchers' frequent discussion of the potential vulnerabilities of MUM-T capabilities to electronic warfare suggests that the PLA may prioritize the development of related countermeasures. **Electromagnetic warfare collaboration with allied and partner militaries and defense industrial bases should be expanded.** A positive example of such collaboration is the first trilateral prize challenge

¹²³ Thomas G. Mahnken, “Selective Disclosure: How to Inject Strategy into U.S. Capability Development,” War on the Rocks, January 27, 2021.

through the Australia-United Kingdom-United States (AUKUS) Pillar II, organized by DoD's Defense Innovation Unit.¹²⁴ It is critical to deny and disrupt the PLA's key calculations to counter U.S. mosaic warfare concepts and the further integration of distributed warfare doctrines in the future.

- **As the DAF stands up the Integrated Capabilities Command, it should also ensure that its intelligence cell—augmented by China specialists—actively monitors, analyzes, and informs the command's acquisition activities on the advancement of the PLA's electronic warfare and information warfare capabilities.**
- **Gain a better understanding of the PLA's insecurity about political control under complex combat conditions to develop tailored concepts of employment for CCA.** The PLA most likely will not be replacing human political commissars with well-developed algorithms to ensure political control anytime soon, and political indoctrination will be done on the ground before missions are launched. But how exactly the PLA political work system will adapt to MUM-T and unmanned conditions, particularly in the air, remains an understudied topic. The DAF should encourage more all-source analysis to gauge the PLA's willingness to reform and generate insights to identify possible PLA C2 vulnerabilities to exploit in combat.

¹²⁴ Defense Innovation Unit, "DIU Partners with AUKUS Pillar II for International Prize Challenge," U.S. Department of Defense, March 26, 2024; Tim Welter and Jason Blessing, *Operationalizing Pillar 2 of the Australia–United Kingdom–United States (AUKUS) Partnership: Issues in Electronic Warfare: A Roundtable Summary*, Potomac Institute for Policy Studies, August 2024.

Abbreviations

AI	artificial intelligence
C2	command and control
CCA	Collaborative Combat Aircraft
CCTV	China Central Television
CMC	Central Military Commission
CONOPS	concepts of operations
DoD	U.S. Department of Defense
DAF	Department of the Air Force
DARPA	Defense Advanced Research Projects Agency
MUM-T	manned-unmanned teaming
NGAD	Next Generation Air Dominance
PLA	People's Liberation Army
PLAAF	People's Liberation Army Air Force
UAS	unmanned aerial system
UAV	unmanned aerial vehicle

References

Unless otherwise indicated, the author of this report provided the translations of bibliographic details for the non-English sources included in this report. To support conventions for alphabetizing, sources in Chinese are introduced with and organized according to their English translations. The original rendering in Chinese appears in brackets after the English translation.

Air Force Research Laboratory, “Skyborg,” webpage, undated-a. As of May 15, 2025:
<https://afresearchlab.com/technology/skyborg/>

Air Force Research Laboratory, “XQ-58A Valkyrie,” webpage, undated-b. As of June 12, 2025:
<https://afresearchlab.com/technology/xq-58a-valkyrie/>

Alberts, David S., John J. Garstka, and Frederick P. Stein, *Network Centric Warfare: Developing and Leveraging Information Superiority*, CCRP, 2nd ed. (revised), 1999.

“Assuming That the Two-Seat Version of the J-20 Can Control an Unmanned Wingman, What Advantages Will It Have In Combat?” *Guangming Online*, December 23, 2022.

Bresnick, Sam, *China’s Military AI Roadblocks: PRC Perspectives on Technological Challenges to Intelligentized Warfare*, Center for Security and Emerging Technology, June 2024.

Burke, Edmund J., Kristen Gunness, Cortez A. Cooper III, and Mark Cozad, *People’s Liberation Army Operational Concepts*, RAND Corporation, RR-A394-1, 2020. As of May 16, 2025:
https://www.rand.org/pubs/research_reports/RRA394-1.html

Cebrowski, Arthur K., and John H. Garstka, “Network-Centric Warfare—Its Origin and Future,” *Proceedings*, Vol. 124, No. 1, January 1998.

Chai Shuiping [柴水萍] and Yang Hongxia [杨红霞], “Cooperative Combat Aircraft Accelerates to the Battlefield” [“协同作战飞机加速飞向战场”], *PLA Daily* [解放军报], September 13, 2024.

Chase, Michael S., Kristen Gunness, Lyle J. Morris, Samuel K. Berkowitz, and Benjamin Purser, *Emerging Trends in China’s Development of Unmanned Systems*, RAND Corporation, RR-990-OSD, 2015. As of May 16, 2025:
https://www.rand.org/pubs/research_reports/RR990.html

Chen Jie [陈杰] and Xin Bin [辛斌], “Key Scientific Problems in the Autonomous Cooperation of Manned-Unmanned Systems” [“有人/无人系统自主协同的关键科学问题”], *Scientia Sinica: Informationis* [中国科学: 信息科学], Vol. 48, No. 9, 2018.

Chen Shitao [陈士涛], Sun Peng [孙鹏], and Li Daxi [李大喜], *Analysis of New Combat Concepts* [新型作战概念剖析], Xidian University Press [西安电子科技大学出版社], 2021.

Chen Yugong [陈育功], “Research on the Realization Methods of Autonomous Collaborative Operations of Swarm Intelligent Unmanned Systems” [“群体智能无人系统自主协同作战实现方法研究”], *China Military Science* [中国军事科学], Vol. 4, No. 172, 2022.

- Cheng Fuming [程福明] and Qian Renyuan [钱人源], "I Have a Better Understanding of Political Work During Training" ["做训练中政治工作更有底了"], *PLA Daily* [解放军报], July 21, 2013.
- China Association for Science and Technology [科普中国], "The Weapon of a Great Power Makes Its First Public Debut! 'Loyal Wingman' Appears at Zhuhai Air Show" ["大国利器, 首次公开亮相! '忠诚僚机' 现身珠海航"], *The Paper* [澎湃新闻], November 9, 2022.
- China National Knowledge Infrastructure, database, undated. As of June 2, 2025:
<https://oversea.cnki.net/index/>
- China Social Sciences Network [中国社会科学网澎湃账户], "Strengthening the Political Work of the Military in the Era of Military Intelligence" ["加强军事智能化时代的军队政治工作"], *The Paper* [澎湃新闻], November 21, 2019.
- Chinese Institute of Command and Control [中国指挥与控制学会], "Mosaic Warfare: Redefining the Battlefield" ["马赛克战: 重新定义战场"], December 7, 2023.
- Chinese Institute of Command and Control [中国指挥与控制学会], "Manned-Unmanned Teaming: Five Keys to Achieving Highly Collaborative Combat Aircraft" ["有人-无人编队协同: 实现高度协同作战飞机的 5 个关键"], March 31, 2024.
- Chue Xiangqian [啜向前], Sun Wei [孙炜], and Li Yongbing [栗勇兵], "Attach Importance to Carrying Out Intelligent Command Training" ["重视开展智能化指挥训练"], *PLA Daily* [解放军报], April 27, 2023.
- Clay, Marcus, "To Rule the Invisible Battlefield: The Electromagnetic Spectrum and Chinese Military Power," *War on the Rocks*, January 22, 2021.
- Clay, Marcus, and Roderick Lee, "Unmasking the Devil in the Chinese Details: A Study Note on the Science of Military Strategy 2020," China Aerospace Studies Institute, January 2022.
- DARPA—See Defense Advanced Research Projects Agency.
- DARPA tv, "Mosaic Warfare and Multi-Domain Battle," video, September 24, 2018. As of April 20, 2025:
<https://www.youtube.com/watch?v=33VAnIEjDgk>
- Defense Advanced Research Projects Agency, "DARPA Tiles Together a Vision of Mosaic Warfare," undated.
- Defense Advanced Research Projects Agency, "Strategic Technology Office Outlines Vision for 'Mosaic Warfare,'" August 4, 2017.
- Defense Innovation Unit, "DIU Partners with AUKUS Pillar II for International Prize Challenge," U.S. Department of Defense, March 26, 2024.
- Deng Peng [邓鹏], Ding Hao [丁浩], Zhang Yong [张永], and Wang Xinhua [王新华], "Discussion on the Use of Underwater Manned and Unmanned Combat Based on 'Mosaic Warfare'" ["基于'马赛克战'的水下有人-无人作战使用探讨"], *Ship Science and Technology* [舰船科学技术], Vol. 46, No. 1, 2024.
- Deptula, David A., and Heather Penney, "Mosaic Warfare," *Air & Space Forces Magazine*, November 1, 2019.
- DiMascio, Jennifer, "U.S. Air Force Collaborative Combat Aircraft (CCA)," Congressional Research Service, IF12740, version 4, updated January 22, 2025.

- Dong Yanfei [董彦非], Cui Wei [崔巍], and Zhang Wang [张旺], “Comprehensive Index Model for Evaluating Manned/Unmanned Aircraft Collaborative Air Combat Effectiveness” [“有人机/无人机协同空战效能评估的综合指数模型”], *Flight Dynamics* [飞行力学], Vol. 32, No. 5, 2014.
- “Drones and J-16 Fighters Rarely Appear in the Same Frame. Experts: The PLA Is Exploring and Practicing Coordinated Combat Tactics” [“无人机与歼 16 战斗机罕见同框, 专家: 解放军摸索演练协同作战战术”], *Global Times* [环球时报], August 11, 2023.
- Finkelstein, David M., *The PLA's New Joint Doctrine: The Capstone of the New Era Operations Regulations System*, Center for Naval Analyses, September 2021.
- Fu Bingzhong [傅秉忠], “Research on the Concept of Integrated Unmanned Warfare” [“天地一体无人战概念研究”], *Military Art* [军事学术], Vol. 1, No. 554, 2022.
- Gordon, Chris, “America’s First Unmanned Fighters Are Here: YFQ-42 and YFQ-44,” *Air & Space Forces Magazine*, March 3, 2025.
- “The Great Scientist Qian Xuesen Highly Praised the Man-Machine-Environment System Engineering” [“伟大科学家钱学森对人-机-环境系统工程的高度评价”], Beijing KeCui Man-Machine-Environment System Engineering Technology Research Institute, April 1, 2020.
- Han Lin [韩林], Wei Bing [魏兵], and Liu Jianwei [刘建伟], “Promoting Joint Operations Training to Achieve Higher Standards—A One-Year Review of the Implementation of the *Guidelines of Joint Operations of the People’s Liberation Army of China (Trial)*,” *PLA Daily* [解放军报], January 5, 2022.
- Han Yueming [韩月明], Liu Tielin [刘铁林], and Xue Hui [薛辉], “Evaluation of Manned/Unmanned Aircraft Collaborative Combat Effectiveness Based on Grey Theory” [“基于灰色理论的有人/无人机协同作战效能评估”], *Military Operations Research Assessment* [军事运筹与评估], Vol. 38, No. 1, February 2023.
- Hua Ji [花吉], “A Study of the Laws in Winning Informatized and Intelligentized Warfighting” [“信息化智能化作战制胜规律浅探”], *China Military Science* [中国军事科学], Vol. 187, No. 1, 2023.
- Huang Yingxu [黄迎旭], “To Win the Information War, People Are the Decisive Factor” [“要打赢信息化战争, 人是决定因素”], *PLA Daily* [解放军报], January 9, 2017.
- Jian Zihan [简子涵], “Examining Modern Wars with the Marxist View of War” [“用马克思主义战争观检视现代战争”], *PLA Daily* [解放军报], June 7, 2016.
- Jiang Yucheng [姜禹呈] and Guo Jilian [郭基联], “Modeling Manned-Unmanned Collaboration” [“有人机/无人机协同效果评估模型设计”], *Military Operations Research and Systems Engineering* [军事运筹与系统工程], Vol. 30, No. 3, 2016.
- Jing Tao [景涛], “In-Depth Study of Manned-Unmanned Collaborative Combat” [“基于联合作战体系的‘有人+无人’协同空降作战深化研究”], *Military Art* [军事学术], No. 1, 2022.
- Joe, Rick, “Assessing the J-35A: The Chinese Air Force’s New Stealth Fighter,” *The Diplomat*, November 20, 2024.

- Kang Huaihai [康怀海], “Integrate Emerging Fields, Innovate Thinking and Concepts, and Promote the Intelligent Development of Political Work” [“融合新兴领域, 创新思维理念, 推动政治工作向智慧化发展”], *PLA Daily* [解放军报], May 30, 2024.
- Kitchener, Samara, “First Flight for Loyal Wingman,” Defence, Australian Government, March 3, 2021.
- Konaev, Margarita, and Husanjot Chahal, “Building Trust in Human-Machine Teams,” Brookings Institution, February 18, 2021.
- Levine, Peter, “If You Want More Defense Innovation, Spend Less on Legacy Platforms,” War on the Rocks, August 20, 2018.
- Li Jiyong [李计勇] and Zou Li [邹力], “Grasping the Integration Point of Theory and Technology for Innovative Tactics” [“找准战法创新的理技融合点”], *PLA Daily* [解放军报], May 9, 2023.
- Li Long [李龙] and Zheng Tianhui [郑天慧], “Analysis of Low Cost, Attributable UAV and Its Power Development” [“低成本可消耗飞行器及其动力发展分析”], *Aerospace Power* [航空动力], No. 3, 2021.
- Li Lu [李路] and Chen Xinling [陈歆铃], “Anchor Takes You to the Air Show|Large Stealth Drone, Cloud Shadow 5000T!” [“主播带您看航展|大型隐身无人机, 云影 5000T!”], video, *Beijing Daily* [北京日报], November 13, 2024. As of January 21, 2025:
<https://xinwen.bjd.com.cn/content/s6733dedfe4b0e1ace8a84741.html>
- Li Qing [李清], “Discussion on U.S. Military’s ‘Mosaic Warfare’” [“说说美军‘马赛克战’”], *China Aviation News* [中国航空报], December 24, 2020.
- Li Wenqing [李文清] and Zhou Dewang [周德旺], “Optimizing Joint Operations Command System of Systems” [“优化联合作战指挥体系”], *PLA Daily* [解放军报], January 5, 2023.
- Li Yi [李义], “U.S. Military’s ‘Mosaic Warfare’—Make the Organization of Combat Units More Efficient” [“美军‘马赛克战’—让作战单元组合更高效”], *PLA Daily* [解放军报], January 16, 2020.
- Liang Chunhui [梁春晖] and Zhang Jingrui [张景瑞], “The U.S. Air Force Is Accelerating the Development of ‘Cooperative Combat Aircraft’” [“美空军加快发展‘协同作战飞机’”], *China National Defense Newspaper* [中国国防报], February 21, 2024.
- Liang Yongqiang [梁永强], Wang Wei [王巍], and Jiang Zhen [姜振], “Understanding Human-Machine Relationships in Future Wars” [“厘清未来战争中的人机关系”], *PLA Daily* [解放军报], June 11, 2020.
- Liaowang Yunxiao [瞭望云霄], “The U.S. Air Force Turns to Loyal Wingmen, China Develops Fixed-Wing Drones. Which of the Two Countries Made the Wrong Choice in the Technology Tree?” [“美空军转向忠诚僚机, 中国发展飞翼无人机, 中美谁点错科技树?”], *QQ News*, October 5, 2024a.
- Liaowang Yunxiao [瞭望云霄], “The Advanced Design Concept of Feihong 97 Does Not Mean That It Is a Loyal Wingman of the Chinese Air Force. It Is the Key to Success or Failure” [“飞鸿 97 设计理念先进, 不等于中国空军忠诚僚机, 决定成败的关键”], *QQ News*, November 29, 2024b.
- “Lifeline Is Revitalized in Intelligent Warfare” [“生命线在智能化作战中焕发新活力”], *China Social Sciences Journal* [中国社会科学报], February 4, 2021.

- Liu Bo [刘波], Wei Xiaolong [魏潇龙], Qu Hong [屈虹], Gan Xusheng [甘旭升], and Liu Fei [刘飞], “Research on Maneuvering Decision-making in Manned-Unmanned Aerial Combat” [“有人-无人机协同空战机动决策研究”], *Advancement in Aeronautical Science and Engineering* [航空工程进展], Vol. 14, No. 6, 2023.
- Liu Haijiang [刘海江], “Accelerate the Innovation and Transformation of Operational Concepts—Generating New Combat Capabilities Through Operational Concept Innovation Is an Inevitable Choice to Achieve Strategic Initiative” [“加速推进作战概念创新转化-通过作战概念创新生成新质作战能力是达成战略主动的必然选择”], *PLA Daily* [解放军报], June 23, 2022.
- Liu Peng [刘鹏], “The Achilles Heel of U.S. Mosaic Warfare” [“美军马赛克战的阿喀琉斯之踵”], *PLA Daily* [解放军报], March 1, 2021.
- Liu Shuguang [刘树光] and Wang Huan [王欢], “Review of Research on Manned/Unmanned Aircraft Collaborative Formation Control” [“有人/无人机协同编队控制研究综述”], *Flight Dynamics* [飞行力学], Vol. 40, No. 5, 2022.
- Liu Xuanzun, Cao Siqi, and Fan Wei, “China’s New Loyal Wingman Drone to Greatly Change Air Combat: Designer,” *Global Times*, November 8, 2022.
- Long Zhengzhao, “Overview of Man-Machine-Environment System Engineering,” Beijing KeCui Man-Machine-Environment System Engineering Technology Research Institute, April 1, 2020.
- Lu Yuanjie [卢元杰] and Chen Xingyi [陈星伊], “Analysis of the Overall Scheme of the XQ-58A UAV” [“XQ-58A无人机总体方案分析”], *Aircraft Design* [飞机设计], Vol. 41, No. 3, 2021.
- Ma Xiangling [马向玲], Lei Yuyao [雷宇曜], and Sun Yongqin [孙永芹], “Summary of Key Technologies for Manned/Unmanned Aerial Vehicle Collaborative Air-Ground Combat” [“有人/无人机协同空地作战关键技术综述”], *Electrooptical and Control* [电光与控制], Vol. 18, No. 3, 2011.
- Mahnken, Thomas G., “Selective Disclosure: How to Inject Strategy into U.S. Capability Development,” *War on the Rocks*, January 27, 2021.
- Mao Zedong [毛泽东], *Selected Military Writings of Mao Zedong* [毛泽东军事文集], Vol. 2, Academy of Military Science Press [军事科学出版社] and Central Party Literature Publishing House [中央文献出版社], 1993.
- Military Fans World [军迷天下], “Gongji-2 and J-16 Engage in Joint Operations! An Exclusive Look into the PLA’s First Integrated Reconnaissance-and-Strike Drone Unit: A ‘Post-90s’ Squadron Commander Provides an In-Depth Analysis of the Latest Combat Models for Domestic Drones!” [“攻击-2 与歼-16 联合作战! 独家探访解放军首支察打一体无人机部队: ‘90 后’大队长详细解读国产无人机最新作战模式”], video, August 31, 2023. As of May 20, 2025: https://www.youtube.com/watch?v=_ZWw0jvR13o
- Pomerleau, Mark, “DoD’s Third Offset Strategy: What Man and Machine Can Do Together,” *Defense One*, May 4, 2016.
- Privy Council No. 10 [枢密院十号], “Far Ahead of China and Other Countries! Is This Breakthrough of the US Air Force Really So Amazing?” [“遥遥领先中国等国! 美国空军这次突破, 当真如此牛?”], *Huanqiu.com* [环球网], May 7, 2024.

- Qi Jiayin [齐佳音], "Reflections on Human-Machine Teaming Intelligence Decision-Making" ["人机混合智能决策的一点思考"], *Science Network*, April 20, 2023.
- "Qian Xuesen: The Man the U.S. Deported—Who Then Helped China into Space," BBC, October 26, 2020.
- Rossetti, Livio, "Manned-Unmanned Teaming: A Great Opportunity or Mission Overload?" *Journal of JAPCC*, Vol. 29, January 2020.
- Shanghai Jiao Tong University Graduate School, "Researcher Yu Quan, Academician of the Chinese Academy of Engineering, Was a Guest Speaker at the 165th Master Forum" ["中国工程院院士于全研究员第 165 期大师讲坛"], April 20, 2021.
- Shen Lincheng [沈林成], Niu Yifeng [牛轶峰], and Zhu Huayong [朱华勇], *Theories and Methods of Autonomous Cooperative Control for Multiple UAVs* [多无人机自主协同控制理论与方法], 2nd ed., National Defense Industry Press [国防工业出版社], 2018.
- Stewart, Emilie B., *Survey of PRC Drone Swarm Inventions*, China Aerospace Studies Institute, October 2023.
- Sun Shengzhi [孙盛智], Meng Chuning [孟春宁], Hou Yan [侯妍], and Cai Xiao [蔡晓], "Research on Manned/Unmanned Aircraft Collaborative Combat Mode and Key Technologies" ["有人机/无人机协同作战模式及关键技术研究"], *Aero Weaponry* [航空兵器], No. 5, 2021.
- Systems Engineering Society of China, "Introduction to the Human-Machine-Environmental Systems Engineering Committee" ["人-机-环境系统工程专委会简介"], August 29, 2024.
- Tang Suyan [唐苏妍], Tang Xueqin [唐雪琴], and Wang Jiongqi [王炯琦], "Behind the First Public Appearance of 'Loyal Wingman': Entering the World of Algorithms" ["'忠诚僚机'首次公开亮相背后: 走进算法的世界"], *PLA Daily* [解放军报], November 18, 2022.
- Tang Yi-feng [汤一峰], "Analysis of the History and Progress of the US Air Force's Distributed Operations from the Perspective of System Integration Technology and Experimental Projects" ["从体系综合技术与试验项目分析美空军分布式作战历程与进展"], *Avionics Technology* [航空电子技术], Vol. 54, No. 4, December 2023.
- Tianjin University, "Academy of Military Science Introduction to the Institute of Systems Engineering," undated.
- "The United States Conducts a Test Flight of an AI-Controlled Fighter Jet, and the Air Force Minister Personally Experienced It" ["美国进行 AI 控制战斗机试飞, 空军部长亲自体验"], *Phoenix New Media*, May 6, 2024.
- "US Air Force Secretary Takes AI-Controlled Fighter Jet for Test Ride" ["美空军部长试乘 AI 控制战机"], *Reference News* [参考消息], May 6, 2024.
- Wang Guangyuan [王光源], Sun Tao [孙涛], Mao Shichao [毛世超], and Zhang Yaoqing [章尧卿], "Research on Evaluation of Manned/Unmanned Aircraft Sea Attack Combat Effectiveness Based on Task Collaboration" ["基于任务协同的有人机/无人机对海攻击作战效能评估研究"], *Journal of Naval Aeronautical and Astronautical University* [海军航空工程学院学报], Vol. 32, No. 5, 2017.
- Wang Wenfeng [王文峰], Yu Xuemei [余雪梅], and Xu Dongmei [徐冬梅], "Overview of Unmanned Systems Interoperability Standardization" ["无人系统互操作性标准化综述"], *China Electronic Standardization Institute* [中国电子技术标准化研究院], Vol. 572, No. 12, 2020.

- Wang Wenhao [王文豪], Zhang Yan [张言], Dong Lei [董磊], Li Zhipeng [李志鹏], and Hu Shenghua [胡盛华], "Research on Typical Applications of Manned and Unmanned Aircraft Collaboration in Landing Operations" ["登陆行动中有人机协同典型应用研究"], *Proceedings of the Sixth China Command and Control Conference*, Vol. 1, 2018.
- Wang Xun [王勋], Yao Peiyang [姚佩阳], and Shui Dongdong [税冬东], "Discussions About Manned-Unmanned Aerial Vehicle Formation Collaborative Combat Decision-Making" ["关于有人机/无人机编队协同作战决策"], *Computer Simulation* [计算机仿真], Vol. 32, No. 9, 2015.
- "Weapons in All Aspects: What Signal Does the US Air Force Secretary Personally Advertising for AI Fighter Jets Send?" ["兵器面面观: 美国空军部长亲自为 AI 战斗机打广告 释放什么信号"], video, CCTV-7, May 23, 2024. As of January 21, 2025:
<https://tv.cctv.com/2024/05/23/VIDEIBq5fp70VMiHA1cf0uFu240523.shtml>
- Welter, Tim, and Jason Blessing, *Operationalizing Pillar 2 of the Australia–United Kingdom–United States (AUKUS) Partnership: Issues in Electronic Warfare: A Roundtable Summary*, Potomac Institute for Policy Studies, August 2024.
- Wong, Hayley, and Amber Wang, "Swarming Drones and Counter-Drone Systems Dazzle at China's Zhuhai Air Show," *South China Morning Post*, November 14, 2024.
- Wu Dingping [吴定平], Cao Ergang [曹二刚], and Su Shengdi [苏生迪], "Preliminary Discussion of Military Party Leadership and Construction Under Intelligentized Conditions" ["刍议智能化条件下军队党的领导和党的建设"], *China Military Science* [中国军事科学], No. 187, 2023.
- "Xi Jinping Emphasized at the Meeting on Equipment Work of the Whole Army: Accelerate the Construction of an Equipment System That Meets the Requirements of Fulfilling Missions" ["在出席全军装备工作会议时强调: 加快构建适应履行使命要求的装备体系"], *People's Daily* [人民日报], December 5, 2014.
- "Xi Jinping: Hold High the Great Banner of Socialism with Chinese Characteristics and Work Together to Build a Modern Socialist Country in All Respects—Report to the 20th Party Congress of the Chinese Communist Party" ["高举中国特色社会主义伟大旗帜, 为全面建设社会主义现代化国家而团结奋斗—在中国共产党第二十次全国代表大会上的报告"], *Xinhua* [新华社], October 25, 2022.
- Xi'an University of Post and Telecommunications, "Yin Hao," webpage, undated. As of June 2, 2025:
<https://www.xiyou.edu.cn/info/2430/69562.htm>
- Xie Kai [谢恺], Zhang Dongrun [张东润], and Liang Xiaoping [梁小平], "Insights into the Evolution of the Winning Mechanism of Intelligent Warfare" ["透视智能化战争制胜机理嬗变"], *PLA Daily* [解放军报], April 26, 2022.
- Xu Yatao [徐亚涛] and Liu Jingyi [刘静怡], "Insights into the Phased Characteristics of the Evolution of Intelligent Warfare" ["透视智能化战争演进的阶段性特征"], *PLA Daily* [解放军报], August 21, 2024.
- Xu Yurou [徐宇茹], Gong Wei [龚伟], and Jiang Wenzhi [姜文志], "CGF Model of Island Reef Air Defense Based on OODA Process" ["基于 OODA 过程的岛礁防空 CGF 模型"], *Journal of Naval Aeronautical and Astronautical University* [海军航空工程学院学报], Vol. 30, No. 1, 2015.
- Xu Zhongbo [徐忠波], "The Key Factor That Determines the Outcome of a War Is People" ["决定战争胜负的关键因素是人"], *PLA Daily* [解放军报], October 25, 2015.

- Xue Ya [薛亚], Tan Xiaolong [谭小龙], and Li Qinan [李奇男], "Exploring the Development Rules of Building New Quality Combat Effectiveness" ["探寻新质战斗力建设发展规律"], *PLA Daily* [解放军报], March 23, 2021.
- Yang Cunyin [杨存银], "From 'Cyberwarfare' to 'Mosaic Warfare'" ["从'赛博战'到'马赛克战'"], *PLA Daily* [解放军报], September 14, 2021.
- Yang Fan [杨帆] and Dong Zhenghong [董正宏], "Research on Cooperation Technologies and Combat Patterns of Manned/Unmanned Platforms" ["有人/无人平台协同技术与行动模式研究"], *Defense Technology Review* [国防科技], Vol. 39, No. 4, August 2018.
- Yang Huijun [杨慧君] and Liu Jia [刘佳], "X-47B Completed Aircraft Carrier Collaborative Flight Demonstration Verification with F/A-18 for the First Time" ["X-47B 首次与 F/A-18 完成航母合作飞行演示验证"], *Aerodynamic Missile Journal* [飞航导弹], No. 11, 2014.
- Yang Wenzhe [杨文哲], "Exploring the Way to Win Intelligent Warfare Amidst Change and Immutability" ["在变与不变中探寻智能化战争制胜之道"], *PLA Daily* [解放军报], October 22, 2019.
- Ye Kunwu [叶坤武], Niu Chao [牛超], Liu Zehua [刘泽华], Luo Diqin [罗堤钦], and Yang Wenjia [杨文佳], "Human-Machine Relationship in Intelligent Air Combat" ["智能空战中的人机关系"], *Proceedings of the 11th China Conference on Command and Control*, Ordnance Industry Press [兵器工业出版社], October 2023.
- Yin Hao [尹浩], Wei Jibo [魏急波], Zhao Haitao [赵海涛], Zhang Jiao [张姣], Wang Haijun [王海军], and Ren Baoquan [任保全], "Key Technologies of Intelligent Communication and Networking for Manned/Unmanned Collaboration: Current Status and Trends" ["面向有人/无人协同的智能通信与组网关键技术:现状与趋势"], *Journal on Communications* [通信学报], Vol. 45, No. 1, 2024.
- Yin Xiaohui [阴小晖], *Research on the Effectiveness Evaluation of Manned and Unmanned Aerial Vehicle Collaborative Operations* [有人机/无人机协同作战效能评估研究], thesis, Nanchang Hangkong University [南昌航空大学], June 2013.
- Yu Quan, "From 'Network Center' to 'Decision-Making Center': Deciphering the U.S. Mosaic Warfare" ["从'网络中心'到'决策中心'—解读美军马赛克战"], *PLA Daily* [解放军报], December 23, 2023.
- Zeng Zilin [曾子林], "How to 'Intelligently Mix and Match' Humans and Machines" ["人机如何'智能化混搭'"], *PLA Daily* [解放军报], July 22, 2021.
- Zhang Dan [张丹], "Unmanned Combat Forces Accelerate to the Battlefield" ["无人作战力量走向战场"], *PLA Daily* [解放军报], January 17, 2025.
- Zhang Fengpo [张凤坡], "Intelligent Warfare Also Requires Good Political Work" ["智能作战也要做好政治工作"], *Study Times* [学习时报], January 14, 2019.
- Zhang Ke [张珂], "The U.S. Air Force Continues to Advance the Development of Artificial Intelligence Wingman" ["美空军持续推进人工智能僚机的研发"], Sohu.com, March 25, 2019.
- Zhang Xuri [张旭日] and Kang Zhengce [康政策], "Will AI Pilots Step into More Fighter Cockpits?" ["AI 飞行员将进入更多战机座舱?"], *PLA Daily* [解放军报], September 20, 2024.
- Zhao Lei, "Twin-Seat J-20S Stealth Fighter to be Unveiled," *China Daily*, November 10, 2024.

- Zhao Renxing [赵仁星], Wang Ling [王玲], Feng Mingyue [冯明月], and Jia Wentong [贾文通], “Analysis of the Combat Concept ‘Mosaic Warfare’ and Countermeasures” [“马赛克战作战概念构想及对策分析”], *Aerospace Defense* [空天防御], Vol. 4, No. 3, 2021.
- Zhao Wanxu [赵万须] and Zhai Qinghua [翟清华], “On Mao Zedong’s Views on the Main Determinants of Victory or Defeat in War” [“论毛泽东关于战争胜负的主要决定因素观点”], *Mao Zedong and the Great Rejuvenation of the Chinese Nation: Proceedings of an Academic Seminar Commemorating the 120th Anniversary of the Birth of Comrade Mao Zedong (Part 2)* [毛泽东与中华民族伟大复兴: 纪念毛泽东同志诞辰 120 周年学术研讨会论文集(下)], Central Compilation Press [中央文献出版社], 2014.
- Zhao Xiangang [赵先刚] and Lu Cong [吕聪], “Accurately Grasp the Balance Point of Manned/Unmanned Collaborative Operations—Opening the Door to Victory in Unmanned Operations” [“准确把握有人/无人协同作战的平衡点—叩开无人作战制胜之门”], *PLA Daily* [解放军报], April 20, 2023.
- Zhong Yun [钟贇], Zhang Jieyong [张杰勇], and Deng Changlai [邓长来], “Issues in Manned/Unmanned Aircraft Collaborative Combat” [“有人/无人机协同作战问题”], *Command Information Systems and Technology* [指挥信息系统与技术], Vol. 8, No. 4, 2017.



As the Department of the Air Force (DAF) accelerates its testing of manned-unmanned teaming (MUM-T) concepts and further integrates the Collaborative Combat Aircraft program into operations against highly capable adversaries, it is critical for U.S. Department of Defense and DAF planners, strategists, and analysts to better understand Chinese perspectives and similar lines of effort to integrate autonomous systems into air operations. Additionally, understanding China's approach to MUM-T can help the DAF anticipate and counter adversarial tactics, ensuring that U.S. forces maintain a strategic advantage in the foreseeable future.

The analysis presented in this report is intended to improve the DAF's understanding of the People's Liberation Army's (PLA's) perceptions regarding MUM-T and the PLA's efforts to integrate autonomous systems into air operations. These insights into China's MUM-T capabilities can inform the DAF's operational planning, enhance interoperability with allied forces, and guide investment in relevant technologies.

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