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PLA CONCEPTS OF UAV SWARMS AND MANNED/UNMANNED TEAMING

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ABSTRACT

Manned/unmanned teaming techniques and swarm tactics are an increasingly visible aspect of the People's Liberation Army's (PLA) military modernization effort, with even the slightest hints of operationalization within the PLA's various arms attracting considerable Western media attention. Indeed, the PLA and its research, development, and acquisition (RDA) apparatus are keen to adopt these advanced techniques and technologies as part of efforts to transform the PLA from "a human-centric fighting force with unmanned systems in support, to a force centered on unmanned systems with humans in support" ("有人为主、无人为辅" 向 "无人为主、有人为辅").[1] But a review of publicly available sources ranging from authoritative PLA texts to unofficial blogs suggests that the PLA's thinking on manned/unmanned teaming and swarm tactics is still evolving and its development, adoption, and deployment of these tactics and technologies remains uneven or even unverified in practice.

This paper describes how the PLA is approaching the use of unmanned aerial systems (UAS) swarms and manned/unmanned teaming (MUM-T) in three main parts. The first surveys several strategic documents informing the PLA's development of swarm tactics and MUM-T techniques, including force modernization priorities and dilemmas surrounding autonomy and command and control. Next, the paper describes the PLA's efforts to operationalize swarm tactics and MUM-T techniques, highlighting both the operations research and technical work that PLA researchers and China's defense-industrial base are undertaking to harness these techniques and precipitate transformation of PLA airpower. Finally, the paper concludes by summarizing the variety of challenges articulated by PLA researchers regarding the successful use of swarm tactics and MUM-T techniques in a conflict and assesses several prospects and trajectories for the PLA's future use of swarms and MUM-T techniques in future combat.

Key Findings

- The PLA's development and adoption of unmanned aerial vehicles (UAV) swarm tactics are comparatively more mature than its work on MUM-T techniques. The technological advances and operational thought supporting the PLA's use of swarm tactics appear comparatively more mature than the PLA's progress in MUM-T techniques and technologies, and the PLA has apparently employed swarm tactics in exercises. MUM-T techniques are ambitious in theory and potentially advanced in experimental prototypes, but remain rudimentary in practice.
- "Mothership" concepts are popular within the PLA's ecosystem for developing operational thought for both MUM-T and swarm operations. Larger manned and unmanned vehicles or aircraft can serve as "arsenal ships" to extend range and potentially recover smaller UAVs deployed in large numbers.
- PLA researchers stress the importance of stealth, numbers, and timing in swarm operations, and view these qualities as especially useful for laying ambushes and staging sequential or adaptive attacks on targets.
- China's defense industry has developed numerous prototypes and demonstrators for swarm and MUM-T technologies, including some that make extensive use of artificial intelligence. There is no public evidence, however, that any of these prototypes or demonstrators have reached full operational status with line units in the PLA.
- The PLA has already begun using UAV swarms for battlefield reconnaissance in exercises but is still experimenting with roles for using UAVs together with manned aircraft.

The PLA's Strategic Context for Swarm Tactics and Manned/Unmanned Teaming Techniques

The PLA views the employment of unmanned systems as a strategic imperative but is apparently still settling on exactly how to employ swarm tactics and MUM-T techniques in unmanned warfare. This is evident from high-level PLA strategic writings, such as textbooks and authoritative pronouncements of the PLA's strategic priorities, which laud the advent of unmanned warfare but do not articulate any specific details about the use, value, or complications of swarm tactics or MUM-T techniques. This is unsurprising and suggests the PLA prefers to let the relevant technologies mature more fully before settling on strategic integration and the tactics of employment.

Among the most glaring illustrations of this contrast, for instance, is the full-throated embrace of unmanned warfare in PLA texts like the 2013 and 2020 editions of the *Science of Military Strategy* juxtaposed with the complete absence in these texts of any discussion of the autonomy required for effective command and control in unmanned warfare. Instead, discussions of the latter are left to PLA academic journals and technical research that do not bear the same imprimatur of authoritativeness but have more license to push the boundaries of novel discussion. This contrast will be addressed in the following sections, covering the stature of unmanned systems in the PLA's modernization effort as a reflection of authoritative consensus as well as less authoritative writings on autonomy and its implications for command and control.

Unmanned Systems in the PLA's Breakneck Modernization Effort

Some of the earliest publicly available technical writings on UAS swarm tactics and MUM-T techniques appeared in 2003, well before the PLA had entered its self-defined era of intelligentized warfare around 2019.[2] Often authored by watchers of the US military within China's defense industry, many of these writings were likely inspired by early observations of U.S. military developments, with little in the way of corresponding PLA development. Though unmanned systems were referenced in early PLA works like *The Science of Campaigns*, it was some time before the PLA began to incorporate these systems into high-level military thinking at the level of consensus and enthusiasm seen today.[3]

The PLA may have been slow to realize the value of unmanned systems but has since compensated for its tardiness by embracing unmanned systems as a strategic modernization priority. As the PLA embarked upon an ambitious modernization effort, first precipitated by observations of the 1991 Persian Gulf War, authoritative texts like the 2013 *Science of Military Strategy* continued to shape the PLA's modernization trajectory.[4] Among other assertions about the state of modern warfare and how the PLA should adapt, the volume argues that future warfare will increasingly be defined by long-range (to include reaching the Second Island Chain), "remote combat," high-precision, and highly-networked combat operations, and characterizes future warfare as an increasingly unmanned, silent, and intangible (无人, 无声, 无形) contest between unmanned systems featuring intelligent technology employed on land, at sea, in air, and in space.[56] Unmanned, potentially low-observable, and silent systems are expected to be "massively employed" on future battlefields.[7] These expressions signaled the unmistakable arrival of unmanned warfare among the PLA's foremost scholars of military doctrine.

Many of the views on unmanned systems articulated in the 2013 *Science of Military Strategy* are echoed in other authoritative expressions of Chinese military strategy, suggesting consensus regarding their importance in future warfare. Contemporaneous strategy documents like the 2015 defense white paper proclaimed that "long-range, precise, smart, stealthy, and unmanned weapons are becoming increasingly sophisticated,"[8] while later writings like the 2019 defense white paper again note a "prevailing trend to develop long-range precision, intelligent, stealthy or unmanned weaponry and equipment."[9] The 2020 *Science of Military Strategy* devotes significant attention to "intelligent unmanned systems," citing their extensive use in recent conflicts and their potential for altering the basic nature of warfare. Specifically, it discusses intelligent unmanned systems in the role of military intelligence and the intelligence domain overall, calling for systems with "excellent technical and tactical performance, long continuous working hours…greatly shortened training period, and low overall cost," as well as improved combat effectiveness.[10] The overall importance of unmanned systems has captured the attention of Xi Jinping, who noted the rapid proliferation of unmanned combat systems and their outsized impact on warfare during a 2020 visit to the PLA Air Force Aviation University, and whom the PLA reportedly briefed on development and applications of unmanned combat forces during a highly choreographed 2024 gathering of the National People's Congress and the Chinese People's Political Consultative Congress.[11]

Despite this apparent consensus on the importance of unmanned systems in warfare, the PLA is still determining how to employ MUM-T and swarm tactics. However, a cross-section of authoritative documents like defense white papers and the various editions of the *Science of Military Strategy* reveals the modernization and operational priorities likely to shape the PLA's approach to swarm tactics and MUM-T techniques.

China's defense white papers and editions of the *Science of Military Strategy* describe key missions and ambitious modernization priorities that swarm tactics and MUM-T are likely being developed to support. The 2015 defense white paper called for the PLA Air Force to improve its capabilities across seven main areas, listed in Figure 1.[12] These priorities were repeated in the 2019 defense white paper, and the 2020 edition of the *Science of Military Strategy* echoes several of these modernization priorities, specifically airborne early warning, offensive air, air defense and missile defense, airdrop delivery, and base support capability, potentially indicating future support roles for swarms and MUM-T.[13] [14]

PLA Air Force Modernization Priorities from the 2015 Defense White Paper

- Strategic early warning (战略预警)
- Air strike (空中打击)
- Air and missile defense (防空反导)
- Information countermeasures (信息对抗)
- Airborne operations (空降作战)
- Strategic projection (战略投送)
- Comprehensive support (综合保障)

Figure 1: PLAAF Modernization Priorities

Beyond these broad modernization priorities, any concrete development and employment of swarm and MUM-T techniques will likely be undertaken in support of the combat operations identified in credible PLA writings. The 2020 *Science of Military Strategy*, for instance, identifies a variety of combat operations that swarm and MUM-T technologies may be applied to, including strategic operations like reconnaissance and early warning, strategic and operational airlift, assault, counter-air attack, and blockade operations, as well as border defense, island operations, sea maneuver operations, cyber-electromagnetic warfare, and psychological, public opinion, and legal warfare, otherwise known as the Three Warfares.[15] Although swarms are only broadly addressed and MUM-T techniques are not discussed at all in these writings, these technologies will likely be employed in support of each of these missions and some of the PLA's previously discussed technological ambitions to varying degrees.[16]

Grappling with Autonomy and Command and Control Architectures

Despite the inclusion of emerging unmanned technologies in high-level PLA strategic discourse and authoritative expressions of force modernization priorities, these writings largely ignore strategic considerations surrounding autonomy and command and control. Instead, discussions on the most important prerequisite for successful swarm and MUM-T techniques are left to PLA scholars and operations researchers writing in somewhat less authoritative fora, suggesting that the PLA continues to wrestle with the strategic implications of autonomy and command and control architectures in future unmanned warfare. Drawn from writings in *China Military Science*, *PLA Daily*, and PLA research papers, the following section illustrates the PLA's exploration of and uncertainty regarding autonomy in its approach to swarm and MUM-T techniques. While some of these writings are more than six years old and are unlikely to represent the cutting edge of PLA thought on this fast-developing subject, they offer a useful snapshot of the overall contours of the PLA's views on autonomy and its role in unmanned aerial warfare.

Conceiving of Autonomy in Unmanned Warfare

Though few authoritative PLA writings explicitly address the strategic implications of autonomy in swarm and MUM-T operations, some have attempted to group UAS operations along a spectrum ranging from human-controlled operations to full autonomy. One 2023 assessment characterized "human-machine coordinated operations" (人机协同作战) as the second of a three-step evolution in unmanned autonomy and human-machine interaction in warfare and the current norm in informationized, intelligentized operations, summarized in Figure 2.[17] Swarm operations, which rely heavily on higher machine autonomy, are likely grouped in the third stage of this evolution and are regarded as somewhat less mature or less frequently applied in contemporary intelligentized warfare.

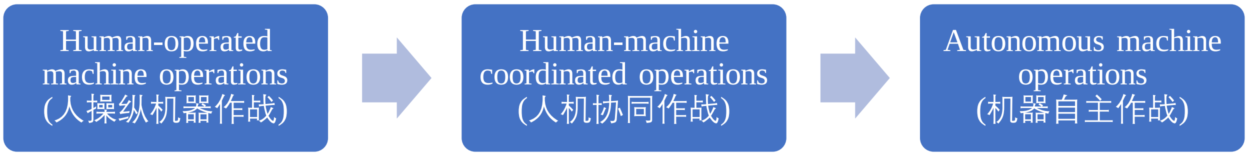

Figure 2: Three types of human-machine interaction in warfare[18]

This sequential description of autonomy in warfare is unsurprising given the PLA's longstanding emphasis on human-machine interplay. Manned/unmanned teaming is a manifestation of a broader effort to better incorporate machines and the information they provide, process, and require into the PLA's way of war. Where terms like "human-machine integration" (人机结合) and "human-machine fusion" (人机融合) describe human interaction with command information systems entering service with the PLA and typically revolve around command decision-making dynamics, related but distinct terms like "human-machine coordination" (人机协同) increasingly refer to a wide spectrum of efforts to use all manner of manned and unmanned platforms in multiple domains together on the battlefield.[19]

Nearly all the concepts of operation described in PLA academic literature straddle a middle ground between contemporary human-controlled UAV operations and fully-autonomous UAV operations. In these "human-on-the-loop" (人在环上) operations—detailed in Table 1—humans "intervene" to supply autonomous UAVs with critical decision input on matters such as kinetic strike execution, while unmanned systems wield their sensing and computing power and communications datalinks to supply the humans with timely and sufficient information to make their intervening command decisions.[20] Broadly speaking, many PLA researchers writing on the topic expect MUM-T techniques and swarms to evolve into a significant force multiplier, while also acknowledging the challenges wrought by increased mission planning complexity when adding these capabilities into an overall campaign.[21]

	Level of UAV Autonomy	**Distinguishing Characteristics**	**Remarks**
Human-in-the-loop (人在环中)	Low	UAVs completely controlled by humans by remote control	Current norm for UAV operations
Human-on-the-loop (人在环上)	Medium	UAVs have modicum of autonomy and can act according to pre-defined instructions, with human intervention when necessary	Human intervention necessary to execute kinetic strikes and to avoid collisions
Human-outside-the-loop (人在环外)	High	UAVs autonomously understand and execute combat tasks according to their understanding of command intentions	

Table 1: Categories of UAV operations[22]

Command and Control Architectures

The complexities and myriad vagaries of mission planning are obvious motivations for the PLA to explore alternative command and control architectures, even if the results of this exploratory work have not extended far beyond the theoretical categorizations described above. While PLA scholars and operations researchers attempt a broader grasp of autonomy in unmanned operations, experimentation with command and control architectures are typically the province of technical researchers within both the PLA and China's defense industry.

Work from U.S. scholars offers a comparative lens for interpreting PLA developments in unmanned command and control. While not explicitly used by PLA engineers and researchers, Paul Scharre's four models of unmanned command and control offer a framework for comparing PLA developments in command-and-control architectures for swarm tactics and MUM-T techniques, summarized in the table below.[23]

	Definition and Features	Assessment
Centralized coordination	Each UAV is a sensor or strike platform, but all data collected from each UAV is funneled back to a centralized node and all commands are directed from that node to each UAV individually.	Likely present state of PLA developments in command-and-control architectures.
Hierarchical coordination	Layers of UAVs divide responsibility of what would otherwise be centralized coordination. One node (mothership or ground station) controls a designated number of UAVs, and those UAVs control a number of smaller "slave" UAVs.	Closely resembles "mothership warfare" described in PLA writings and is a popular model within PLA swarm patent applications. Is also discussed for MUM-T and multi-domain operations.[24]
Coordination by consensus	Typically involves each UAV acting as a sensor while continuously broadcasting collected data to whole swarm formation, which categorizes the data and sends further tasking to each UAV based on location and capabilities.	Among the most prolific model discussed in PLA-affiliated patents.[25]
Emergent coordination	Resembles how swarms operate in nature (e.g. schools of fish or flocks of birds). Each UAV reacts only to nearest swarm mates and relies on "digital pheromones" or similar messages to neighbors to reduce redundant effort and yield faster, more efficient solutions.	Found in PLA-affiliated patents addressing pathfinding, navigation, and target tracking solutions, but likely among the least prolific models discussed.[26]

Table 2: Assessment of PLA Approaches to Unmanned Command and Control

In a sign that the PLA is still settling on the details of command and control for unmanned systems, PLA-affiliated technology research on swarm tactics appeared to address all four models, while PLA writings on MUM-T surveyed for this paper only addressed the centralized coordination and hierarchical coordination models. Even so, coordination by consensus could also potentially lend itself future to MUM-T operations. This model may similarly provide the "human-on-the-loop" decision-making ability the PLA is more comfortable with, while also allowing for a greater amount of autonomy in big data analysis.[27] These models could also potentially extend to a broader network of manned and other-domain assets.

Operationalizing Swarm Tactics and Manned/Unmanned Teaming Techniques

Beyond what is broadly discussed in PLA strategic writings, other texts lay out the operational priorities guiding the development and employment of swarm tactics and MUM-T techniques. Prominent PLA publications like *China Military Science* (中国军事科学) and *PLA Daily* (解放军报) provide valuable insight into informed, high-level PLA discussion on military thought, and while they are perhaps not as authoritative as the *Science of Military Strategy* or defense white papers, they offer substantially more detail on how the PLA intends to apply swarm tactics and MUM-T techniques in unmanned warfare. Selected articles from *PLA Daily* round out the boundaries of discussion on swarm tactics and MUM-T techniques within the PLA.

PLA researchers writing in these venues have eyed several specific missions for unmanned aerial vehicles for which MUM-T and swarm techniques may be applied. Among various formulations, one researcher identified broad mission types for unmanned aerial vehicles: ISR, precision-guided strikes, communications relay, electronic warfare, and battlefield support and logistics, all of which can theoretically extend to swarm and MUM-T employment, and most of which are echoed in additional writings.[28] A PLA colonel further identified four broad types of UAV applications in contemporary and future warfare, illustrated below in Table 1.[29] The first encompasses MUM-T techniques, the third addresses swarm operations, and the fourth could potentially represent a hybrid MUM-T construct that employs swarms as its unmanned component.[30]

	Key Features	**Author Remarks**
Hybrid grouping, agile, interactive human-machine coordinative operations (人机协同式作战)	Vehicle sensor and situational awareness, coordinated task assignment and route planning, formation flight and tracking control	Currently under development
"Lone eagle" operations (孤鹰猛禽式作战)	Reliant upon high-endurance UAVs, satellite communications/datalinks, and precision-guided munitions, with controllers in the rear	Primary present-day use of UAVs
Autonomous swarm operations (群峰自主式作战)	Simple individual units, numerical superiority, decentralized control, limited contact between units, and group-derived intelligence	"Main mode for future intelligent drone operations"
Multi-modal integrated operations (体系联动式作战)	Multi-capable combat ecosystem (体系)[31] with UAVs deployed in different modes by troops at all levels of command, with long-range and close-in coverage and diverse capabilities	To be fully integrated into a joint force and joint combat ecosystem

Table 3: Main forms of unmanned warfare[32]

Further, among a variety of different possible operational applications, one PLA researcher grouped possible concepts of operation into three different types of swarm warfare.[33] The first of these, termed "goose flock warfare" (雁群战), proposes that swarms comprised of multi-functional UAVs could carry out a sequence of activities, including reconnaissance, electronic warfare, and kinetic strikes against all manner of targets, that would ultimately yield the desired cumulative operational effect. A second concept of operations dubbed "bee swarm warfare" (蜂群战) would employ decentralized, coordinated, autonomous saturation attacks against pre-determined targets, relying on numerical superiority to overwhelm an opponent. The idea of overwhelming an adversary and saturating the battlespace with aerial swarms is echoed by other authors in *PLA Daily* articles as well.[34] [35]

A final model styled "mothership warfare" (舰群战) would blend the UAV swarms with manned platforms acting as arsenal aircraft or ships to achieve UAV cluster coverage over a larger geographic area for all manner of missions.[36] Researchers have also noted that the mothership construct could be advantageous in allowing data processing, analysis, and decision making to be offloaded to larger platforms with more computing power, allowing the smaller, more numerous drones to focus on data collection as well as extending these assets' operating area.[37] This idea is complementary to the previously mentioned researcher's idea of "hybrid grouping."

	Main Applications	**Key Features**
"Goose Flock Warfare" (雁群战)	Sequential, cumulative strikes	Multi-functional grouping of UAVs with multiple mission types
"Bee Swarm Warfare" (蜂群战)	Saturation strikes on fixed or pre-determined targets	Dense numerical superiority
"Mothership Warfare" (舰群战)	UAV cluster coverage over larger area	Arsenal aircraft/ships, retrievable UAVs

Table 4: Types of unmanned swarm warfare[38]

"A Group of Fools Generate Wisdom" – PLA Writings on Swarms

PLA researchers are attempting to exploit broad characteristics such as small UAV size, large numbers, and low electromagnetic profile in their swarm employment techniques. Beyond the three applications of swarm warfare described previously, other concepts of operations for swarms are also under discussion. One PLA researcher describes a concept that exploits the small individual vehicle size and easy dispersal of UAV swarms to spring ambushes. In this model, small UAVs could be covertly infiltrated into a contested area either by themselves or through another platform and quickly assembled to generate a sudden, unexpected amassing of kinetic combat power for anti-ship, ground strike, air defense, and anti-submarine missions. This concept would rely heavily on quietly "pre-infiltrating" a strategically important area before combat begins, and making use of self-repairing communications and coordination capabilities to remain a persistent and evolving threat in the area even after an initial ambush was sprung.[39]

PLA researchers are especially optimistic about the prospects and utility of swarm operations. UAV swarms can offer "full area coverage" with close-in reconnaissance, especially in complex urban terrain where object clutter might stymie other sensor platforms.[40] PLA researchers have noted that swarms may be useful in extending the edge of a cloud computing network, allowing sensors to penetrate deep into adversary weapons engagement zones (WEZ) while protecting larger and more valuable assets.[41] This utility has also been borne out in some technical research on UAV support to air defense systems; where UAVs carrying early warning radars are used in conjunction with ground-based air defense weapon systems to conduct long-range early warning detection of low, slow, and small targets in directions with greater terrain obstruction, increasing the detection distance and providing more time for command decisions and fire interception.[42]

In an offensive context, UAV swarms are thought to impose significant costs upon defenders while remaining low-cost, even as these operations would conceivably require large numbers of UAVs to maximize their effectiveness.[43] For both of these mission types, the small size of the individual UAVs and the large numbers used in unmanned swarm operations contribute to the oft-repeated PLA belief that swarm operations are the "main mode for future intelligent unmanned operations."

The small size of individual UAVs in swarm operations is a favorite topic of PLA researchers and officers studying unmanned warfare. Several argue that small size confers stealth and surprise applicable to various wartime applications, including precision strikes against enemy C4ISR infrastructure that is likely to be well-hidden or well-defended.[44] Small size allows for dispersal and wide distribution of combat assets that can ensure the rapid and discreet generation of combat power when needed even in heavily surveilled theaters of combat.[45]

PLA researchers attribute many of the perceived advantages of swarm tactics to the weight of numbers. The large numbers of vehicles used in UAV swarms are thought to confer significant battlefield advantage, especially for saturation attacks on an enemy where it might be beneficial to disperse combat power to a larger number of relatively disposable, low-cost, less-sophisticated platforms.[46] Large numbers are also thought to make UAV swarms more survivable as a defender would have difficulty detecting and tracking individual UAVs at a level sufficient to sustain a defensive firing solution.[47]

Others note the psychological impact of large numbers of autonomous UAVs operating in swarms, arguing that these large numbers and their effectiveness in penetrating air defenses to strike key command posts, weapons systems, and logistics nodes can strike fear in the hearts of the enemy and weaken their fighting resolve.[48] Further, PLA researchers have noted the potential for increase in operational diversity and integration across domains in a joint environment; rather than relying on a small number of exquisite platforms, commanders and war planners may focus on the high efficiency of a combat system as a whole.[49]

Technological features underlying the distributed nature of UAV swarms are also thought to make them ideal for operating in degraded or disrupted electromagnetic environments and for carrying out electronic warfare operations themselves. Through the potential for increased autonomy in sensing equipment and independent analysis, a swarm or MUM-T system can operate in contested domains by offloading tasks and analysis to assets in less degraded areas,[50] while others may provide navigation data from drones recovering from a GNSS degraded area.[51] Citing U.S. military research, one PLA researcher argues that UAV swarms can operate in highly degraded electromagnetic environments because they only require a small window of spectrum for mutual communication, with autonomous coordination making up for any shortfalls or disruptions in communications ability.[52] Should these axioms be borne out by technological research and development, PLA researchers anticipate that jamming-resilient or -resistant UAV swarms could be employed for SEAD or other electronic warfare missions with particular effectiveness. Some of this has made its way into more technical research work.

"A Symbiotic Force Multiplier" – Manned /Unmanned Teaming in PLA Writings

Much of the discussion within PLA academia regarding potential operational use of MUM-T techniques in unmanned warfare is focused on improving the survivability and strike effectiveness of manned platforms. One summary describes three main ways to use MUM-T techniques, all of which evince an abiding concern for survivability. In the first, the unmanned platform "points" at targets with sophisticated ISR equipment and the manned platform "fights" with long-range munitions. This allows the manned asset to stay beyond an enemy WEZ, while the smaller, less observable UAV locates the target, presumably undetected. In the second, the unmanned platform "kicks in the door" and the manned platform follows on to substantively break the enemy. This tactic would likely be employed by using the UAV to degrade or destroy the enemy's ability to locate and track the manned asset, either by kinetically or electromagnetically striking a target tracking radar. In a third, unmanned platforms carry out reconnaissance, decoy, attack, and escort missions for the manned platforms that serve as the core of the formation, carrying out command and decision-making activities.[53]

Although not as prolific as swarm discussions, MUM-T techniques and swarm tactics feature prominently in PLA academic writings. Nested within and descended from PLA thought on human-machine interaction, MUM-T techniques are considered to be especially applicable to UAV employment because of the symbiotic nature of the human-machine team. One PLA researcher argues that present-day UAVs are not actually unmanned, but rather have simply physically separated machine from person, rendering MUM-T techniques an ideal coupling of "human creativity and thought and machine accuracy and [information processing] speed."[54]

This thinking is echoed in other writings that discuss merely using manned systems to control UAV swarms, increasing their diversity, lethality, resilience, elasticity, and responsiveness, but not necessarily delegating significant autonomy to the UAVs themselves.[55] Others have expounded on this reasoning, noting that MUM-T techniques bring the best of both manned and unmanned capabilities to any use of UAVs. Where humans have "combat experience, intuition, inspiration, initiative, and the art of command, unmanned systems have fewer environmental restrictions, lower cost, no fear of casualties, and the ability to close in on a target."[56]

PLA operational thought on MUM-T techniques coalesces around two main concepts of operations. In the first, PLA researchers broadly conceive of the manned elements in a MUM-T operation as the command element, making certain operational decisions and executing "command by intervention" over nearby unmanned elements.[57] Manned command elements intervene when necessary in the operations of UAVs from the relative safety of the rear, while unmanned elements act as the main combatant force. This model lends itself to a number of variations: In one permutation, the unmanned systems bring various payloads ranging from reconnaissance to electronic warfare to kinetic munitions into the combat area—somewhat echoing the "Goose Flock Warfare" described above—while the manned elements monitor for opportunities and risks from outside the combat zone. In a second permutation, unmanned systems undertake reconnaissance and electronic warfare missions with the corresponding payloads, while manned platforms follow up with kinetic strike missions, similar to the idea of "kicking in the door." A third permutation envisions unmanned systems carrying kinetic payloads, while manned systems carry out reconnaissance and command missions from outside the combat area, all designed to increase the survivability of manned assets.[58]

PLA researchers are also beginning to explore more explicit uses of MUM-T techniques for specific missions. In one 2022 example, researchers associated with the Department of Combined Tactics at the Air Force Command College and the National Defense Science and Technology Key Laboratory of Weapons and Equipment Systems outlined many potential operational missions for MUM-T employment:[59]

- Challenging stealth aircraft like the F-22, F-35, or B-2 by using a UAV to detect a stealth aircraft ahead of manned/ground platforms and then sending the information to the manned/ground platforms for contact;
- Using a manned asset operating from a safe distance to provide target data to an unmanned asset to execute at closer range;
- Using a UAV as a forward relay guidance for air-to-air missiles, allowing the manned asset to peel off without entering the WEZ;
- Striking high-value air targets where the manned aircraft commands and controls UAVs to move forward to increase the effective range of the manned aircraft's ability to find, fix, track, and target;
- Suppressing adversary air defense networks, sending UAVs ahead to provide target data to manned systems to eliminate enemy air defense systems;
- Using UAVs to continuously monitor target location and provide real-time updates to manned platforms and/or other munitions;
- Using UAVs to carry out deception missions to lure air defense systems into attacking them while ignoring inbound munitions/manned platforms;
- Using unmanned systems for electronic warfare, sending UAVs ahead to jam and provide reconnaissance and intermediate- and long-range jamming cover;
- Striking time-sensitive targets, using reconnaissance UAVs to track time-sensitive targets over long periods of time and manned platforms to allocate targets to either more agile unmanned systems or more plentiful munitions options among manned aircraft.

The boundaries of MUM-T force employment debates have apparently expanded as the PLA modernizes and technology matures. In 2022, for instance, some PLA theorists suggested adding UAVs (presumably reconnaissance only) into the battlespace with manned aircraft to increase the number of sensors providing data into a theoretical cloud environment.[60] By 2024, however, other contributors to the same publication were theorists discussing more ambitious multi-modal integrated operations using a mixed manned/unmanned lethal network (杀伤网络) for systemic operations, relying on a diverse, hierarchical force package with aircraft (manned &

unmanned) at various altitudes, with various ranges and diverse capabilities from the tactical to the strategic.[61]

Hybrid Use of Swarms and MUM-T Techniques

Many MUM-T concepts found in PLA literature are not exclusively designed for MUM-T. Instead, many of these concepts emerge from a milieu where PLA researchers and theoreticians discuss all manner of advanced concepts of operations for UAVs. As a result, some of their observations and the concepts that result are distinct but still closely related to swarm operations, suggesting that the PLA could embrace hybrid employment of swarm tactics and MUM-T techniques.

One frequently cited concept of operations leaves open the prospect of hybrid use of swarm and MUM-T techniques. Termed "mothership warfare" (舰群战) by one PLA researcher, the concept calls for large manned or unmanned systems to launch small unmanned systems into a combat area from relative safety.[62] Those studying this concept of operations depict it as a more cost-effective alternative to the first concept and stress the recoverability of the UAVs used in this scenario, though both disposable and recoverable UAVs could be employed.[63] Where possible, UAVs with reconnaissance and electronic warfare payloads and missions should be recoverable, while any small UAVs with kinetic strike missions should be considered disposable.[64]

Research, Development, and Acquisition

All of the previous concepts depend on a vast research, development, and acquisition (RDA) ecosystem to supply the required technologies and platforms to the PLA. This section describes some of the more prominent institutions, personnel, and efforts supporting the PLA's development of MUM-T techniques and swarm tactics.

In an example of technology determining tactics, technical work on swarm tactics and MUM-T techniques long preceded the doctrinal development described above, with some of the earliest research dating back to at least 2003 and 2004, well before the PLA had entered its self-defined era of intelligentized warfare.[65] That technical work continues today: available evidence indicates that the PLA and its research, development, and acquisition apparatus are pursuing both of these techniques apace.

Research Areas

Technical writings on UAV swarms address a wide range of topics, especially subjects that could mitigate or resolve difficulties in implementing swarm tactics. Beyond identifying the realm of the possible, swarm research is addressing the challenges earlier researchers and strategists have identified regarding efficient UAV collaboration, balancing the need for power and data analytics with bandwidth limitations and more developed payloads. While earlier papers still discuss the key technologies required to make exquisite, collaborative swarms,[66] PLA and defense industry research institutions are undertaking multi-faceted approaches to algorithm optimization, especially for better spectrum management,[67] more effective UAV task allocation solutions,[68] more cooperative reconnaissance,[69] multi-mission collaboration,[70] faster target detection and tracking solutions,[71] and coordinated and collaborative attacks.[72]

Many of these works emphasize using these swarms in highly dynamic, contested operations, with complex geography and limited network resources.[73] For instance, one 2022 article covered many of these concepts, describing how a distributed swarm may be programmed using a function of game theory to gather data in a scenario with unknown boundaries and find the optimal solution in a spectrum-degraded environment. The study purports to even allow the swarm to organize itself into subnetworks to best increase data transmission quality.[74]

Technical research on MUM-T concepts is similarly ambitious but somewhat less mature. Like writings on swarm tactics, much of this work stresses operations in contested and degraded environments in high-intensity conflict, but much of the literature appears exploratory in nature, rather than focusing on optimization as is the case for swarm research.[75] Much of the publicly available research from the PLA and the Chinese defense industrial base focuses on literature reviews of technology required for MUM-T employment and evaluations of other countries' MUM-T concepts, especially the U.S. Loyal Wingman program.[76] Many of the more technical writings on MUM-T concepts addressed task organization,[77] asset bandwidth scheduling, and command and control constructs,[78] many of which discuss combining manned aircraft with swarms.[79] One such research paper suggests using a decision-making model for manned aircraft combined with unmanned swarm teams using decision-making "stages" in a series of zero-sum games utilizing a non-complete strategy. Each stage is executed until a decision-making sequence is generated. This is said to increase effectiveness when an opponent's strategy is not completely known, and when it is unknown how the opponent will respond to their information-constrained environment. This research focuses on maneuverability of opponent aircraft and opponent missile strikes in order to improve UAV swarm decision-making with incomplete information.[80]

INSTITUTIONS PRODUCING RESEARCH AND PROTOTYPES

Judging by domestic research publication output, PLA academic institutions and institutions associated with the PLA appear to be hotbeds of research and development for both swarm tactics and MUM-T techniques. Much of the public academic funding for this RDA work is civilian, though in several instances papers on swarm tactics and MUM-T techniques are funded by national defense or PLA research funds.[81] Several of the most prominent institutions publishing research on swarms and MUM-T are noted in Table 4. Notably, while many academic institutions and private companies across China have been prolific in producing research and patents on UAV swarms, MUM-T and attempted technology is exclusively—though not surprisingly—associated with the PLA and PLA-aligned institutions, and also far less prolific.[82]

Research Institutions Working on Swarm Tactics	Research Institutions Working on MUM-T Techniques
• National University of Defense Technology (国防科技大学) • Nanjing University of Aeronautics and Astronautics (南京航空航天大学） • PLA Air Force Engineering University (空军工程大学) • Northwest Polytechnic University (西北工业大学) • PLA Army Engineering University (中国人民解放军空军工程大学) • PLA Naval Aviation University (中国人民解放军海军航空大学) • CETC 54th Research Institute (中国电子科技集团公司第五十四研究所) • Beijing University of Aeronautics and Astronautics (北京航空航天大学) • Nanjing University of Science and Technology (南京理工大学) • PLA Academy of Military Sciences (中国人民解放军军事科学院)	• PLA Air Force Engineering University (空军工程大学) • PLAN Aviation Engineering Academy (海军航空工程学院) • Nanjing University of Aeronautics and Astronautics (南京航空航天大学） • National University of Defense Technology (国防科技大学) • Northwest Polytechnic University (西北工业大学) • CETC 28th Research Institute (中国电子科技集团公司第二十八研究所) • CETC 20th Research Institute (中国电子科技集团公司第二十研究所) • Nanchang Aeronautical University (南昌航空大学) • PLA Army Engineering University (中国人民解放军陆军工程大学) • Beijing Institute of Technology (北京理工大学)

Table 5: Prominent Academic Research Institutions Studying MUM-T and Swarm Tactics[83]

FIELD TESTS

Beyond academic papers and publications, several of these institutions are conducting field tests on UAV swarms to make them more effective on the battlefield.[84] One prominent research cluster at the National University of Defense Technology's College of Intelligence Science and Technology (智能科学学院) is working to make UAV swarms more resistant to electronic jamming that could disrupt the key vehicle-to-vehicle communications that keep the swarm functional.[85] National University of Defense Technology electronic information instructor Xiang Xiaojiaand his graduate student researchers have used a variety of simulation tools and flight tests to develop algorithms that will make UAV swarms more resilient to electronic jamming.[86] Other professors at universities with strong defense ties have reportedly developed small tube-launched UAVs that can launch from other UAVs, potentially dramatically increasing the number of vehicles in a UAV swarm at a moment's notice, thereby complicating tracking for anti-UAV defense systems.[87]

Prototypes, Demonstrators, and Speculation

Though not necessarily as well-represented in academic publications, both the PLA and the Chinese defense-industrial base supporting the PLA's RDA efforts are also working on swarm tactics and MUM-T techniques. Some of these institutions have demonstrated swarm and MUM-T technologies with varying degrees of maturity and available public information.

Western observers have speculated that the PLA is devoting considerable energy to operational testing and evaluation for MUM-T platforms. In March 2021, several unofficial Western observers reported that the Shenyang Aircraft Corporation was testing an artificial intelligence algorithm named "Intelligent Victory" (智胜) aboard a J-16 fighter aircraft based on rumors, an unoccupied backseat, and tail art with the characters for "intelligent victory." [88] Conjectures about PLA MUM-T testbeds arise frequently, but these occurrences could not be verified with any publicly available sources in English or in Chinese at the time of writing.

Figure 3: J-16 testbed aircraft reportedly equipped with an artificial intelligence algorithm[89]

MUM-T testing would likely occur under the auspices of the PLA Air Force's Testing, Experimentation, and Training Base (空军试验训练基地), also known as Unit 95861.[90] The unit claims prominent UAV test pilot Li Hao (李浩) and Zhao Xu (赵煦), regarded as China's "father of UAVs," as members of the unit.[91] Some of this testing may be occurring at Malan airbase, which according to unofficial observers hosts PLAAF UAV training brigade Unit 95835 and in June 2021 displayed a Flanker fighter next to a series of other UAVs, prompting further speculation from Western observers that the PLA was testing MUM-T techniques and technologies.[92]

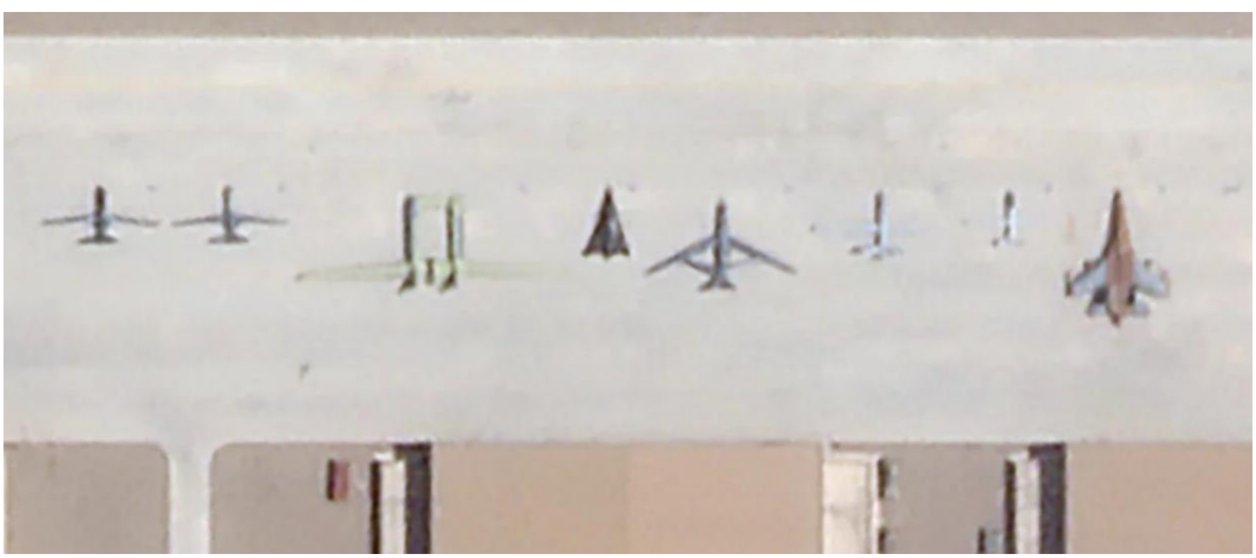

Figure 4: Flanker fighter aircraft (far right) parked on tarmac with UAVs at Malan airbase, dated June 1 2021[93]

The FH-97A (飞鸿-97A) is a more deliberately publicized example of the defense-industrial base's MUM-T aspirations. Reportedly developed by the Aerospace Era Feihong Technology Company (航天时代飞鸿技术有限公司), a subsidiary of China Aerospace Science and Technology Corporation's 9th Academy, 9th Design Department (中国航天科技集团有限公司第九研究院第九设计部),[94] the FH-97A is explicitly marketed as a "loyal wingman" and bears a striking visual resemblance to Western counterparts like the XQ-58 Valkyrie.[95] Despite a high-profile publicity campaign, there has been no public evidence suggesting the FH-97A has made any actual flights, and certainly none suggesting deployment to PLA units.

Perhaps a more mature example of MUM-T development is the Sky Hawk (天鹰). Designed by the Hiwing Aviation General Equipment Company (海鹰航空通用装备有限责任公司), a subsidiary of the China Aerospace Science and Industry Corporation's (CASIC) 3rd Academy, and tested by personnel from CASIC's 159th Factory, the Sky Hawk allegedly first flew in November 2017 after nearly four years of development, and made several appearances at airshows before being prominently revealed again to the public in February 2024.[96] The Sky Hawk team reportedly experienced significant difficulty in achieving long range flight with the compromises made for the aircraft's stealthy design, and was ultimately comprised of more than 80 percent new technology.[97] The Sky Hawk's chief designer Ma Hongzhong (马洪忠) and head of Hiwing confirmed in an interview with state media that the Sky Hawk had the capability to coordinate with manned aircraft, but offered no further details.[98]

Figure 5: Sky Hawk UAV's first flight in November 2017[99]

While some institutions work on hardware components, others are working on the software elements needed to accomplish MUM-T techniques. One example at a 2021 arms exhibition suggested that the China Electronics Technology Group Corporation's (CETC) 28th Research Institute had developed a flight simulator to demonstrate the utility of a "loyal wingman." Part of a display of an “air-to-air formation intelligent battle management and command-and-control system” (空中编队智能作战管理与指挥控制系统), the simulator reportedly was able to make an assessment of a manned fighter aircraft’s relative standing when approached by an enemy aircraft and dispatch a loyal wingman to draw incoming fire, thereby saving the manned aircraft from destruction in an air-to-air battle.[100]

CETC 28th Research Institute engineer and National Defense Key Laboratory (国防重点实验室) project leader He Jiafan (贺嘉璠),[101] who worked on the simulator and has published other work on the utility of spatial-temporal graph convolutional neural networks in tactical recognition of two-ship aircraft formations,[102] claimed that the simulator featured a domestically-designed and configured combination of fuzzy-tree modeling based on a genetic algorithm (基于遗传模糊树) and deep reinforcement learning, and used extensive air combat training data to generate options for the pilot and their unmanned loyal wingman. He’s description of the simulator suggested the computation and the options were handled off board and then pushed to the manned aircraft, as well as the loyal wingman.[103]

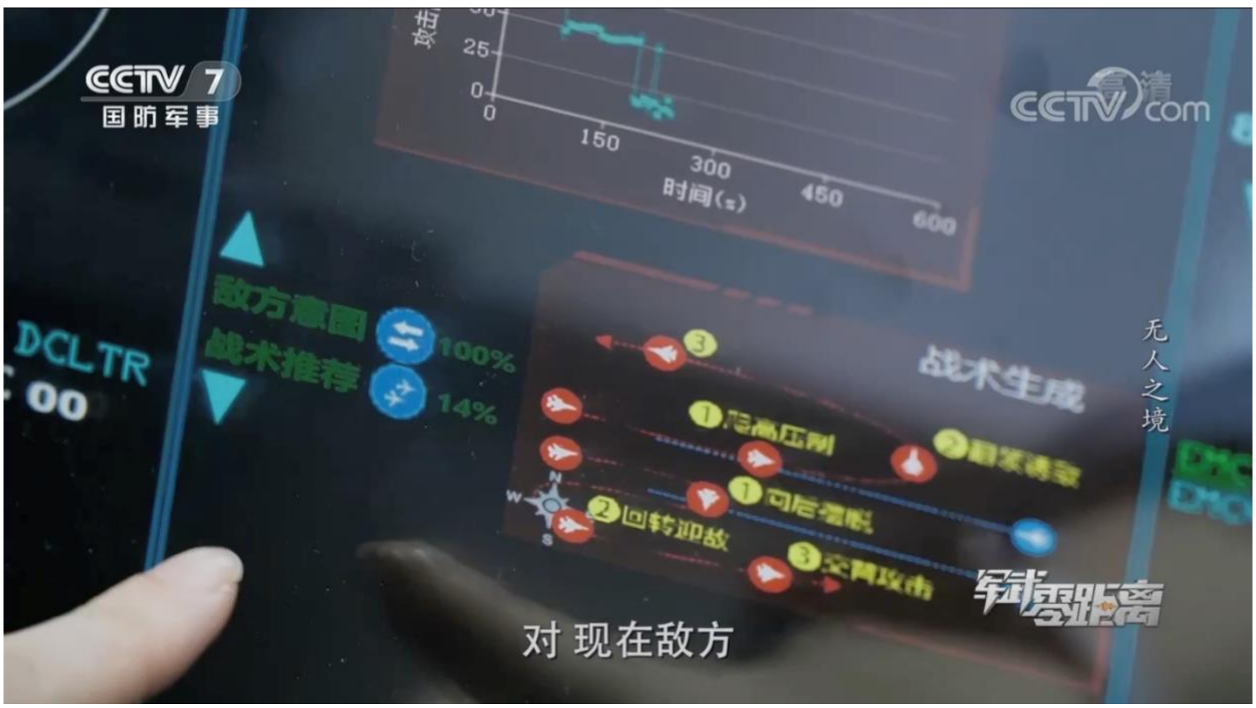

Figure 6: Image of CETC 28th Research Institute MUM-T loyal wingman simulator screen, displaying assessment of enemy intention, tactical recommendation, and several tactical maneuver options for the pilot[104]

Other Chinese defense conglomerates are also working on prototyping swarm technologies and platforms. In October 2020, official Chinese sources reported that CETC’s China Academy of Electronics and Information Technology (中国电科集团电科院) had developed and tested a UAV swarm with 200 fixed-wing drones launching from a truck-based tube launcher and by helicopter.[105] These systems apparently continue to proliferate within China’s defense industry:

another truck-based UAV launcher was exhibited in November 2022 at the Zhuhai Airshow, this time by China South Industries Group (中国兵器装备集团).[106]

Figure 7: Test footage from October 2020 showing a swarm of loitering munitions rearranging aerial formation[107]

Use in Training and Exercise Activities

Despite a groundswell in public references to swarm or MUM-T techniques within both the PLA and China's defense-industrial base, there is little robust public evidence of operational PLA units using swarm or MUM-T techniques outside the parameters of testing and evaluation. Nevertheless, PLA sources claim that adoption and usage of UAVs is continuing apace, including one *China Military Science* article that claims "certain, definite breakthroughs in swarm tactics."[108] In November 2023, the PLA reported one of its combined arms brigades in the Eastern Theater Command deployed drones for aerial reconnaissance to provide commanders with battlefield info to formulate combat plans. However, the article did not include photographs of the drones used and the photograph of the "reconnaissance team" was a picture of a ground element. It is unclear if this employment could be considered a true "swarm," but is more likely to be a handful of small UAVs comparable to the US Department of Defense's Group 1 and 2 classification, and are likely not collaborative.[109] The exact nature of these breakthroughs is unclear from publicly available sources, partially because swarm tactics and MUM-T techniques can be difficult to verify.

Despite the scarcity of verifiable proof of MUM-T and swarm tactics, available evidence suggests the PLA likely takes an expansive and somewhat rudimentary view of these techniques, with simple or scripted operation and coordination between manned and unmanned systems in the same geographic area counting as MUM-T experience. A December 2023 news segment describing a pioneering application of MUM-T techniques with a J-16 and a GJ-2 UAV in the Western Theater Command, for instance, suggested that the aircraft were operating together with surface-to-air missile and radar units as part of a joint exercise. GJ-2 UAVs in the exercise reportedly transmitted target information for an air-to-ground strike to the base control tower, which then ordered the J-16s to strike the target based on “uploaded” information. The report did not make clear whether the UAVs uploaded target information directly to the J-16s, or if the J-16s had any control over the UAVs in the area. Nevertheless, PLA media championed the drills as a breakthrough that “helped break down the barriers between manned and unmanned operations.”[110]

Of the various PLA services experimenting or training with MUM-T or swarm tactics, the PLA ground forces appear to be the most prolific in official media reports. PLA Army forces in the Eastern Theater Command have reportedly begun to use UAV swarms during exercises. New equipment familiarization exercises in 2021 showed an Eastern Theater Command PLA Army brigade flying small quadcopter UAVs in what appeared to be a swarm-like formation, with the news segment claiming that the brigade was using these for battlefield reconnaissance.[111] A well-publicized July 2021 news report covering the 73rd Group Army’s 14th Amphibious Combined Arms Brigade showed footage of 40-50 quadcopters in a swarm-like formation flying over a coastal area, likely performing reconnaissance duties.[112] Other evidence suggests that PLA Army aviation units have already begun to experiment with force structures incorporating unmanned vehicles at company-grade level organizations, offering structural opportunities for these aviation brigades to practice coordination with unmanned systems. In a rudimentary but still valid example of this MUM-T implementation, an 80th Group Army attack helicopter brigade with an organic UAV company conducted manned/unmanned flight exercises where UAVs “painted” targets with lasers for attack helicopters.[113]

IDENTIFIED CHALLENGES

Given the developmental nature of MUM-T techniques and swarm tactics both within the PLA and its RDA apparatus, assessments of anticipated difficulties and problems in employing these technologies in the PLA are commonplace. Many of these assessments describe problems inherent to MUM-T techniques and swarm operations, as well as problems integrating these new concepts into the PLA's way of war.

DEFICIENCIES AND LIMITATIONS IN MANNED/UNMANNED TEAMING AND SWARM OPERATIONS

PLA academics recognize that even if fully matured, MUM-T techniques and swarm operations are not a panacea. From an operations standpoint, MUM-T techniques and swarm operations come with inherent difficulties related to command-and-control, demanding support requirements, vexing cost concerns, and the possibility of human casualties.

PLA scholars have devoted considerable attention to the command-and-control difficulties that may arise from any larger adoption or employment of MUM-T techniques or swarm operations in combat. Researchers are skeptical that commanders will be able to effectively monitor and manage manned and unmanned coordination at scale, and one noted that commanding multiple unmanned systems in a fight "is very likely to cause chaos and even render it impossible to complete combat missions."[114] The same researcher noted that autonomous swarm operations would require a veritable reconstruction of command and control methods and even military documents, with a corresponding emphasis on transforming human-readable command information into machine-readable counterparts.[115]

Both MUM-T techniques and swarm operations were also criticized by PLA scholars for their extensive and demanding support requirements. MUM-T formations are reliant on extensive space-based communications and datalinks to transmit information between manned and unmanned elements in a MUM-T formation, which might not be assured in a conflict, though using UAVs as communication nodes has also been discussed to mitigate any dependency on space assets.[116] Others cautioned that because UAV swarms derive their combat effectiveness from numerical superiority, UAV swarms could be used inefficiently if battle damage assessment was inaccurate or slow to arrive. As a result, these swarms likely would demand more robust and dynamic battle damage assessment capabilities than other applications of combat power might require.[117]

For PLA academics, the manned component of MUM-T techniques brings along the unavoidable prospect of human casualties in a mode of combat whose great promise was to significantly reduce them. One PLA scholar expressed skepticism that any division of labor that resulted in manned systems carrying out follow-up strike missions would be able to avoid human casualties.[118]

Cost considerations appear to be a vexing deficiency for swarm operations. One 2020 assessment claimed that large UAVs with suitable speed and payload were not cost-effective enough for use in swarms, even though they were assessed to be more combat capable than their small UAV counterparts. On the other hand, small, cost-effective UAVs were believed to be too slow to successfully penetrate enemy air defenses, and too limited in their payloads to be combat-effective.[119] Another 2023 article in *China Military Science* complained about the high absolute cost of swarm tactics, especially if large numbers of swarming UAVs were paired with expensive precision-tracking technologies or sensors.[120]

SHORTCOMINGS IN INTEGRATING SWARMS AND MUM-T TECHNIQUES

Beyond some of the more inherent problems associated with MUM-T techniques and swarm operations, other broader deficiencies might impede effective integration of these capabilities into the PLA's unmanned force. Commonly cited shortcomings include insufficient doctrinal and operational research, a lack of familiarity and training among the PLA's UAV operators, and an overly scripted command-and-control ecosystem.

PLA researchers have argued that the PLA's doctrinal and operational research on UAVs is lacking. A 2018 assessment called for deeper studies on MUM-T and swarm usage in particular based on the development of specific payload capabilities, including ISR, data transmission, ECM, and damage assessment payloads. A more concrete deficiency in integrating swarm and MUM-T techniques was the apparent absence of authoritative outlines (纲要) or operational regulations (条令) governing usage of UAVs at the operational level in 2018, to say nothing of research-based prescriptions for more advanced swarm operations and MUM-T applications.[121] Our research could not definitively determine if these issues have been remedied. Although the PLA has almost certainly conducted more doctrinal and operational research in the intervening years, some more recent evidence suggests that not all of it has reached line UAV units, some of which were still learning on the job in 2023.[122]

Other problems that have hindered the PLA in the past include a lack of familiarity and training within the force. PLA researchers decry a pervasive unfamiliarity with UAVs within the force, noting that many troops "do not dare to use and do not know how to use" (不敢用、不会用) UAVs in their work.[123] Other evidence suggests that command staff at PLA UAV units have to write their own training and maintenance manuals after breaking in new equipment.[124] As the PLA continues to embrace unmanned warfare, some researchers called for more force-on-force training and more simulation equipment to reach deployed units.[125] These issues could significantly impede the PLA's adoption of advanced UAV employment techniques if the PLA has not resolved them since they were articulated six years ago.

Perhaps the most difficult and intractable are in the command-and-control ecosystem as the PLA strives achieve "decentralization" in autonomous swarm operations and MUM-T techniques.[126] These challenges include balancing payload size and its associated weight with data processing capabilities and the need for smaller and smaller microchips, frequency crowding when multiple assets are using the same frequency in the same battlespace, and the possibility that electromagnetic interference affecting one asset may take down the entire network. In 2018, PLA scholars acknowledged the need to develop command and control nodes that could handle multiple UAV platforms at once, as well as a shift from static task planning in advance to real-time, dynamic, autonomous control of UAVs.[127] By 2020, PLA academics writing on swarm and MUM-T techniques opined that command-and-control methods would need to be completely overhauled, upending existing command processes and rhythms to account for autonomous swarms and UAVs.

Other elements of the command-and-control cycle would also need revamping, down to the reformatting of command directives from human-readable to machine-readable data.[128]

CONCLUSION

Though neither is fully realized, the PLA's operational thought surrounding UAV swarm tactics and applications is likely more mature and more likely to be deployed in a near-term conflict than MUM-T techniques. This may be due to an extensive research and development ecosystem that is steadily developing more mature swarm technologies, as well as PLA observations about the heavy use of small UAVs in the recent Russian invasion of Ukraine as well as more tactically in Syria and Israel. In some instances, like the ones detailed in previous sections, the PLA has apparently used UAV groups for reconnaissance during exercises. Even if potentially rudimentary, these groups of UAVs may approximate some of the effects of swarm tactics on the PLA's expected future conflicts by virtue of comparative stealth, large numbers, and beneficial timing in tactical employment.

For their part, MUM-T techniques are perceived as less of an advanced leap and are also buttressed by technological advances from China's defense industry, but counterintuitively few if any of these technologies have reached the force and the PLA's implementation of MUM-T techniques are still rudimentary in practice. The PLA's experimentation with MUM-T techniques are likely focused first on operating manned aircraft alongside unmanned counterparts in various scenarios, rather than deployment of a more autonomous "loyal wingman" in practice. Prototypes and rumors of a "loyal wingman" abound, but there is likely some ways to go before the PLA deploys these platforms to an operational unit.

Some concepts of operation are prolific across both swarm tactics and MUM-T techniques, offering the PLA an opportunity to more rapidly develop closely integrated battlefield uses for both. "Mothership" concepts, in which larger manned and unmanned vehicles or aircraft can serve as "arsenal ships" to extend range and potentially recover smaller UAVs deployed in large numbers, are popular within the PLA's ecosystem for developing operational thought for both MUM-T and swarm operations. PLA development and testing of these "mothership" concepts warrants particular attention going forward.

Nevertheless, there is considerable potential for effective future PLA application of MUM-T techniques and swarms in various tactical scenarios, if not operational or strategic ones. At the tactical level, PLA units with existing command structures and mandates to fulfill support missions like reconnaissance and close-air support could easily incorporate UAV swarms comprised of low-cost, potentially off-the-shelf vehicles, without necessarily forcing substantial changes in command-and-control dynamics. Additionally, these could be used in support of lower-intensity conflict such as border security and psychological operations. The PLA is already adapting its organization to account for these new technologies, incorporating more use of UAVs within manned aircraft units of the same PLA service and integrating these tools and any concomitant MUM-T or swarm techniques in an approach akin to combined arms integration rather than suffer the difficulties of joint force integration.

Use of fully autonomous systems with theater-level or strategic effects, however, would likely encounter more friction from a PLA chain of command that may still be unaccustomed to the benefits and effects of more autonomous platforms. Though not conclusive evidence of resistance to autonomy, the sources encountered for this paper stressed autonomy only within the scope of non-lethal uses of unmanned systems, namely ISR, targeting, and other enabling functions. More clarity will emerge as swarms and MUM-T concepts are increasingly used in training, exercises, and future operations, but given the dearth of publicly available evidence on the use of these systems and the potential impact on PLA warfighting capabilities, autonomy in unmanned combat techniques is another area worth special attention.

Finally, it is especially important to understand how China's defense industry will help develop these systems and associated tactics. China's defense industry has developed numerous prototypes and demonstrators for swarm and MUM-T technologies, including some that make extensive use of artificial intelligence. There is no public evidence, however, that any of these prototypes or demonstrators have reached full operational status with line units in the PLA.

Given that authoritative PLA documents stress the need for multi-domain and joint warfare, more analysis is needed to assess how swarms and MUM-T will be integrated into larger warfighting strategy. As the PLA's thinking on MUM-T techniques and swarm tactics continues to evolve, and as China's defense industry and R&D apparatus continue to devote resources and attention to these technologies, the PLA's development, adoption, and deployment of these tactics will continue apace.

ENDNOTES

[1] Li, Jiafu [李家福] "A Study of the Operational Employment of Unmanned Aerial Vehicles," [无人机作战运用研究], *China Military Science [中国军事科学*], 2018 No. 6, pp. 130-131.

[2] See Shao, Ningning [邵凝宁], "Research on Air and Surface Strike Using UAV Swarm Supermobility Under Datalink Command" [数据链指挥下无人机群超机动对空地攻击研究], Nanjing University of Aeronautics and Astronautics Master's Dissertation, February 1, 2006 and Cao, Juhong [曹菊红] and Gao Xiaoguang [高晓光], "An Intelligent Command and Control System for Multi-UAV Operations" [多架无人机系统作战智能指挥控制系统], *Firepower Command and Control* 2003 No. 5.

[3] Zhang, Yuliang [张玉良], Yu Shusheng [郁树胜], Zhou Xiaopeng [周晓鹏], eds. "Science of Campaigns" [战役学] *Beijing: National Defense University Press [国防大学出版社]*, 2006.

[4] Assembled by the Academy of Military Sciences Military Strategy Research Department, the 2013 version of the "Science of Military Strategy" is regarded as one of the most authoritative publicly available articulations of the PLA's views on military strategy.

[5] PLA Academy of Military Sciences Military Strategy Research Department [军事科学院军事战略研究部], ed., "Science of Military Strategy" [战略学], *Beijing: Academy of Military Sciences Press [军事科学出版社]*, 2013 pp. 73, 223-224.

[6] Ibid., p. 97.

[7] Ibid., pp. 73, 97.

[8] These documents are arguably the most faithful public expressions of China's military strategy, referred to in China as the "military strategic guidance" (军事战略方针). See Joel Wuthnow and M. Taylor Fravel, "China's military strategy for a 'new era': Some change, more continuity, and tantalizing hints," *Journal of Strategic Studies*, March 1, 2022, p. 1. For the 2015 defense white paper, see State Council Information Office of the People's Republic of China [中华人民共和国国务院新闻办公室], "China's Military Strategy" [中国的军事战略], May 26, 2015, http://www.china.org.cn/chinese/2015-05/26/content_35663186.htm

[9] State Council Information Office of the People's Republic of China [中华人民共和国国务院新闻办公室], "China's Defense in the New Era" [新时代的中国国防], July 2019, http://www.mod.gov.cn/gfbw/fgwx/bps/4846424.html

[10] Xiao, Tianliang [肖天亮], ed., "Science of Military Strategy" [战略学], *Beijing: National Defense University Press 国防大学出版社*, 2020, pp. 176-177.

[11] Xinhua Net, "Xi Jinping Visits PLA Air Force Aviation University on the Eve of August 1st, Stresses Deepening Reform and Innovation and Raising Education Standards, and Congratulates PLA and PAP Officers, Enlisted, Reservists, and Veterans" [习近平八一前夕观察空军航空大学时强调深化改革创新不断提高办学育人水平 向全体人民解放军指战员武警部队官兵民兵预备役人员致以节日祝贺], July 23, 2020, *Xinhuanet*, www.xinhuanet.com/politics/leaders/2020-07/23/c_11265277488.htm. Xi was reportedly briefed on numerous other military topics in the same meeting. See: "Xi Jinping stressed strengthening mission responsibility, deepening reform and innovation, and comprehensively improving strategic capabilities in emerging fields when attending the plenary meeting of the People's Liberation Army

and the Armed Police Force delegation" 习近平在出席解放军和武警部队代表团全体会议时强调强化使命担当 深化改革创新 全面提升新兴领域战略能力, *CCTV*, March 7, 2024, https://news.cctv.com/2024/03/07/ARTI5nQ1AwDuxnRktZf0q6R240307.shtml

[12] State Council Information Office of the People's Republic of China [中华人民共和国国务院新闻办公室], 2015.

[13] State Council Information Office of the People's Republic of China [中华人民共和国国务院新闻办公室], 2019.

[14] Xiao, Tianliang [肖天亮], ed., 2020, pp. 374-377.

[15] Ibid, pp. 217-245.

[16] There are many technologies inherent in employing assets in support of these strategies; some are more prolific in PLA writings than others, but that discussion lies beyond the scope of this paper.

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