SMALL SKIES: COUNTERING SMALL UAS ON A MULTI-DOMAIN BATTLEFIELD

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Over the last decade, state and non-state actors around the world have employed small unmanned aerial systems (sUAS) to achieve battlefield effects. This thesis explores the manner in which these systems have been employed in contemporary operations, and the way peer forces may employ these systems in high-intensity combat operations. It also examines existing efforts by the Department of Defense to combat this threat. By establishing models for small UAS employment this thesis provides a basis for tactical units to conduct counter-sUAS on a multi-domain battlefield. Finally, it uses threat models to describe the capabilities required by tactical formations to conduct counter-sUAS operations in high-intensity Multi-Domain Operations and recommends changes through the Doctrine, Organizations, Materiel, and Leadership and Education domains of DOTMLPF-P.

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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the US Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

SMALL SKIES: COUNTERING SMALL UAS ON A MULTI-DOMAIN BATTLEFIELD, by Eric Allen Rowland, 150 pages.

Over the last decade, state and non-state actors around the world have employed small unmanned aerial systems (sUAS) to achieve battlefield effects. This thesis explores the manner in which these systems have been employed in contemporary operations, and the way peer forces may employ these systems in high-intensity combat operations. It also examines existing efforts by the Department of Defense to combat this threat. By establishing models for small UAS employment this thesis provides a basis for tactical units to conduct counter-sUAS on a multi-domain battlefield. Finally, it uses threat models to describe the capabilities required by tactical formations to conduct counter-sUAS operations in high-intensity Multi-Domain Operations and recommends changes through the Doctrine, Organizations, Materiel, and Leadership and Education domains of DOTMLPF-P.

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ACRONYMS

ADA	Air Defense Artillery
ADAM	Air Defense and Airspace Management
AFC	US Army Futures Command
AFRL	Air Force Research Laboratory
AGL	Above Ground Level
AI	Artificial Intelligence
AMD	Air and Missile Defense
AO	Area of Responsibility
APD	Army Publishing Directorate
ATP	Army Techniques Publication
BCT	Brigade Combat Team
BLOS	Beyond Line of Sight
BN	Battalion
C2	Command and Control
CARL	Combined Arms Research Library
CBRN	Chemical, Biological, Radiological, Nuclear
CENTCOM	US Central Command
CRS	Congressional Research Service
C-sUAS	Counter-Small Unmanned Aerial System
DDoS	Distributed Denial of Service
DHS	Department of Homeland Security
DoD	US Department of Defense

DOTMLPF-P	Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, Facilities, and Policy
DTIC	Defense Technical Information Center
EA	Electronic Attack
ELINT	Electronic Signals Intelligence
EMS	Electromagnetic Spectrum
EO/IR	Electro-optical/Infrared
EW	Electronic Warfare
FAAD	Forward Area Air Defense
FL	Flight Level (100 ft increments)
FM	Field Manual
FORSCOM	US Army Forces Command
GCS	Ground Control Station
GPS	Global Positioning System
HQDA	Headquarters, Department of the Army
IADS	Integrated Air Defense Systems
ID	Infantry Division
IED	Improvised Explosive Device
ISIS	Islamic Republic of Iraq and Syria
ISR	Intelligence, Surveillance, and Reconnaissance
JAGIC	Joint Air-Ground Integration Cell
JCO	Joint Counter-Unmanned Aerial System Office
JEL	Joint Electronic Library
KIA	Killed in Action
LOE	Line of Effort

LRS	Long Range Surveillance
LSS-UAS	Low-slow-small Unmanned Aerial System
MANPADS	Man-Portable Air Defense Systems
MDO	Multi-Domain operations
MLRS	Multiple Launch Rocket System
NATO	North Atlantic Treaty Organization
PLA	Chinese People's Liberation Army
PNT	Position, Navigation and Timing
RADAR	Radio Detection and Ranging
RAM	Rockets, Artillery and Mortars
RF	Radiofrequency
ROE	Rules of Engagement
SHORAD	Short Range Air Defense
SOF	Special Operations Forces
SPF	Special Purpose Forces
sUAS	Small Unmanned Aerial System
TRADOC	US Army Training and Doctrine Command
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
UCAV	Unmanned Combat Aerial Vehicle
VEO	Violent Extremist Organization
WIA	Wounded in Action

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CHAPTER 1

INTRODUCTION

Background

On 21 September 2014, Hezbollah fighters used a small Unmanned Aerial System (UAS) to deliver a kinetic attack against Syrian rebel linked bases near the Lebanese town of Arsal.[1] Although Hezbollah used small UAS for reconnaissance as early as 2004, the 2014 Arsal attack demonstrated novel use of Low-Slow-Small UAS (LSS-UAS) by a non-state actor to deliver explosive effects.[2] Violent extremist organizations (VEOs) in the Middle East and beyond soon emulated the use of UAS as a low-cost method to inflict casualties. In particular the Islamic State of Iraq and Syria (ISIS) seized upon the ability of these low-flying, inexpensive, easy-to-use aircraft to deliver and film precision attacks, achieving effects on the battlefield and in the information domain.[3] The proliferation of these aircraft, commonly referred to as Small UAS (sUAS), has created a new vulnerability to US Forces in the CENTCOM AOR, one that has yet to be fully resolved.[4]

[1] Adiv Sterman, "Hezbollah Drones Wreak Havoc on Syrian Rebel Bases," *Times of Israel*, September 21, 2014, https://www.timesofisrael.com/hezbollah-drones-wreak-havoc-on-syrian-rebel-bases/.

[2] Joe Gould, "It 's a Cat and Mouse Game as Militaries Fight the Big Threat of Small Drones," *Defense News*, February 15, 2019, https://www.defensenews.com/congress/2019/02/15/its-a-cat-and-mouse-game-as-militaries-fight-the-big-threat-of-small-drones/.

[3] Ben Watson, "The Drones of ISIS," *Defense One,* January 12, 2017, https://www.defenseone.com/technology/2017/01/drones-isis/134542/.

[4] Thomas Braun, "Miniature Menace: The Threat of Weaponized Drone Use by Violent Non-State Actors," ed. Alexander Fleiss, *Wild Blue Yonder* (September 14,

As the Army continues to grapple with the threat that sUAS pose on an asymmetric battlefield, sUAS use in conventional operations grows. The Nagorno-Karabakh conflict between Azerbaijan and Armenia in the autumn of 2020 saw extensive use of sUAS, particularly by Azerbaijan. Azerbaijan's use of sUAS to target air defense and maneuver forces proved decisive in ending the war quickly.[5] This conflict, coupled with examples of Russian sUAS employment against Ukrainian maneuver forces, highlights the value of sUAS to adversaries in high-intensity conflict.[6] As strategic adversaries continue to develop, improve, and proliferate these systems, the likelihood that US forces will face sUAS on the battlefield grows.[7]

2020), https://www.airuniversity.af.edu/Wild-Blue-Yonder/Article-Display/Article/2344151/miniature-menace-the-threat-of-weaponized-drone-use-by-violent-non-state-actors/.; Mark Pomerleau, "How $650 Drones Are Creating Problems in Iraq and Syria," *C4ISRNET*, January 5, 2018, https://www.c4isrnet.com/unmanned/uas/2018/01/05/how-650-drones-are-creating-problems-in-iraq-and-syria/.

[5] Ron Synovitz, "Technology, Tactics, And Turkish Advice Lead Azerbaijan To Victory In Nagorno-Karabakh," *Radio Free Europe, Radio Liberty,* November 13, 2020, https://www.rferl.org/a/technology-tactics-and-turkish-advice-lead-azerbaijan-to-victory-in-nagorno-karabakh/30949158.html.; Can Kasapoglu, "Turkey Transfers Drone Warfare Capacity to Its Ally Azerbaijan," *Eurasia Daily Monitor* 17, no. 144 (October 15, 2020), https://jamestown.org/program/turkey-transfers-drone-warfare-capacity-to-its-ally-azerbaijan/.

[6] Shawn Woodford, "The Russian Artillery Strike That Spooked the US Army," *Mystics & Statistics* (blog), *Dupuy Institute*, March 29, 2017, http://www.dupuyinstitute.org/blog/2017/03/29/the-russian-artillery-strike-that-spooked-the-u-s-army/.

[7] Gregory C. Allen, *Understanding China's AI Strategy: Clues to Chinese Strategic Thinking on Artificial Intelligence and National Security* (Washington, DC: Center for a New American Security, February 2019, 1-22, https://www.cnas.org/publications/reports/understanding-chinas-ai-strategy.

The Army's Multi-Domain Operations (MDO) 2028 Operating Concept provides a compelling picture of future conflict, emphasizing the importance of layering air defense assets in multi-domain formations and the role of the divisions in Short-Range Air Defense (SHORAD).[8] However, existing doctrine, formations, and materiel fail to provide tactical commanders the ability to effectively conduct Counter-sUAS (C-sUAS) operations within this construct.[9] Countering sUAS requires different and more flexible capabilities, processes and responses than countering traditional air power, and traditional ADA equipment designed to counter large, fast aircraft is poorly suited to detect and engage low-slow-small UAS.[10]

[8] US Army Training and Doctrine Command (TRADOC), TRADOC Pamphlet 525-3-1, *The US Army in Multi-Domain Operations 2028* (Ft. Eustis, VA: TRADOC, 2018)., 19, 43; US Army Futures Command, Futures and Concepts Center, Army Futures Command Pamphlet, *Army Futures Command Concept for Maneuver in Multi-Domain Operations* (Ft. Eustis, VA: Army Futures Command, July 7, 2020), https://www.armyupress.army.mil/Portals/7/Hot-Spots/docs/NEBF/AFC-Pam-71-20-1.pdf.

[9] Jason Kowrach, "US Army Counter-Unmanned Aerial Systems: More Doctrine Needed," (MMAS thesis, US Army Command and General Staff College, 2018); Edward A. Guelfi, Buddhika Jayamaha, and Travis Robiso, "The Imperative for the US Military to Develop a Counter- UAS Strategy," *Joint Forces Quarterly* 97 (2nd Quarter 2020): 4–12.

[10] Benjamin Scott, "Army Counter-UAS 2021-2028," *Military Review* (March-Apri 2021): 65–80, https://www.armyupress.army.mil/Journals/Military-Review/English-Edition-Archives/March-April-2021/Scott-Counter-UAS/; Headquarters, Department of the Army, Army Techniques Publication 3-01.8, *Techniques for Combined Arms for Air Defense* (Washington, DC: Army Publishing Directorate, 2016).

Problem Statement

Emerging sUAS technologies and tactics demonstrated in real-world operations and developed by strategic adversaries pose a grave risk to US Army tactical formations.[11] Small UAS can rapidly and responsively perform observation and deliver kinetic effects at a low cost.[12] To counter this threat, US tactical formations must understand past employment of sUAS in contemporary operations, identify the way that adversaries may employ sUAS, and recognize the vulnerabilities of friendly forces and critical capabilities. After identifying and understanding the threat, tactical formations must integrate C-sUAS capabilities onto a large-scale, multi-domain battlefield to deny adversary use of sUAS.

Research Questions

The primary research question this paper seeks to answer is: What capabilities do tactical formations need to conduct counter-sUAS operations in high-intensity Multi-Domain Operations?

In support of this, the paper also addresses the following secondary research questions:

1. How have sUAS been employed in contemporary operations?
2. How will sUAS be employed by peer forces during high-intensity combat operations?

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[11] Woodford, "The Russian Artillery Strike That Spooked the US Army,"; Watson, "The Drones of ISIS."

[12] Guelfi, Jayamaha, and Robison, "The Imperative for the US Military to Develop a Counter- UAS Strategy."

Assumptions

This study makes three assumptions to focus and target research and analysis.

1. This study assumes that the C-sUAS capabilities as currently fielded by US Forces in support of asymmetric operations will not be sufficient to defend tactical formations in Large Scale Combat Operations, as large conflicts conducted under the Multi-Domain Operations operating construct will differ from the conflicts in Iraq in Afghanistan.
2. This study also assumes that a revolutionary technological advancement in Electronic Warfare, Artificial Intelligence, or Cyber Operations will not render the employment of sUAS obsolete before the next major conflict, and that the technology used in the near future will be incremental improvements of the technology currently in place.
3. This study also assumes incremental advancements in sUAS technologies (command and control, speed, lift capacity) rather than revolutionary change.

Definitions of Terms

Unmanned Aerial Systems. UAS are aircraft that are operated remotely or autonomously, do not have a human operator on the airframe and are also known as Unmanned Aerial Vehicles (UAVs), Unmanned Aircraft Systems, drones, or colloquially as "non-air-breathing" threats. The Department of Defense (DoD) groups UAS by weight, speed, and operating altitude. These groups are also widely used outside the DoD and are shown in Figure 1.[13]

[13] UAS Task Force, *Airspace Integration Integrated Product Team, Unmanned Aircraft System Airspace Integration Plan*, version 2 (Washington, DC: Department of

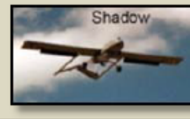
UAS Groups	Maximum Weight (lbs) (MGTOW)	Normal Operating Altitude (ft)	Speed (kts)	Representative UAS	
Group 1	0 – 20	<1200 AGL	100	Raven (RQ-11), WASP	
Group 2	21 – 55	<3500 AGL	< 250	ScanEagle	
Group 3	< 1320	< FL 180		Shadow (RQ-7B), Tier II / STUAS	
Group 4	>1320		Any Airspeed	Fire Scout (MQ-8B, RQ-8B), Predator (MQ-1A/B), Sky Warrior ERMP (MQ-1C)	
Group 5		> FL 180		Reaper (MQ-9A), Global Hawk (RQ-4), BAMS (RQ-4N)	

Figure 1. UAS Groups

Source: UAS Task Force, Airspace Integration Integrated Product Team, *Unmanned Aircraft System Airspace Integration Plan*, version 2 (Washington, DC: Department of Defense, 2011), D-3, Table 3.

Low-Slow-Small UAS. LSS UAS are small, unmanned aircraft, typically in Groups 1-2, although some LSS UAS may qualify as Group 3.[14] They are typically under 55 pounds, move at speeds significantly below 250 knots, and operate below 3500 feet above ground level (AGL). LSS UAS may be able to deliver a kinetic strike. The term

Defense, March 2011), http://www.acq.osd.mil/sts/docs/DoD_2011_UAS_Airspace_Integration_Plan_(signed).pdf.

[14] Headquarters, Department of the Army (HQDA), Army Techniques Publication (ATP) 3-01.81, *Counter-Unmanned Aircraft System Techniques* (Washington, DC: Army Publishing Directorate, 2017), https://fas.org/irp/doddir/army/atp3-01-81.pdf.

small UAS (sUAS) is synonymous with LSS UAS and is frequently used.[15] This paper uses the term sUAS when referring to all Group 3 and below UAS, including LSS UAS.

Quadcopter. A common type of sUAS, a quadcopter uses four rotors to provide lift for a small central body. Quadcopters are typically slower than fixed-wing aircraft but are more maneuverable. Similar rotary-wing aircraft may use more than four rotors.[16]

Loitering munitions: Loitering munitions provide an explosive payload attached to a small, typically fixed-wing UAS airframe. Loitering munitions can remain in an area until given a command to engage the target. Loitering munitions are distinct from armed UAS that drop munitions, as a loitering munition detonates during engagement of the target.[17]

Counter-Small UAS (C-sUAS). C-sUAS includes any operation intended to prevent sUAS from successfully influencing friendly forces. C-sUAS operations typically include electronic warfare detection and defeat capabilities, or more traditional air defense capabilities including RADAR and direct fire. C-sUAS also consists of passive techniques such as employment of bunkers or camouflage.[18]

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[15] Bhargav Patel and Dmitri Rizer, *Counter-Unmanned Aircraft Systems Technology Guide* (Washington, DC: National Urban Security Technology Laboratory, US Department of Homeland Security, September 2019).

[16] Joseph Flynt, "What Is a Quadcopter?," *3D Insider*, January 18, 2018, https://3dinsider.com/what-is-a-quadcopter/.

[17] Kelsey Atherton, "Loitering Munitions Preview the Autonomous Future of Warfare," Tech Stream, Brookings, August 4, 2021, https://www.brookings.edu/techstream/loitering-munitions-preview-the-autonomous-future-of-warfare/.

[18] Patel and Rizer, *Counter-Unmanned Aircraft Systems Technology Guide*.

Jamming. Jamming is the act of transmitting on a frequency with sufficient power to prevent reception of intended signals on that frequency.[19] In the context of C-sUAS, this typically entails jamming of positioning-navigation-timing (PNT), command and control, or video signals.

DOTMLPF-P. DOTMLPF-P is a force management tool used to analyze capabilities. DOTMLPF-P includes eight analytical domains: doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy.[20]

Scope

This study examines past and future sUAS employment in warfare. It explores sUAS Operations in Nagorno-Karabakh as well as the use of sUAS by insurgents in Iraq and Afghanistan. It also examines how Russia and China may employ sUAS on large-scale battlefields. This study considers adversary sUAS capabilities, both potential and realized, and how US tactical forces should counter them. This study focuses specifically on Group 3 and below UAS as opposed to the large, traditional, fixed-wing UAS currently used by militaries around the world or the automation of traditional military aircraft. While these systems pose a growing threat, the methods used to counter them and the threat they pose are distinct from those used against sUAS and existing air defense doctrine and equipment appropriately address them. This study also does not

[19] Headquarters, Department of the Army (HQDA), Field Manual (FM) 3-12, *Cyberspace Operations and Electromagnetic Warfare* (Washington, DC: Army Publishing Directorate, 2021), Glossary-4, https://armypubs.army.mil.

[20] Headquarters, Department of the Army (HQDA), Army Regulation (AR) 5–22, *The Army Force Modernization Proponent System* (Washington, DC: Army Publishing Directorate, 2015), 11.

explore the use of other applications of sUAS in enabling non-combat operations, such as mapping or communications relay. This study explores how existing and emerging sUAS technology may be employed in future conflict but does not attempt to predict the evolution of technologies employed by sUAS in the future. Finally, this study describes the C-sUAS capabilities required by tactical formations by using the DOTMLPF-P framework, however, it only explores the domains of Doctrine, Organizations, Materiel, and Leadership and Education.

Limitations and Delimitations

While this study attempts to provide an extensive examination of the stated problem, a number of limitations (aspects of the study itself that limit the depth to which the study will be conducted) and delimitations (aspects of research identified as outside the scope of the study) prevent an exhaustive exploration of the topic.

1. The compressed timeline available means that this study was conducted in ten months. This inherently limited the scope of the research and analysis conducted.
2. This study was conducted at the unclassified level. This means it did not examine specific technical capabilities of C-sUAS systems currently in the US joint force inventory. This also limited the extent to which this study explored adversary system capabilities and techniques.
3. Independent testing of sUAS was impracticable for this study. This qualitative study drew conclusions from reporting and research regarding sUAS employment but includes no empirical data regarding their behavior or the challenges inherent in detecting and engaging these systems. For instance,

while this study acknowledges the qualitative differences between RADAR detection of a large, fixed-wing aircraft with substantial momentum and a large cross-section and detection of a small cross-section sUAS able to rapidly change direction, this study did not attempt of quantify these differences.

4. This study examined limited number of case studies and overlooked sUAS employment by other actors.
5. This study did not examine events that occur after 31 March 2022. While current events in Ukraine may provide compelling insight into emerging sUAS employment techniques, the study period did not permit an exhaustive consideration of this ongoing conflict.

Significance of Study

There is currently limited scholarship on employment and countering of sUAS in large-scale combat operations, and existing US Joint and Army doctrine provides limited guidance on the topic. Military leaders will benefit from a thorough examination of the sUAS threat and how to counter it. This study provides insight into how to conduct effective protection and preservation of tactical forces when an adversary employs sUAS and how existing air defense principles, such as the air defense engagement sequence, may require modification for C-sUAS operations.[21] Such ideas as identified in this study may help shape the refinement of existing and emerging doctrine. This study also

[21] Headquarters, Department of the Army (HQDA), Field Manual (FM) 3-01, *US Army Air and Missile Defense Operations* (Washington, DC: Army Publishing Directorate, 2020).

provides insight into how to develop scenarios and opposing force activities in exercises that appropriately mirror the threat posed by sUAS.

Summary

Recent sUAS use in conflicts highlights the way these systems can complement maneuver operations and threaten friendly forces. The US Army must have the right air defense doctrine and the appropriate equipment and staffing of tactical formations to combat sUAS in a multi-domain environment. This study attempts to answer its primary research question: what capabilities do tactical formations need to conduct counter-sUAS operations in high-intensity Multi-Domain Operations? It also includes two secondary research questions: How have sUAS been employed in contemporary operations, and how will sUAS be employed by peer forces during high-intensity combat operations? The scope of the study is focused on the use of Group 3 and below sUAS by specific actors for combat purposes. This study was limited by time, impracticability of testing, and by classification level. This study will examine how sUAS may be employed by peer forces during high-intensity combat operations and provide insight into how tactical units should limit risk to force and maintain operational flexibility for the commander by performing Counter-sUAS operations in a multi-domain environment.

CHAPTER 2

LITERATURE REVIEW

Introduction

This literature review covers a broad range of written sources, including US Joint Force doctrine, strategic documents, papers from academic and professional journals, research papers, and news articles. Literature collection for this study primarily employed the Defense Technical Information Center (DTIC) database, the JSTOR Journal Storage Database, the Combined Arms Research Library (CARL), the Mendeley Reference Database, and general internet searches using the Bing and Google search engines. Army Doctrine was retrieved from the Army Publishing Directorate (APD), and Joint Doctrine was retrieved from the Joint Electronic Library (JEL). Exploratory search terms in these databases and tools included variations on “Counter-UAS operations” and “UAS Threats.” Throughout the research process, the terms “drone,” “UAV,” and “UAS” were employed in repetitive searches. Subsequent searches used “Small UAS,” “sUAS” or “Low-slow-small UAS” to narrow results. As the literature review progressed, specific regional employment of sUAS became apparent. Search terms for regional focuses were like those used for initial searches, using regional or conflict descriptors to modify searches such as “Russian small UAS in Ukraine” and “Chinese small UAS.” Specific searches, using the search engines Bing and Google were also used when amplifying or clarifying information about a particular system was required.

The literature review is organized into three sections: C-sUAS Operations by US Forces, Contemporary sUAS employment, and Peer Force sUAS Employment and Capabilities. The three sections are built around each of the study’s research questions

(What capabilities do tactical formations need to conduct counter-sUAS operations in high-intensity Multi-Domain Operations? How have sUAS been employed in contemporary operations? How will Low-Slow-Small UAS be employed by peer forces during high-intensity combat operations?). As required, subsections within each section address specific focuses or regions.

C-sUAS Operations by US Forces

The Department of Defense, the Department of Homeland Security, international partners, and various experts and scholars have recognized the threat of armed and unarmed sUAS. This section identifies existing assessments and analysis regarding the primary research question: what capabilities do tactical formations need to conduct counter-sUAS operations in high-intensity Multi-Domain Operations? While the secondary research questions of this study will provide the preponderance of input into answering this question, the literature in this section provides information regarding currently assessed capability requirements. This literature highlights requirements identified by the Joint C-UAS Office (JCO), as well as capabilities, opportunities and shortfalls identified by military and civilian leaders. This section consists of three sub-sections exploring the Joint C-sUAS Strategy, DOD C-sUAS Technologies, and existing Army Doctrine relevant to C-sUAS capabilities required by tactical formations.

Joint C-sUAS Strategy. In 2020, the DoD published its first C-sUAS strategy. Notably, this strategy highlights the lessons hostile nations have learned from non-state and US employment of sUAS. China sees both economic and military incentives in sUAS development and will continue to grow its capabilities. Russia has made sUAS a focus of future warfare capabilities, particularly in fires/sUAS integration. Adversary surrogates will field these capabilities as well. Small UAS enable adversaries to apply greater presence and pressure from distance by performing intelligence collection, precision strikes, target designation, sensor and communications range extension, and non-kinetic attacks.[22]

To execute this strategy, the Department of Defense designated the Army as the executive agent for C-sUAS (Groups 3 and below) and the Army established the Joint Counter-UAS Office (JCO) under HQDA G-3/5/7.[23] The JCO will address challenges in homeland, host nation, and contingency environments through three Lines of Effort (LOEs). LOE 1, "Ready the Force," focuses on materiel and research. LOE 2, "Defend the Force," focuses on doctrine, training, and concepts. LOE 3, "Build the Team," is how the joint force can maximize capabilities through interagency and multinational interoperability.[24]

The JCO does not view the C-sUAS problem set as requiring a single solution, but a range of capabilities.[25] Thus, the JCO works to fill capability gaps in a system-of-systems construct, including finding directed energy and C2 integration solutions. The DoD intends to leverage Centers of Excellence research, development, test, and

[22] US Department of Defense (DOD), *Counter-Small Unmanned Aircraft Systems Strategy* (Washington, DC: Department of Defense, 2020).

[23] Ibid., 11.

[24] Devon Suits, "Joint Counter-SUAS Strategy to Address Need for Improved Technology," US Army, October 8, 2020, https://www.army.mil/article/239593/joint_counter_suas_strategy_to_address_need_for_improved_technology.

[25] Mandy Mayfield, "Small Drone Threat: Pentagon Consolidates Counter-UAS Programs as Menace Grows," *National Defense,* no. 105 (April 12, 2021): 23-26.

evaluation resources (RDT&E) to pursue next-generation C-sUAS capabilities and innovations through streamlined acquisition methods. The strategy acknowledges the wide range of systems built for C-sUAS and states the need for common materiel and non-materiel solutions across the force. Finally, the strategy identifies that the US must extend these capabilities to partners.[26] The JCO also recognizes the importance of providing tactical C-sUAS education to military personnel. The JCO plans to establish a Joint C-sUAS school in 2024, moving the existing school from White Sands Missile Range to the home of the Air Defense School at Fort Sill.[27]

The JCO is the arm through which the DoD executes C-sUAS strategy and since its inception in 2020, the JCO has worked to focus DoD C-sUAS development. C-sUAS technologies take a variety of forms, and employ a variety of C-UAS detection mechanisms (RADAR, electro-optical/infrared [EO/IR], radiofrequency [RF], acoustic) and mitigations (RF and Position, Navigation, and Timing [PNT] jamming, protocol spoofing and kinetic/direct fire countermeasures).[28] Each service (as well as other government agencies such as the Department of Homeland Security) has pursued independent solutions, including Electronic Warfare, Microwave, and Laser based systems. The JCO has synchronized C-sUAS development efforts by selecting key systems for further development and terminating investment in others, a process called

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[26] DOD, *Counter-Small Unmanned Aircraft Systems Strategy*, 10, 18.

[27] Suits, "Joint Counter-SUAS Strategy to Address Need for Improved Technology."

[28] Patel and Rizer, *Counter-Unmanned Aircraft Systems Technology Guide*.

"down-select."[29] This has narrowed the field of C-sUAS systems in which the DoD continues to invest. The JCO has also addressed the importance of cross-system integration. Interoperable systems capable of interfacing with one another or with common control networks allow cross-cueing of sensors and reduced operator workload.[30] The JCO was instrumental in building the requirement for common C2, and for identifying a DoD solution in the Forward Area Air Defense Command and Control system (FAAD C2), which will serve as the foundation for DoD C-sUAS interoperability.[31]

A lack of cross-system interoperability, cueing, and command and control create recurring challenges for C-sUAS. A 2021 *Military Review* journal article describes how the 25th Infantry Division (25ID) staff conducted Counter-UAS operations in a Division Warfighter Exercise against sUAS and larger UAS. From the outset, intelligence and ADA cells separately controlled and monitored their sensors, and cross-communication was initially poor on the staff. The 25ID resolved this by performing C-UAS fusion in the Joint Air Ground Integration Cell (JAGIC). The division prioritized strikes against enemy Ground Control Stations (GCS) to prevent UAS employment. 25ID defined countering

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[29] Kelley Sayler, "Department of Defense Counter-Unmanned Aircraft Systems," (In Focus, Congressional Research Service, Washington, DC, last updated May 31, 2022).

[30] DHS Science and Technology Directorate, "Questions to Ask When Researching Counter Unmanned Aircraft Systems," (US Department of Homeland Security, Washington, DC, August 20, 2020), https://www.dhs.gov/publication/st-questions-ask-when-researching-counter-unmanned-aircraft-systems.

[31] Suits, "Joint Counter-SUAS Strategy to Address Need for Improved Technology."

Group 3 and above UAS as a Division responsibility with actions against Groups 1-2 falling under the purview of a brigade combat team (BCT).[32]

DoD C-sUAS Technology. The majority of DoD's C-sUAS technologies and systems are non-kinetic.[33] The 2020 JCO "down-select" focused DoD C-UAS efforts toward particular systems, including FS-LIDS, NINJA, CORIAN, L-MADIS, Bal Chatri, Drone Buster, Smart Shooter, and the FAAD C2 Command and Control system.[34] These were selected out of systems employed in the CENTCOM AOR and are predominantly electronic warfare systems.[35] Open-source manufacturer documentation from JCO-selected systems provides insight into the mechanisms these systems use to counter sUAS. [36] An information sheet for the CORIAN fixed-site C-sUAS system states that it can identify, geolocate, and mitigate sUAS threats using non-kinetic electronic warfare

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[32] Scott, "Army Counter-UAS 2021-2028,", 70.

[33] Sayler, "Department of Defense Counter-Unmanned Aircraft Systems."

[34] Army Public Affairs, "Army Announces Selection of Interim C-SUAS Systems," US Army, June 25, 2020, https://www.army.mil/article/236713/army_announces_selection_of_interim_c_suas_systems.

[35] CACI International Inc., "CORIAN: Fixed Site, Dismount, and Mobile C-UAS Technology," (Reston, VA, June 2021), https://www.caci.com/sites/default/files/2021-06/F424_2106_Corian Flyer.pdf.; SRC Inc., "SRC Technology Chosen for DoD's Fixed-Site Counter-UAS Solution," December 3, 2020, https://www.srcinc.com/news-and-events/press/2020/20201203-src-technology-chosen-for-dod-fixed-site-counter-uas-solution.html.; AFRL Information Directorate, "AFRL Information Directorate Overview, 2019," US Air Force, 2019, slide 19, https://www.wpafb.af.mil/Portals/60/documents/afrl/ri/AFRL-RI-Overview-2019.pdf?ver=2020-02-19-092432-287.

[36] Army Public Affairs, "Army Announces Selection of Interim C-SUAS Systems."

means and can also identify and locate ground stations.[37] An open-source presentation provides general information about the NINJA C-sUAS system developed by the Air Force Research Laboratory (AFRL). The NINJA provides cyber-enabled EMS detection and defeat of sUAS through layered link, spectrum, and "Hard-Kill" mechanisms.[38] Finally, a manufacturer press release describes the FS-LIDS as a system-of-systems that integrates AN/TPQ-50 RADAR, electronic warfare (EW) defeat mechanisms, and an electro-optical/infrared camera.[39]

In addition to dedicated C-sUAS implementations of electronic warfare, the Army has created Electronic Warfare platoons in BCTs. Each EW platoon consists of three teams, capable of detecting and jamming activity in the EMS.[40] Cyber and EW doctrine does not describe the role of EW platoons in tactical C-sUAS operations. FM 3-12 *Cyberspace Operations and Electromagnetic Warfare*, for instance, mentions the general term "UAS" only twice, both in reference to supporting protection planning for countering these systems.[41] While Electronic Warfare soldiers are not the primary

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[37] CACI, "CORIAN."

[38] AFRL Information Directorate, "AFRL Information Directorate Overview."

[39] SRC, "SRC Technology Chosen for DoD's Fixed-Site Counter-UAS Solution."

[40] HQDA, FM 3-12, 3-3.

[41] Ibid., 2-9, 3-7.

practitioners of C-sUAS, these teams possess the technical skills and equipment to best employ non-kinetic effects against sUAS.[42]

These solutions all employ EW to exploit communications between Ground Stations or navigation satellites and the sUAS itself, but adversaries may seek to harden and protect these links.[43] Secure communications between peer UAS in a swarm and between UAS and Ground Stations can reduce sUAS vulnerability to EW, hardening communications against radiofrequency-based spoofing, distributed denial of service (DDOS) attacks, and Man-in-the-Middle cyberattacks. Even unsophisticated practitioners can easily upgrade inexpensive platforms using open-source techniques, potentially reducing the effectiveness of US C-sUAS systems that rely on this type of attack.[44]

In addition to the primarily non-kinetic C-sUAS capabilities, the Army has sought to field kinetic C-sUAS capabilities. Among these, the Maneuver-Short Range Air Defense (M-SHORAD) program is notable. New M-SHORAD solutions have reportedly been in development since the Russian annexation of Crimea in 2014.[45] SHORAD

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[42] Mark Pomerleau, "Army Shares Details on New Electronic Warfare Units," *C4ISRNET*, December 31, 2020, https://www.c4isrnet.com/electronic-warfare/2021/01/01/army-shares-details-on-new-electronic-warfare-units/.

[43] Patel and Rizer, *Counter-Unmanned Aircraft Systems Technology Guide*.

[44] Yongho Ko, Jiyoon Kim, Daniel Gerbi Duguma, Philip Virgil Astillo, Ilsun You, and Giovanni Pau, "Drone Secure Communication Protocol for Future Sensitive Applications in Military Zone," *Sensors* 21, no. 6 (March 2021): 1–25, https://mdpi-res.com/d_attachment/sensors/sensors-21-02057/article_deploy/sensors-21-02057-v2.pdf.

[45] Jared Keller, "The Army Is Officially Adding Missile-Hauling Strykers to Its Arsenal," *Task and Purpose*, October 5, 2020, https://taskandpurpose.com/news/army-stryker-shorad-contract/.

battalions once existed in every Division, but were phased out in the mid-2000s.[46] In 2019 the Army officially announced its intent to re-establish SHORAD battalions and described an ultimate goal of 10 battalions mirroring the previous divisional alignment.[47] An M-SHORAD vehicle includes Avenger pods with Stinger and Hellfire missiles and a 30mm cannon giving it some capabilities against sUAS like those encountered by US Forces in the Middle East, but also against traditional close-range rotary- and fixed-wing aircraft fielded by peer adversaries.[48] In 2021 submissions to congress, the Army formally outlined the role of M-SHORAD as a countermeasure for traditional fixed- and rotary-wing aircraft and Group 3 and above UAS. Acknowledging the shortfalls of the system against smaller sUAS, the Army also highlighted the Rapid Capabilities Office's Directed Energy SHORAD efforts, designed to provide a counter to a greater range of sUAS and rocket, artillery, and mortar (RAM) threats. The Army plans to transition these efforts to the M-SHORAD project office in FY23.[49]

Early references to M-SHORAD battalions describe the combat power as three M-SHORAD batteries with three M-SHORAD platoons and a RADAR platoon, and a

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[46] David C. Norwood, "Reintegrating Short Range Air Defense into the Maneuver Fight," (MMAS thesis, US Army Command and General Staff College, 2019), 53.

[47] Gary Sheftick, "Army Rebuilding Short-Range Air Defense," US Army, July 3, 2019, https://www.army.mil/article/224074/army_rebuilding_short_range_air_defense.

[48] Keller, "The Army Is Officially Adding Missile-Hauling Strykers to Its Arsenal."

[49] US Department of Defense (DOD), *Department of Defense Fiscal Year (FY) 2021 Budget Estimates: Army, Justification Book of Missile Procurement*, vol. P-121PB (Washington, DC: Department of Defense, February 2020), https://www.asafm.army.mil/Portals/72/Documents/BudgetMaterial/2021/Base Budget/Procurement/MSLS_FY_2021_PB_Missile_Procurement_Army.pdf.

dismounted Man-Portable Air Defense System (MANPADS) battery of twelve teams equipped with Stinger missiles.[50] Each M-SHORAD platoon is equipped with four M-SHORAD vehicles capable of firing independently, and each RADAR platoon is equipped with a Sentinel RADAR as its primary detection platform.[51] Later descriptions add that each M-SHORAD battery will have one directed-energy platoon.[52] Public information on whether M-SHORAD battalions as fielded include a MANPADS battery is not available. SHORAD battalions as fielded prior to the mid-2000s included MANPADS in the SHORAD batteries.[53]

The divisional alignment of M-SHORAD battalions has not yet come to fruition. In 2020, the Army awarded a $1.2 billion contract to field M-SHORAD close-range air defense systems, with an initial twenty-eight systems for one battalion in the first order and enough systems for three battalions as soon as FY23.[54] The first M-SHORAD

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[50] Norwood, "Reintegrating Short Range Air Defense into the Maneuver Fight," 33.

[51] The Office of the Director of Operational Test and Evaluation, "FY20 Army Programs Initial Maneuver Short-Range Air Defense," Office of the Secretary of Defense, 2020, https://www.dote.osd.mil/Portals/97/pub/reports/FY2020/army/2020im-shorad.pdf?ver=gjza9jYKDIdZwDAa6YktzA%3D%3D.

[52] Andrew Feickert, *U. S. Army Short-Range Air Defense Force Structure and Selected Programs: Background and Issues for Congress,* Congressional Research Service Report for Congress R46463 (Washington, DC: Library of Congress, July 23, 2020), 4.

[53] Daniel P. Sauter, "Cutting Fat or Removing the Brain: Is the Divisional ADA Battalion Headquarter Necessary," (Monograph, School of Advanced Military Studies, US Army Command and General Staff College, 1999), 4, https://apps.dtic.mil/sti/pdfs/ADA366313.pdf.

[54] Keller, "The Army Is Officially Adding Missile-Hauling Strykers to Its Arsenal."

battalion, the non-divisionally aligned 5-4ADA Battalion in Germany, received its systems in 2021.[55] The Army performed environmental assessments at Fort Bliss, Fort Hood, Fort Riley, Fort Stewart, Fort Carson, and Fort Sill to consider these bases as possible locations for four M-SHORAD battalions.[56] A 2020 Congressional Research service paper, however, indicates that the second Battalion will be stationed at Joint Base Lewis-McChord to support the 1st Multi-Domain Task Force, and that two subsequent battalions will be stationed at Fort Bragg to support Army Forces Command (FORSCOM).[57]

Individual C-sUAS solutions are insufficient on their own. Traditional air defense weapon systems are poorly suited to bearing sole responsibility for the C-sUAS fight, both due to the cost of traditional munitions, and because these systems struggle to engage such small, slow-moving targets.[58] In 2016, Israeli forces fired millions of dollars of missiles at an sUAS which they failed to destroy. This demonstrates another key consideration in engaging sUAS: air defense munitions are extremely expensive. A US

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[55] Paul Szoldra, "Army Fires New Missile-Hauling Stryker for the First Time in Europe," *Task and Purpose*, October 11, 2021, https://taskandpurpose.com/news/us-army-mshorad-stryker-fire-europe/.

[56] US Army Environmental Command, *Programmatic Environmental Assesmet for the Fielding of the Maneuver - Short Range Air Defense Capability: Including the Draft Finding of No Significant Impact* (Joint Base San Antonio-Fort Sam Houston: US Army Environmental Command, May 2021).

[57] Feickert, *U. S. Army Short-Range Air Defense Force Structure and Selected Programs;* US Army Environmental Command, *Programmatic Environmental Assesmet for the Fielding of the Maneuver - Short Range Air Defense Capability*.

[58] Guelfi et al., "The Imperative for the US Military to Develop a Counter- UAS Strategy,", 8; Sayler, "Department of Defense Counter-Unmanned Aircraft Systems,"; HQDA, ATP 3-01.8, 1-6.

Patriot Missile costs $3 million; a stinger missile costs $38,000; a commercial sUAS may cost as little as a few hundred dollars. Adversaries could exploit this cost imbalance and present low-cost but credible threat targets to deplete operational-level air defense capabilities.[59] On the other hand, exclusively targeting signals presents problems as well. Systems operating autonomously are not generally targetable with C2 jamming. Instead the Joint Air Power Competence Centre (JAPCC, a NATO affiliated research center staffed by personnel from sponsor militaries) recommends multiple countermeasures against sUAS: passive force protection procedures, traditional air defense, air interdiction against launch/recovery elements, special operations strikes on enemy ground control stations (GCS), cyberattacks, EMS attacks, ISR identification, and space-based position, navigation and timing (PNT) or beyond line-of-sight (BLOS) command and control (C2) denial. On their own, each provides a tool for countering sUAS, but not a comprehensive solution. JPACC recommends viewing C-sUAS as a cross-domain and cross-functional fight and that NATO approach solutions through that lens[60].

Existing Army C-sUAS Guidance. Overall, existing C-UAS doctrine is insufficient for tactical units. Commanders and staffs require more guidance on how to employ detection and defensive assets, resolve ROE issues, and integrate emerging C-

[59] Guelfi et al., "The Imperative for the US Military to Develop a Counter- UAS Strategy," 8.

[60] Andre Haider, "A Comprehensive Approach to Countering Unmanned Aircraft Systems | And Why Current Initiatives Fall Short," (Joint Air Power Competence Centre, Kalkar, Germany, August 2019), https://www.japcc.org/portfolio/a-comprehensive-approach-to-countering-unmanned-aircraft-systems/.

sUAS assets.[61] Existing Army doctrine provides limited insight into how the US intends to conduct C-sUAS at the tactical level. ATP 3-01.81, *Counter-Unmanned Aircraft Systems Techniques*, is the most authoritative and specific US Army doctrine regarding the sUAS threat. Because the Army published ATP 3-01.81 in 2017, it does not incorporate more recent lessons learned in Afghanistan and Iraq. This doctrine provides limited guidance on C-sUAS operations at the tactical level, and cursory coverage of C-sUAS system employment. However, ATP 3-01.81 does assess elevated vulnerability to sUAS when conducting convoys, moving troops, or conducting resupply, as these actions tend to concentrate forces in open areas. The small launch footprint for sUAS may allow their use for continuous observation, and friendly forces should assume they are being observed when operating in an sUAS threat environment. The tactical C-sUAS techniques in ATP 3-01.81 focus on sUAS identification and protection measures such as camouflage and troop dispersion to mitigate this observation.[62] The C-sUAS Planning guidance in ATP 3-01.81 consists of general guidelines, such as incorporating early warning, identifying capabilities, addressing locations of likely targets, training troops to identify UAS, using "Air Guards" or human observers, and establishing reporting procedures.[63]

ATP 3-01.8, *Techniques for Combined Arms for Air Defense*, focuses more on general SHORAD threats but does discuss UAS to some extent. The publication

[61] Kowrach, "US Army Counter-Unmanned Aerial Systems."

[62] HQDA, ATP 3-01.81, 2-5.

[63] Ibid., 4-4.

identifies Group 1-3 UAS as the predominant UAS threat to land forces. It acknowledges the challenges associated with detecting these systems with traditional air defense RADARs and sensors, the difficulty in visual identification due to small size, low altitude, and slow movement. It also addresses the difficulties in effective direct-fire engagement against such small targets.[64] The publication goes on to outline adversary UAS considerations, such as possible launch points, but does not provide analytical tools or guidance for assessing adversary UAS behavior. The publication highlights operational considerations, including the threat to communications nodes and facilities, logistical concentrations, and command posts. The publication assesses that the enemy will attempt to use small UAS to strike air defense systems or enhance their ability to do so. UAS are well suited to do so due to their small size and long standoff, whereas traditional rotary-wing and fixed assets lack survivability in a contested environment.[65] The publication also assesses that UAS may coordinate or provide fire support during maneuver operations, with Group 1-3 UAS well-suited for this role due to the ability to be launched at close range with short notice.[66] Other UAS missions include surveillance, indirect and direct attack, and swarm attacks.[67] Again, guidance regarding countering sUAS activity focuses on passive measures and general planning considerations.[68] The

[64] HQDA, ATP 3-01.81, 1-6.

[65] Ibid., 1-8.

[66] Ibid., 1-9.

[67] Ibid., 3-12.

[68] Ibid.

publication recommends the use of human observers to visually observe above the horizon and report contacts.[69] The limited range of human observation may limit reaction time to sUAS, so engagement authority should be held at low levels to allow rapid response.[70]

FM 3-01, *US Army Air and Missile Defense Operations*, designates BCT Air Defense and Airspace Management (ADAM) cells as the tactical-level integration elements for air defense against air threats, including UAS. The ADAM cell consists of a small number of ADA soldiers (depending on unit type), but is integrated with the Brigade Aviation element into an ADAM/BAE cell that includes aviation soldiers for airspace and friendly UAS management.[71] The publication recognizes that BCTs do not have organic ADA assets and that the assets available will be external.[72] While BCTs integrate air defense capabilities, engagement authority is vested in the Area Air Defense Commander and delegated through the Air Defense Task Force chain of command.[73] FM 3-01 recommends decentralizing engagement authority to the air defense platoon level for low-altitude fast-moving threats, and engagement authority for sUAS can be doctrinally delegated all the way to the SHORAD team leader level.[74] In these cases,

[69] HQDA, ATP 3-01.81, 3-14.

[70] Ibid., 3-14, 4-5.

[71] HQDA, FM 3-01, 10-3 – 10-6.

[72] Ibid.

[73] Ibid., 9-5.

[74] Ibid., 9-5, 9-6.

platoons can engage imminent threats without positive control from higher headquarters. However, higher headquarters must impose controlled airspace zones and no-fire areas and ensure effective use of the Forward Area Air Defense Command and Control network to enable permissive engagement controls.[75]

US Doctrine also outlines general air defense principles and tenets that, while not specific to C-sUAS, provide a useful framework through which to view C-sUAS employment. Doctrine describes the ADA employment principles as fundamental rules for planning air defense operations; they include mass, mix, mobility, flexibility, integration, and agility.[76] Tenets are specific employment concepts that generally hold true that are applied after the air defense principles when creating a defense design; they include mutual support, overlapping fires, balanced fires, and weighted coverage.[77]

Finally, US Doctrine provides general guidance regarding the defended area in a tactical operation. The MDO operating concept expands the deep-close-rear battlefield framework to better reflect the complexities of a multi-domain battlefield. MDO refines the deep area into the deep maneuver area, operational deep fires area, and strategic deep fires area, and the rear area into tactical, operational, and strategic support areas.[78] The deep, close and rear areas of tactical formations fit into the center of this construct, with tactical support located in the rear, the preponderance of ground combat in the close, and

[75] HQDA, FM 3-01, 9-5, 9-6.

[76] Ibid., 1-5.

[77] Ibid., 1-5, 1-6.

[78] TRADOC, TRADOC Pamphlet 525-3-1, 16.

shaping fires in the deep area. Notably, however, MDO emphasizes that in addition to employing fires, tactical formations conduct breakthrough maneuver into the deep maneuver area where possible, integrating joint fires with ground combat forces.[79] While the exact dimensions of a tactical formation's AO will vary depending on echelon, mission, terrain, and enemy posture, a division conducting large-scale ground combat operations (LSGCO) should have a frontage between eleven to seventeen miles (18 to 28 km). A division's close area extends nine miles (15 km) from its rear area, and a division's deep area further extends from nine to fifteen miles (15 to 24 km). These dimensions provide useful guidelines for divisional Short-range Air Defense Operations.[80]

Contemporary sUAS Employment

The literature in this section is relevant to the initial secondary research question in this study: how have sUAS been employed in contemporary operations? This section is broken into two key subcategories: the employment of sUAS by violent extremist organization (VEO) and the use of sUAS by Armenia and Azerbaijan in the 2020 Nagorno-Karabakh conflict.

VEO sUAS Employment. VEOs have employed sUAS for at least the last seven years, against both other non-state actors and occupying forces, including the US in Iraq and Afghanistan. Notably, in the last few years, this has included arming commercial

[79] TRADOC, TRADOC Pamphlet 525-3-1, C-3.

[80] Headquarters, Department of the Army (HQDA), Field Manual (DM) 3-94, *Armies, Corps, and Division Operations* (Washington, DC: Army Publishing Directorate, 2021).

sUAS with explosive devices either to perform "kamikaze"-style attacks or drop munitions. While these systems were employed in an asymmetric environment, these applications demonstrate what may be possible in LSGCO; as explosive payloads have become greater, the utility of these systems has increased.[81]

A 2014 *Times of Israel* article describes a Hezbollah UAS strike in September of that year against militants in Syria.[82] While the systems employed were not identified, this is an early, possibly the earliest, VEO employment of sUAS for munition delivery. Over subsequent years, this technique would spread throughout the region and beyond, becoming one of the greatest threats to joint forces since the rise of the IED.[83] In 2017, reports began to emerge of ISIS's self-proclaimed sUAS capability.[84] Then, as Iraqi security forces fought to recapture Mosul, they faced significant armed sUAS opposition. Open-source reporting shows several pictures of recovered sUAS, including commercially available DJI phantoms, some modified to allow a munition drop. These capabilities (which include delivery of a 3lb-mortar shell) served as a low-cost credible

[81] David Hambling, *Swarm Troopers: How Small Drones Will Conquer the World* (Archangel Ink, 2015).

[82] Sterman, "Hezbollah Drones Wreak Havoc on Syrian Rebel Bases."

[83] Guelfi et al., "The Imperative for the US Military to Develop a Counter- UAS Strategy."

[84] Joby Warrick, "Use of Weaponized Drones by ISIS Spurs Terrorism Fears - The Washington Post," *The Washington Post,* February 21, 2017, https://www.washingtonpost.com/world/national-security/use-of-weaponized-drones-by-isis-spurs-terrorism-fears/2017/02/21/9d83d51e-f382-11e6-8d72-263470bf0401_story.html%0Ahttps://www.washingtonpost.com/world/national-security/use-of-weaponized-drones-by-i.

threat to US and coalition forces. [85] This threat drove US forces to begin employing countermeasures, specifically EW attack and detection systems, including the use of EC-130Hs (a US jamming aircraft) and handheld jammers to counter these sUAS.[86] In some cases, nation state actors may have enabled VEO employment. In 2022, Shia Militia Groups may have employed Iranian provided sUAS, similar to loitering munitions, against US Forces in Baghdad.[87] Iran was also likely responsible for enabling earlier sUAS attacks thwarted by US troops in Syria.[88]

The low cost of sUAS make them attractive for adversaries on a limited budget while also reducing the risk, in terms of manpower and cost, associated with employment when compared to larger, more capable systems.[89] VEO may also value sUAS for propaganda purposes. ISIS's use of sUAS may have been as much of a propaganda asset as a kinetic one.[90] VEOs with sufficient funding and networks will make deliberate decisions to acquire sUAS, as these systems offer information opportunities (from

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[85] Watson, "The Drones of ISIS."

[86] Ibid.

[87] "Drone Attack on US Base Foiled , Iraqi Security Sources Say," *Reuters*, January 3, 2022, https://www.reuters.com/world/us/drone-attack-us-base-foiled-iraqi-security-sources-say-2022-01-03/.

[88] Guelfi et al., "The Imperative for the US Military to Develop a Counter- UAS Strategy."

[89] Pomerleau, "How $650 Drones Are Creating Problems in Iraq and Syria,"; Guelfi et al., "The Imperative for the US Military to Develop a Counter- UAS Strategy."; Pete W. Singer, *Wired for War*, 5th ed. (New York, NY: Penguin Group, 2009), 21.

[90] Warrick, "Use of Weaponized Drones by ISIS Spurs Terrorism Fears - The Washington Post."

posting attack videos) and access to hard-to-reach targets.[91] VEOs do, however, require a high degree of operational maturity to effectively carry out sUAS attacks. While sUAS employment may reduce the cost and the risk to force associated with an attack, the employment of new techniques carries with it a risk of an escalation of conflict and the VEO must be sufficiently established to sustain such an increase in operational tempo. Furthermore, while simple commercial systems may be readily available, VEOs require expertise to acquire more sophisticated systems and technical knowledge to assemble them.[92] Still, the benefits likely outweigh the challenges, as the low barrier to entry in piloting UAS mean that they can be employed virtually anywhere by virtually anyone.[93] A 2020 paper from Air University concluded US forces at that time had no practical solutions to counter VEO sUAS due to the limited effectiveness of existing C-sUAS systems and low production rates.[94]

sUAS in the Nagorno-Karabakh Conflict. In September 2020, the ongoing diplomatic conflict between Armenia and Azerbaijan over the status of the Nagorno-Karabakh region erupted into war. While both sides employed sUAS, Azerbaijan's effective use of these systems was decisive in ending the conflict in its favor the following month. Many of these systems and the techniques to employ them were

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[91] Braun, "Miniature Menace."

[92] Ibid.

[93] Singer, *Wired for War*, p361

[94] Braun, "Miniature Menace."

provided by Turkey, and allowed Azerbaijan to rapidly overwhelm Armenian forces, including tanks and air defense assets, and gain overmatch and freedom of maneuver.

An article from *RadioFreeEurope* written shortly after the end of the Nagorno-Karabakh War claims that UAS played a pivotal role in Azerbaijan's victory in only 43 days. Armenia's lack of C-sUAS weaponry left ground forces vulnerable to UAS, ultimately resulting in shattered forces reduced to a disorganized withdrawal. Turkish technological advice and capabilities were decisive for Azerbaijan in Nagorno-Karabakh. Azerbaijan benefited not only from the technology purchased, but a "robotic warfare doctrine and concept of operations" provided by Turkey. [95] The close coordination between unmanned systems and fires assets and the use of UAS to hunt for air defense assets by sacrificing UAS were similar to Turkish doctrine.[96] The high tempo of Azerbaijani UAS strikes during the three-month conflict and close coordination of fires with sUAS observation were similar to techniques employed by Turkish forces in Syria in February 2020. [97]

The war in Nagorno-Karabakh is a good example of the power of small and inexpensive UAS, and the vulnerabilities of even modern air defense systems absent UAS-specific countermeasures.[98] It also demonstrates the utility of sUAS in mountainous

[95] Kasapoglu, "Turkey Transfers Drone Warfare Capacity to Its Ally Azerbaijan."

[96] Synovitz, "Technology, Tactics, And Turkish Advice Lead Azerbaijan To Victory In Nagorno-Karabakh."

[97] Kasapoglu, "Turkey Transfers Drone Warfare Capacity to Its Ally Azerbaijan."

[98] Robyn Dixon, "Azerbaijan's Drones Owned the Battlefield in Nagorno-Karabakh — and Showed Future of Warfare," *The Washington Post,* November 11, 2020,

terrain and their ability to enable a network-centric, limited war model, in this case helping to ensure the war did not extend beyond the border of Nagorno-Karabakh.[99] Azerbaijan employed a range of UAS, including larger, traditional armed platforms as well as loitering munitions and some small UAS.[100] Azerbaijan relied heavily on the Bayraktar TB2, which is a Group 3 medium size and range, armed-UAS more similar to traditional armed UAS than modern sUAS. But Azerbaijan employed smaller systems as well. Azerbaijani loitering munitions (a mix of Israeli produced Harops, SkyStrikers and Orbiters) destroyed a large amount of Armenian equipment, including BMP-2s and T-72s as well as Surface-to-Air Missile systems and RADARs.[101] The employment of loitering munitions from trucks against Armenian surface-to-air missile (SAM) sites (including an advanced SA-10 SAM destroyed by an Israeli-produced Harop) enabled Azerbaijan's employment of the larger TB-2 Bayraktar UAS. [102]

As Azerbaijan reached the outskirts of the city of Shusha—a cornerstone of Armenian defensive lines—it reduced the use of Turkish and Israeli-produced sUAS against Armenian forces, although the reasons are unclear. It may have been in response

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https://www.washingtonpost.com/world/europe/nagorno-karabkah-drones-azerbaijan-aremenia/2020/11/11/441bcbd2-193d-11eb-8bda-814ca56e138b_story.html.

[99] Ridvan Urcosta, "Drones in the Nagorno-Karabakh," *Small Wars Journal* (October 23, 2020), https://smallwarsjournal.com/jrnl/art/drones-nagorno-karabakh.

[100] Ibid.

[101] Stijn Mitzer and Joost Oliemans, "The Fight for Nagorno-Karabakh: Documenting Losses on the Sides of Armenia and Azerbaijan," *Oryx*, September 27, 2020, https://www.oryxspioenkop.com/2020/09/the-fight-for-nagorno-karabakh.html.

[102] Rodney Barton, "Loitering Menace," *Australia Defence Business Review*, May 24, 2021, https://adbr.com.au/loitering-menace/.

to the employment of a claimed Armenian "military secret"[103] (possibly Russian Polye-21 electronic warfare systems) or it may have been due to several days of bad weather.[104] Armenia, however, did use UAS during this period for reconnaissance, specifically the previously unreported Russian Orlan-10.[105] While UAS and loitering munitions played a crucial role in Azerbaijan's dominance of open terrain in the early days of the war, ultimately it was the taking of Shusha that ended the war. The capture of Shusha demonstrates the continued relevance of infantry and armor, even in the face of a UAS enabled environment.[106]

Peer Force sUAS Employment and Capabilities

The literature in this section is relevant to the final secondary research question of this study: how will Low-Slow-Small UAS be employed by peer forces during high-intensity combat operations? This section contains two key subcategories, focusing on how Russia has employed and may employ sUAS, and how the DoD assesses China may

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[103] Karen Minasyan, "The Battle For Shusha Fighting In Nagorno-Karabakh Has Reached A Turning Point. Here Are The Most Recent Developments In The Conflict Zone," *Meduza*, November 6, 2020, https://meduza.io/en/feature/2020/11/07/the-battle-for-shusha.

[104] Shaan Shaikh and Wes Rumbaugh, "The Air and Missile War in Nagorno-Karabakh: Lessons for the Future of Strike and Defense," Center for Strategic and International Studies, December 8, 2020, https://www.csis.org/analysis/air-and-missile-war-nagorno-karabakh-lessons-future-strike-and-defense.

[105] Minasyan, "The Battle For Shusha Fighting In Nagorno-Karabakh Has Reached A Turning Point."

[106] John Spencer and Harshana Ghoorhoo, "The Battle of Shusha City and the Missed Lessons of the 2020 Nagorno-Karabakh War," Modern War Institute, July 14, 2021, https://mwi.usma.edu/the-battle-of-shusha-city-and-the-missed-lessons-of-the-2020-nagorno-karabakh-war/.

employ sUAS. While the sources in this section help shed light on how adversaries may currently employ these systems, this research question will be heavily informed by what is possible, including techniques derived from successes in the Nagorno-Karabakh conflict and by Violent Extremist Organizations (VEOs) in the CENTCOM AOR.

Russian sUAS Employment. Russia has employed sUAS in Ukraine, predominantly to identify targets and coordinate fires. Russia continues to advance their sUAS capabilities, indicating an interest in using this technology to a greater extent in the future.

Russia has employed a variety of sUAS in Ukraine since 2014, including the Orlan, Granat-1 and 2, Forpost, Eleron 3SV, Zastava (or the Israeli produced Birdeye 400) and the ZALA-421-08. Employing sUAS for observation and fire control allowed Russia to avoid the use of conventional air which provided (albeit limited) deniability and reduced the risk associated with manned aircraft.[107] The most notable use of Russian sUAS in Ukraine involves close integration with artillery.[108] In 2014, sUAS (operated by separatists and likely Russian enablers) conducted real-time target observation to enable a multiple rocket launcher (MRL) attack against Ukrainian forces moving in columns near Zelenopillya, Ukraine. Ukrainian forces suffered significant casualties, with the Ukrainian Defense Ministry reporting 19 soldiers killed and 93 wounded.[109] Other reports

[107] Mark Galeotti, *Armies of Russia's War in Ukraine* (Oxford, UK: Osprey Publishing, 2019).

[108] Sydney J. Freedberg, Jr., "Russian Drone Threat : Army Seeks Ukraine Lessons," *Breaking Defense*, October 14, 2015, https://breakingdefense.com/2015/10/russian-drone-threat-army-seeks-ukraine-lessons/.

[109] Woodford, "The Russian Artillery Strike That Spooked the US Army."

claimed the casualties were even higher.[110] In this and other cases, visual identification of an sUAS proved an insufficient protective measure—by the time Ukrainian forces saw an sUAS, it could see them and coordinate fires.[111] Notably, this event may have influenced the initiation of the Russian New Generation Warfare Study by the Asymmetric Warfare Group which influenced the Army MDO concept.[112] Russia appears to be continuing development of this technique. In 2016, Russian media reported that Russian Army artillery successfully integrated sUAS to conduct targeting and observe indirect fires during an exercise in Dagestan. Russian forces used the Takhion sUAS, a 25kg airframe, to spot fires for 122mm howitzers.[113] A Ukrainian activist website claims that in November 2020 Ukrainian forces shot down a Russian produced Granat-1 sUAS, reportedly a part of a Russian artillery reconnaissance system.[114] The Granat-1 is an sUAS with a 10km range used to observe targets for fires assets.[115]

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[110] UNIAN Information Agency, "Year Ago: ATO Troops near Zelenopillya Burnt to the Ground by Russian Grads," UNIAN, November 7, 2015, https://www.unian.info/war/1099656-ukrainian-troops-near-zelenopillya-burnt-to-the-ground-by-russian-grads-year-ago.html.

[111] Kowrach, "US Army Counter-Unmanned Aerial Systems."

[112] Woodford, "The Russian Artillery Strike That Spooked the US Army."

[113] Russian Aviation, "Russian Army Artillery Units Use Takhion Mini-UAV to Perform Reconnaissance Missions," July 11, 2016, http://www.ruaviation.com/news/2016/7/11/5959/.

[114] InformNapalm, "Russian Military UAV Shot down in the War Zone (Updated)," *InformNapalm*, last modified 2020, https://informnapalm.org/en/russian-military-uav-shot-down-in-the-war-zone-updated/.

[115] Ibid.

In addition to sUAS-artillery integration, Russia continues to explore other sUAS applications, including the ability to perform strikes.[116] The Russian military has acquired the Lantset UAS which acts as a loitering munition or *kamikaze drone*. It first appeared in Russia in 2019 and was likely used by Russian Special Forces in Syria in April 2021.[117] This system provides unique reconnaissance and strike capabilities for Russian forces. With a 40 minute loiter time it can search an area and locate a target before engagement. Although it appears to use a ground station link, it does not require satellites for navigation as it can use on-board modules to identify locations and targets. It has a 3kg payload and the total system only weighs 12kg, placing it in Group 2.[118] In 2020 Russian state media announced a successful sUAS swarm exercise using existing Russian sUAS to conduct reconnaissance and strikes.[119] While this exercise may not have been a true swarm of aircraft coordinating as a single entity it indicates an increase in Russian

[116] David Hambling, "Russia Uses 'Swarm Of Drones' In Military Exercise For The First Time," *Forbes* September 24, 2020, https://www.forbes.com/sites/davidhambling/2020/09/24/russia-uses-swarm-of-drones-in-military-exercise-for-the-first-time/?sh=608ac3fa4771.

[117] Roger McDermott, "Russian UAV Technology and Loitering Munitions," *Eurasia Daily Monitor* 18, no. 72 (May 5, 2021), https://jamestown.org/program/russian-uav-technology-and-loitering-munitions/.

[118] Zala Aero, "Zala Lancet-3 Product Listing," accessed January 22, 2022, https://zala-aero.com/en/production/bvs/zala-lancet-3/.

[119] Samuel Bendett, "Strength in Numbers: Russia and the Future of Drone Swarms," Modern War Institute, April 20, 2021, https://mwi.usma.edu/strength-in-numbers-russia-and-the-future-of-drone-swarms/.

capability. A peer-to-peer network of sUAS and fires assets could provide artillery batteries a thorough picture of the battlefield and increase targeting opportunities.[120]

The 2022 Russian invasion of Ukraine greatly expanded the conflict between these two states. At the time of this writing, major combat operations are still ongoing, and it will take some time before the extent of Russian use of sUAS becomes clear. But initial reports of the way sUAS did, or in some cases did not, influence the fight does provide important context. In the weeks preceding the invasion, Russian state media released videos demonstrating Russian sUAS technology.[121] But in the first week of March 2022, despite stiff resistance and a need for battlefield reconnaissance, sUAS played a surprisingly negligible role in Russian operations.[122] The reasons remain unclear, but the situation soon changed. Russian loitering munitions began to appear in social media reporting in mid-March, ostensibly aided by advances in autonomous technology.[123] By the end of March 2022, Russian forces were employing a variety of sUAS in reconnaissance, fire coordination and strike roles.[124]

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[120] Hambling, "Russia Uses 'Swarm Of Drones' In Military Exercise For The First Time."

[121] Sebastien Roblin, "Russian Drone Swarm Technology Promises Aerial Minefield Capabilities," *The National Interest*, last modified 2021, https://nationalinterest.org/blog/reboot/russian-drone-swarm-technology-promises-aerial-minefield-capabilities-198640.

[122] Samuel Bendett, "Where Are Russia's Drones?," *Defense One,* March 1, 2022, https://www.defenseone.com/ideas/2022/03/where-are-russias-drones/362612/.

[123] Will Knight, "Russia' s Killer Drone in Ukraine Raises Fears About AI in Warfare," *WIRED* (San Fransisco, CA, March 2022), https://www.wired.com/story/ai-drones-russia-ukraine/.

[124] Sam Cranny-Evans, "Russian Drones Are Playing a Major Role in the War Against Ukraine," *Techland: When Great Power Competition Meets a Digital World*

Chinese sUAS development and employment. China has not openly employed military sUAS in conflict, however, the People's Liberation Army (PLA) has employed systems in exercises and the Chinese commercial-military sUAS industry is rapidly expanding. US assessments of likely Chinese tactics provide insight into what role sUAS could play in the PLA order of battle.

The US assessment in ATP 7-100.3, *Chinese Tactics,* provides insight into how the PLA will fight but does not, for the most part, distinguish between sUAS and larger, traditional UAS. The document does, however, cover general ideas about how the PLA may employ UAS in combat operations that are directly informative to sUAS employment, and highlights that China is a major UAS producer and employs sUAS at the brigade and battalion level.[125] ATP 7-100.3 assesses that medium-sized systems have been weaponized.[126] Chinese-produced weaponized sUAS systems substantiate this assertion. The PLA has acquired CH-901s, an indigenously produced loitering munition capable of detecting targets from over a mile away. [127] Additionally, China has employed unique, helicopter style sUAS in Tibet. These systems, the Blowfish and Ranger (both

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(blog), *The National Interest*, March 27, 2022, https://nationalinterest.org/blog/techland-when-great-power-competition-meets-digital-world/russian-drones-are-playing-major-role 1/5.

[125] Headquarters, Department of the Army (HQDA), Army Techniques Publication (ATP) 7-100.3, *Chinese Tactics* (Washington, DC: Army Publishing Directorate, 2021), D-2.

[126] Ibid.

[127] David Hambling, "China' s Mini-Drone Packs a Heavyweight Punch," *Popular Mechanics*, May 5, 2016, https://www.popularmechanics.com/military/ a20722/china-mini-drone/.

from the Chinese commercial sUAS manufacturer Ziyan), can move supplies and deliver munitions at high altitude.[128]

ATP 7-100.3 assesses that China will integrate UAS into observer teams. Lower echelons will employ UAS for targeting and will integrate these systems into networks that allow artillery battalions to incorporate targeting data from unit-level UAS in addition to electronic intelligence (ELINT) and traditional forward observer (FO) assets.[129] PLA special operations forces (SOF)—which serve more of a long-range surveillance (LRS) role than US SOF—will likely employ this capability as well in support of maneuver operations.[130] Combined Arms Brigades employ UAS in a variety of roles, including decoy and targeting[131].

China has invested heavily in artificial intelligence (AI) research and may look to apply this technology to sUAS. China views itself as a world leader in both artificial intelligence and sUAS, a claim that Gregory Allen, a technology analyst with the Center for New American Strategy, assesses as accurate.[132] China also claims to be a world leader in sUAS swarm technology, and although this claim is hard to assess, it carries

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[128] Defense News World Bureau, "Chinese Troops Deploy Unmanned Helicopters Near Border With India," *Defense World News*, November 19, 2020, https://www.defenseworld.net/news/28353/Chinese_Troops_Deploy_Unmanned_Helicopters_Near_Border_With_India#.YYGvxp7MLn0.

[129] HQDA, ATP 7-100.3, 2-10, F-1.

[130] Ibid., 2-8.

[131] Ibid., 6-6.

[132] Allen, *Understanding China's AI Strategy*.

some weight given Chinese advancements in both sUAS and AI technologies.[133] Notably, an executive with Ziyan, the Blowfish manufacturer, claimed that unmanned systems will replace human soldiers as early as 2025.[134]

Ziyan claims their system can autonomously conduct complex combat missions. While this claim may sound far-fetched, there is evidence that this technology is feasible. Search and rescue experiments have shown that an sUAS can successfully perform human detection using on-board artificial intelligence without a link to a ground control station. The sUAS can then drop a flotation device to a swimmer in need of rescue.[135] While such an application is unique, this technology is clearly analogous to sUAS munition delivery. Divorcing an armed sUAS from ground control not only creates a fire-and-forget weapon, it also creates one impervious to many traditional electronic countermeasures such as control spoofing, jamming, or hacking.[136] Ongoing research into

[133] David Hambling, "If Drone Swarms Are the Future, China May Be Winning," *Popular Mechanics*, December 23, 2016, https://www.popularmechanics.com/military/research/a24494/chinese-drones-swarms/.

[134] Patrick Tucker, "SecDef: China Is Exporting Killer Robots to the Mideast," *Defense One,* November 5, 2019, https://www.defenseone.com/technology/2019/11/secdef-china-exporting-killer-robots-mideast/161100/.

[135] Eleftherios Lygouras, Nicholas Santavas, Anastasios Taitzoglou, Konstantinos Tarchanidis, Athanasios Mitropoulos, and Antonios Gasteratos, "Unsupervised Human Detection with an Embedded Vision System on a Fully Autonomous UAV for Search and Rescue Operations," *Sensors* 19, no. 16 (August 2019): 1–20.

[136] Adam A. Palmer, "Autonomous UAS : A Partial Solution to America's Future Airpower Needs" (Research Paper, Air University, 2010).

drone navigation without the use of satellite-based PNT could further liberate autonomous drones from reliance on the EMS.[137]

Such autonomy may enable the development of sUAS swarms, and China sees value in massing them. China has invested heavily in combining autonomous technologies and UAS, with the state-owned China Electronics Technology Group Corporation (CETC) demonstrating the ability to operate dozens of sUAS in a synchronized swarm as early as 2016.[138] Chinese manufacturers claim that a single operator can control multiple sUAS, and that this ability will grow over time. To support this type of mass deployment, China uses smaller, lighter launchers for sUAS to enable rapid, sequential launches. Such swarms allow a greater ability to overwhelm air defense systems at a lower cost than traditional systems, and even the ability to deny areas to air power.[139]

The growing Chinese sUAS market underscores the rate at which China is developing these systems. China has a robust UAS industry, including military systems, and widely available commercial systems like DJI, a Chinese manufacturer of consumer sUAS such as the Phantom and Mavic, which own a 74% global market share in

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[137] Unmanned Airspace, "Israeli Pilot Programme Tests Drone Flights in GPS Denied Environments Ahead of Commercial Operations," February 10, 2021, https://www.unmannedairspace.info/uncategorized/israeli-pilot-programme-tests-drone-flights-in-gps-denied-environments-for-commercial-operations/.

[138] Hambling, "If Drone Swarms Are the Future, China May Be Winning."

[139] Irving Lachow, "The Upside and Downside of Swarming Drones," *Bulletin of the Atomic Scientists* 73, no. 2 (2017): 96–101, http://dx.doi.org/10.1080/00963402.2017.1290879.

consumer sUAS.[140] In 2019, Secretary of Defense Mark Esper highlighted the proliferation of Chinese sUAS, including the Blowfish, which can deliver precision strikes.[141] China has also played a major role in proliferating sUAS to state actors in the Middle East.[142] This proliferation is most pronounced in sales of larger UAS to nations unable to acquire such systems from western states.[143]

Summary

This literature review encompassed a range of sources, including military and strategic documents, academic and professional papers, news articles and books. It also described the process used to collect this material. The first section addressed literature relevant to the primary research question by examining existing US C-sUAS strategies and technologies. It also explored department of defense doctrine relevant to C-sUAS operations on a large-scale MDO battlefield, including existing C-sUAS doctrine, air defense doctrine, cyber and EW doctrine, and doctrine on large-scale tactical battlefields. The second section focused on contemporary sUAS employment relevant to the first secondary research question. This section examined the use of sUAS by VEOs in the CENTCOM AOR, which largely consisted of commercially acquired sUAS. It also

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[140] Allen, *Understanding China's AI Strategy.*

[141] Tucker, "SecDef: China Is Exporting Killer Robots to the Mideast."

[142] Allen, *Understanding China's AI Strategy.*

[143] Francesco F. Milan and Aniseh Bassiri Tabrizi, "Armed, Unmanned, and in High Demand: The Drivers behind Combat Drones Proliferation in the Middle East," *Small Wars and Insurgencies* 31, no. 4 (2020): 730–750, https://doi.org/10.1080/09592318.2020.1743488.

delved into the 2020 conflict between Azerbaijan and Armenia in the disputed Nagorno-Karabakh region and the extensive use of sUAS by Azerbaijan to support its operations. The final section explored material relevant to near-peer sUAS use to support the final research question. It investigated the use of Russian sUAS in Syria and Ukraine, as well as Russian development of sUAS technologies, particularly the use of sUAS to coordinate fires. This section also considered Chinese sUAS, examining how sUAS factor into US assessments of Chinese tactics as well as exploring Chinese experimentation with and development of sUAS. In both cases, emerging control technologies including swarm and autonomous systems were considered. This literature provides the foundation for analysis of how sUAS will be employed on the battlefield, and ultimately, the capabilities required to counter sUAS at the tactical level.

CHAPTER 3

RESEARCH METHODOLOGY

Introduction

This chapter outlines the methodology used to answer research questions, analyze data, and draw conclusions. This study addressed one primary and two secondary research questions: What capabilities do tactical formations need to conduct counter-sUAS operations in high-intensity Multi-Domain Operations? How have sUAS been employed in contemporary operations? How will sUAS be employed by peer forces during high-intensity combat operations? The literature reviewed for this study provides a picture of sUAS employment throughout the world that serves as a baseline for establishing a threat framework using case studies. Through that framework this study determined the capabilities and processes tactical formations need to conduct C-sUAS operations on an MDO battlefield. The following paragraphs describe the study method, data collection and analysis approach, and ethical considerations for the study.

Method

This thesis is a qualitative study using case studies. A qualitative study is appropriate in this situation as concrete statistical data is not readily available, and the research questions focus on evaluating the methods with which sUAS have been employed or may be employed in the future. The study examines case studies due to their utility in answering descriptive questions—"what is happening"—or explanatory questions—“how or why did it happen?”[144] They are also commonly used when conducting evaluations. Figure 2 shows a depiction of the overall methodology.

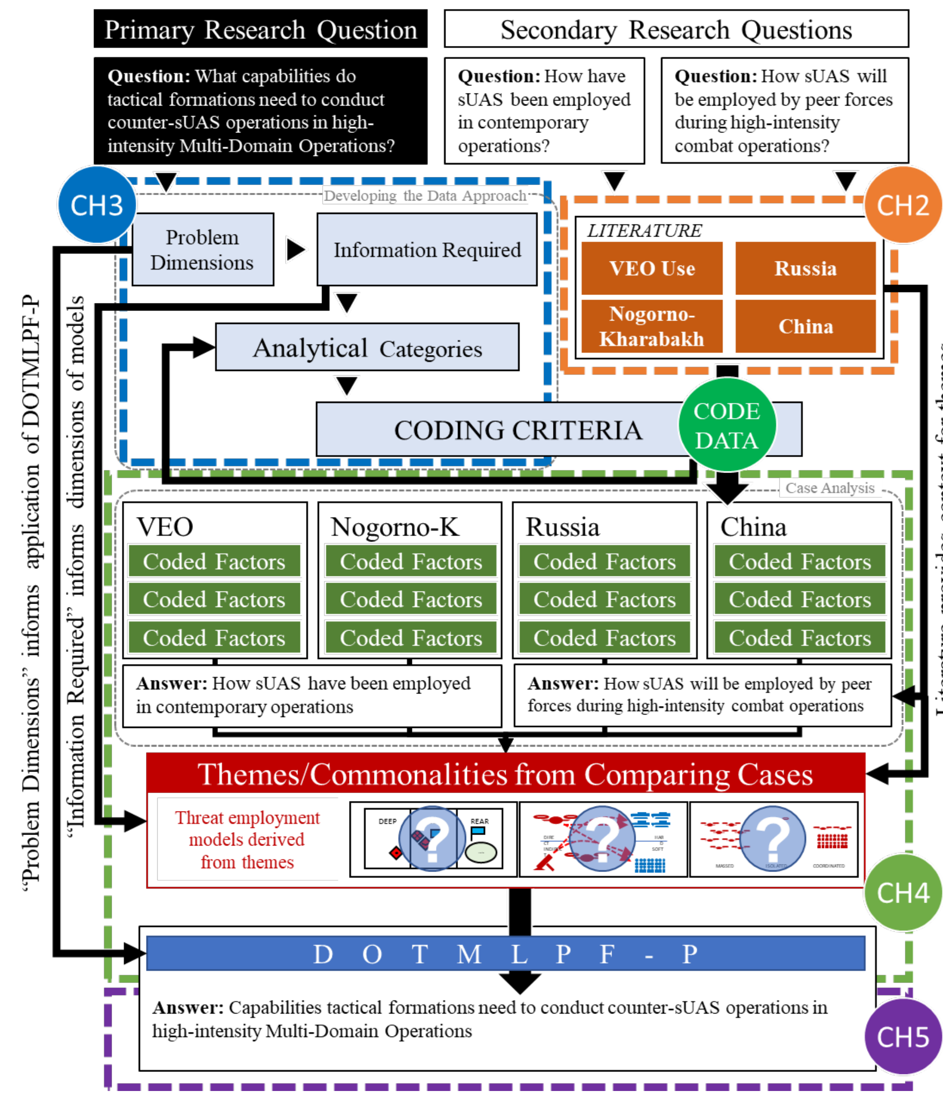

Figure 2. Study Methodology

Source: Created by author.

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[144] Robert K. Yin, *Applications of Case Study Research*, 3rd ed. (Thousand Oaks, CA: SAGE Publications, 2012), 4-5.

As shown in Figure 2, the research method begins and ends with the primary research question: What capabilities do tactical formations need to conduct counter-sUAS operations in high-intensity Multi-Domain Operations? Two secondary research questions support the primary research question and served as the basis for examining four cases of sUAS employment: Violent Extremist Organizations, the 2020 Nagorno-Karabakh conflict, Russia, and China. The literature review in Chapter 2 establishes a pool of journalistic, academic, and military reports and articles regarding each case.

The codes and categories employed during data analysis were derived by identifying the components or "solution parameters" of the capabilities referred to in the primary research question and how adversary sUAS influenced these parameters. The collected codes within each category across the sources became the "study data." Chapter 3 describes this process.

Chapter 4 establishes relationships within the categories of the study data through cross-category and cross case analysis. The study's four cases formed the basis of a cross-case comparison from which this study identifies themes for sUAS across actors. This study develops these themes into sUAS employment models to provide a clear picture of the specific ways sUAS will create risk for US forces. This threat, considering existing doctrine, strategy, assessments, and technology, serves as the basis for establishing which capabilities tactical formations require. DOTMLPF-P was used as the framework for describing these capabilities and identifying which gaps must be corrected.

Finally, Chapter 5 answers the primary research question by determining the capabilities required to fill the gaps identified in combatting the sUAS threat described in Chapter 4.

Data Collection

The literature review for this study included government, academic, journalistic, and web-based sources. This literature served as the basis for case studies by providing information regarding the conditions, methods, and timing of contemporary and potential sUAS employment, and provided a basis for identifying vulnerabilities and C-sUAS responses required by US tactical forces.

The first phase of data collection was gathering formal, stated policy, doctrine, and strategy of the Department of Defense. Data collection began with all US Army and Joint doctrine pertaining to Short-Range Air Defense, Counter-UAS, or air defense in Maneuver Operations. Additionally, DoD, Army and Joint force C-sUAS Strategy and posture documents were collected. Together, these established a base understanding of how the Department of Defense, and the Army as the C-sUAS executive Agent, views C-sUAS within existing air defense constructs. Next, strategic, and operational documents, including operating concepts and doctrine were collected. These provided a larger understanding of the Army and DoD goals that C-sUAS operations support.

The second phase of data collection focused on reviewing academic, military, and journalistic material regarding ongoing C-sUAS and sUAS activity. A broad review of Counter UAS and UAS scholarship and reporting provided a basis for identifying notable contemporary or potential sUAS employment, as well as an understanding of existing vulnerabilities. Identifying notable sUAS activity served as the basis for the final phases of data collection, in this case VEO, Russian, and Chinese use of sUAS, and its use in the Nagorno-Karabakh conflict.

Research into specific regional events was the final phase of the data collection process. Data for each of these events or focus areas was collected in sufficient detail to establish at minimum the method and purpose of the sUAS employment. Once sufficient data was collected, methodical analysis began.

Data Analysis

Analyzing the data collected in this study required identifying the purpose those data serve, and how they answer the primary research question of this study: What capabilities do tactical formations need to conduct counter-sUAS operations in high-intensity Multi-Domain Operations? Ascertaining the capabilities required by tactical formations involved identifying the general parameters of a solution. The data were analyzed in light of the information required to address each parameter. Table 1 shows the solution parameters of the primary research question, and the information required about the threat to inform them.

Table 1. Threat Data Categorization

Threat: How will sUAS be employed by peer forces during high-intensity combat operations? How have sUAS been employed in contemporary operations?	**Requirement:** What capabilities do tactical formations need to conduct counter-sUAS operations in high-intensity Multi-Domain Operations?
INFORMATION REQUIRED	SOLUTION PARAMETERS
Targets of sUAS employment Purpose of sUAS employment	Assets which tactical formations must protect against sUAS
Battlespace location of sUAS employment	Areas tactical formation must protect against sUAS
Type of sUAS employed Number of sUAS employed	Manner in which sUAS must be defeated

Source: Created by author.

Each of the information requirements above served as an analytical category while analyzing data. The study also employed three additional categories. “Event Type” encompassed whether the threat information described an operational event (such as sUAS employed in combat), development of an sUAS capability (such as training or testing), or an assessment of possible sUAS employment. Event Type provided insight into whether the source reported on real world sUAS use, sUAS capabilities development, or analysis of threat doctrine. “Case” encompassed which of the cases in the secondary research questions the source described. By capturing Case, data analysis could compare how different actors employed sUAS. Finally, “Emerging Control Technologies” stood out during the coding process and were captured and analyzed to provide insight into how near-term technology could impact C-sUAS operations.

This study then determined what codes must be applied to the data collected within each factor. The words used in literature to describe these events require context and interpretation, which made text analysis tools unsuitable for coding this data. Instead, code selection criteria, shown in Table 2, served as a basis for analyzing sections of text from literature to determine which codes to apply.

Table 2. Categories and Code Selection

Category	Code Selection Criteria
Case	• Selected from cases described in secondary research questions: VEO, Nagorno-Karabakh, Russia and China.
Event Type	• Operational: Descriptions of real-world combat applications of sUAS. • Development: Descriptions of training, testing, experimentation, or research with sUAS. • Assessment: Descriptions of what an actor may or may not do with sUAS.
Targets of sUAS employment	• Fixed Site: sUAS used against facilities or bases. • Maneuver forces: sUAS used against vehicles or troops conducting operations. • Air Defense: sUAS used against Surface-to-Air missile sites, mobile anti-aircraft. • Artillery: sUAS used against fires, artillery, or mortars. • C2: sUAS used against command elements or headquarters. • Sustainment: sUAS against logistics assets or lines of communication (LOCs). • Not Stated: No description of the sUAS target.
Purpose of sUAS employment	• Fires Coordination: sUAS used to provide target acquisition or observation for fires. • Reconnaissance: sUAS used to observe without employment of fires. • Strike: sUAS delivers a kinetic effect. • Propaganda: sUAS used to record information transmitted for propaganda or information warfare purposes. • Indeterminate: sUAS used for an unknown purpose. • Not Stated: sUAS purpose is not described.

Category	Code Selection Criteria
Battlespace location of sUAS employment	• Close: sUAS used against troops in defensive positions or actively in combat. sUAS described as employed in conjunction with maneuver forces. • Rear: sUAS used against targets associated with a rear or support area such as LOCs, facilities, and ports. Also, sUAS described as attacking behind the front line of troops. • Non-Contiguous: sUAS used against or by actors without a clear close-deep-rear framework such as special purpose forces. • Indeterminate: descriptions of sUAS employment in the battlespace that do not meet the criteria above. • Not Stated: Location of sUAS employment not discernable from source.
Type of sUAS employed	• Fixed-wing: sUAS identifiable as fixed-wing in photographs, described as fixed-wing, or named as known fixed-wing sUAS. • Rotary-wing: sUAS identifiable as rotary-wing in photographs or named as known rotary-wing sUAS. sUAS described as rotary-wing or quadcopters. sUAS described as hovering. • Loitering Munition: sUAS described as loitering munitions. sUAS described as "suicide" or "kamikaze." • Not Stated: Type of sUAS is not stated.
Number of sUAS employed	• Single: Descriptions of the employment of a single sUAS. • Multiple: Descriptions of simultaneous or synchronized employment of sUAS against a specific target or portion of the battlespace. • Indeterminate: Descriptions of multiple sUAS employment where it is unclear whether the employment is simultaneous or synchronized. • Not Stated: The number of sUAS employed is not stated.
Emerging Control Technologies	• Autonomous: Descriptions of sUAS operating autonomously. • Swarm: sUAS were employed in a coordinated mass formation with centralized control. • Not Stated: No emerging control technologies were described.

Source: Created by author.

The criteria in Table 2 were the basis for coding data derived from the literature review. This was a hybrid coding technique, as the criteria above established the categories for coding data prior to analysis, but the codes within each category (for instance, the purpose for which sUAS employed) were identified, modified, or removed as they emerged in the data.[145]

Three Event Type codes were ultimately employed: Operational, Development, and Assessment. Originally, only Operational and Development codes were planned to differentiate between real-world employment and research and training exercises. The Assessment code was added to incorporate US government publications that make projections about how adversaries could employ sUAS without being rooted in actual events.

Seven target codes were selected: Maneuver Forces, Air Defense, C2, Sustainment, Artillery, Fixed Sites, and Not Stated. Maneuver Forces, Artillery and Fixed Sites were identified as the initial codes. However, the coding process identified additional targets, particularly in the Nagorno-Karabakh case, which didn't fit into these categories. Distinct employments against Air Defenses, C2, and Sustainment nodes drove inclusion of these codes. Finally, a "Not Stated" code was used instead of a null value to track where the target was not described.

Five location codes were used: Close, Rear, Non-contiguous, Indeterminate, and Not Stated. Initially, only Close, Rear and Not Stated were used (a Deep area code was considered but found unnecessary). Employment on unconventional battlefields, particularly by VEOs in the Middle East, quickly made clear, however, that a Non-Contiguous code was needed. Additionally, an Indeterminate code became necessary to

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[145] DelveTool, "The Essential Guide to Coding Qualitative Data," Delve, last modified 2020, https://delvetool.com/guide.

describe sources that could not otherwise fit into the deep-close-rear operational framework or were otherwise ambiguous.

Six purpose codes were used: Reconnaissance, Fires Coordination, Strike, Propaganda, Indeterminate, and Not Stated. The initial set identified were Fires Coordination, Reconnaissance and Strike. Descriptions of sUAS use for propaganda were initially expected to align with reconnaissance, but the distinct nature of each type of employment in the literature drove separation of these codes. “Not Stated” was used to track sources where the purpose was not described, but during the coding process, the need for a code to describe situations where the purpose was unknown rather than unstated became clear. Indeterminate is used in these cases.

Four types of sUAS were used as codes: Fixed-wing, Rotary-wing, Loitering Munition, and Not Stated. These emerged early as the major types of sUAS during the literature review and stayed consistent throughout the coding process. Each is distinct from the other in meaningful ways and appears frequently enough to require inclusion. Rotary-wing sUAS were not further divided by number of rotors since differences in performance and employment characteristics are negligible.

Four codes were used to describe the number of sUAS employed. Initially, this code tried to capture whether multiple sUAS were employed simultaneously or sequentially, but this information could not be ascertained. The codes were then simplified to Single, Multiple, or Not Stated. Some cases were still ambiguous, however, with descriptions unclear as to whether multiple sUAS were employed simultaneously; Indeterminate was used in these cases.

Finally, during the coding process, an additional category of interest was identified in the Russia and China data. This category is “Emerging Control Mechanisms” and includes two codes: Autonomous and Swarm. These technologies figure heavily in literature on Russian and Chinese sUAS employment and may be a key component of how US Forces will need to counter sUAS.

Once data were coded, they were consolidated into a Microsoft Access database. Sources were entered as records (rows) and categories as fields (columns). Fields were formatted as tags to allow multiple codes within each entry. This allowed the use of cross-tabulation queries to determine relationships between codes within each field.

Cross-case comparisons were employed to establish relationships between employment in the different cases discussed. Relationships between the data (such as repeated instances of matching target and effect types) were used to develop themes (adversary use of a specific effect against a class of capability). These themes informed development of sUAS employment models. The overall data analysis approach is shown in Figure 3.

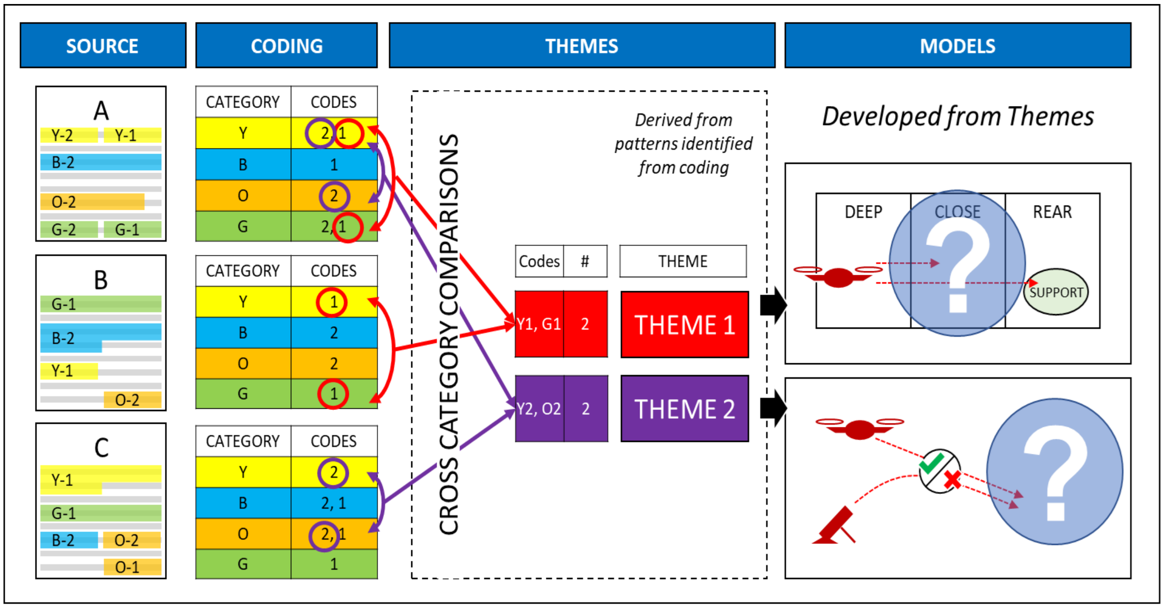

Figure 3. Data Analysis and Comparison Model

Source: Created by author.

These sUAS employment models used the categories identified during threat data analysis to address *where* (battlespace location of sUAS employment) and *how* (type of sUAS employed, number of sUAS employed) adversaries may employ sUAS on the battlefield, *what* (targets of sUAS employment) they will target, and *why* (purpose of sUAS employment) they will employ them. The study then used these models to determine what capabilities are required at the tactical level, and how forces should best employ C-sUAS systems to prevent risk to force and risk to mission by employing the DOTMLPF-P framework.

DOTMLPF-P analysis was driven by identifying how the domains of DOTMLPF-P best align with the solution parameters already identified: Assets and Areas which tactical formations must protect against sUAS, and the Manner in which sUAS must be defeated. Once the most appropriate DOTMLPF-P domains were identified, they were used to answer the primary research question by describing the existing gaps and determining the capabilities required to mitigate these specific risks.

Ethical Considerations

No human subjects were used for this research. But, as with any study considering contemporary events, care must be taken to be sensitive when examining events in which human beings died and left behind grieving family members. This study sought to avoid trivializing the human cost associated with casualties inflicted by unmanned aerial systems.

This study also recognized that many sources reporting on or studying sUAS may have perspectives or aims that create bias in the information presented. Journals associated with the defense industry may emphasize the threat due to potential for DoD investment in new technology. Newspapers or websites associated with nations which encountered sUAS in conflict may exaggerate effects of sUAS to allege atrocities or minimize them to make government forces seem less vulnerable. This study references multiple sources to avoid narrow perspectives but is forthright when providing information from potentially biased sources.

Summary

This is a qualitative study informed by case studies. Data collection was performed through a three-phased collection process that began with broad collection of material on C-sUAS and sUAS concepts, focused into historical sUAS employment, then culminated with the collection of data from published literature about specific sUAS employment. Literature regarding sUAS employment by VEOs, Azerbaijan during the Nagorno-Karabakh conflict, Russia, and China became the basis for a data set created by manually coding sources on each case through the lens of an established set of evaluation criteria. Coded sources become a database, created in Microsoft Access, from which associations between categories could be identified. Themes were identified through cross-category and cross-case comparisons to establish associations between codes in each category. These themes were developed into models that ultimately answer the primary research question through the DOTMLPF-P framework.

CHAPTER 4

ANALYSIS

Introduction

This chapter analyzes cases of sUAS employment by state and non-state actors. The cases themselves derive directly from material collected in the literature review and each highlights the connections identified in the data coding and analysis process. This chapter explores the study's four cases, two associated with each secondary research question. First, this chapter examines VEO employment of sUAS and the use of sUAS by Azerbaijan in the 2020 Nagorno-Karabakh conflict to evaluate how sUAS have been employed in contemporary operations. Then this chapter explores how Russia and China may employ sUAS, including the impacts of emerging technologies, to evaluate how a near-peer adversary will use sUAS in a high-intensity conflict. By comparing these four cases (VEOs, Nagorno-Karabakh, Russia, and China), this chapter then identifies commonalities and differences between them along with recurring themes. These themes are then developed into models, which inform DOTMLPF-P analysis of the capabilities required by tactical formations to conduct C-sUAS on an MDO battlefield. Tables in this chapter draw information from coded study data, found in Appendix A.

Cases of sUAS Employment in Contemporary Operations

This section explores sUAS use by VEOs and by Azerbaijan in the Nagorno-Karabakh Conflict. Together, these cases will answer secondary research question #1: how have sUAS been employed in contemporary operations?

VEOs. This section examines how violent extremist organizations (VEOs) employ sUAS in the CENTCOM AOR. Sources describe VEO sUAS employment mainly against fixed sites and maneuver forces. Data indicates VEO use sUAS most frequently for strikes, followed by reconnaissance and propaganda. The nature of sUAS employment by de-centralized, insurgent forces introduces the possibility of reporting bias. For example, sources frequently associate sUAS reconnaissance with propaganda but may over-represent this relationship because many reports derive sUAS reconnaissance occurrences from propaganda material. Likewise, the dramatic nature of a kinetic sUAS attack makes such attacks more likely to appear in open-source reports. Figure 4 shows the frequency of codes within each category for VEO sUAS employment.

Event Type	Operational	7
	Development	1
	Assessment	0
Target	Fixed Site	4
	Maneuver forces	4
	Air Defense	0
	Artillery	0
	C2	0
	Sustainment	0
	Not Stated	1
Purpose	Strike	7
	Reconnaissance	5
	Propaganda	3
	Fires Coordination	0
	Indeterminate	0
	Not Stated	0

Battlespace Location	Close	3
	Rear	2
	Non-Contiguous	2
	Indeterminate	0
	Not Stated	1
Type	Fixed-wing	2
	Rotary-wing	2
	Loitering Munition	0
	Not Stated	0
Number	Multiple	3
	Indeterminate	1
	Single	0
	Not Stated	0
Data consolidated and coded from 7 sources. *A single source may have multiple codes per category		

Figure 4. VEO sUAS Employment Overview

Source: Created by author using coded study data.

Table 3 shows the associations between the targets of VEO sUAS and the purpose for which they were employed. Examining relationships within this data reveals little information beyond that clearly established in Chapter 2 during the literature review. The collected information describes VEOs use sUAS predominantly for reconnaissance, propaganda, and strikes, split between use against fixed sites and maneuver forces. The maneuver forces described are local national forces; the fixed-site targets include US and coalition bases.[146]

Table 3. VEO Data Cross-Category Association: sUAS Target-Purpose

Target	Purpose	Instances
Fixed Sites	Strike	4
Maneuver Forces	Strike	4
Maneuver Forces	Recon	3
Fixed Sites	Recon	2
Maneuver Forces	Propaganda	2
Fixed Sites	Propaganda	1

Source: Created by author using cross-tabulation analysis in Microsoft Access from coded study data
NOTE: Codes in one category may be associated with multiple codes in another.

Examining associations between VEO sUAS purpose and quantity of sUAS employed, as shown in Table 4, reveals a prominence of multiple sUAS employment.[147] Sources which describe the number of sUAS employed typically describe the use of multiple sUAS. This indicates that when a VEO employs an sUAS for a strike, or for

[146] Warrick, "Use of Weaponized Drones by ISIS Spurs Terrorism Fears."

[147] Reuters, "Drone Attack on US Base Foiled, Iraqi Security Sources Say."

recon/propaganda purposes, they will typically employ two more. Since many cases describe individual sUAS crashing or being shot down, VEOs may employ multiple sUAS to provide redundancy or assurance of effects. In many cases sources either do not report or cannot determine the number of sUAS involved in an event.

Table 4. VEO Cross Category Association: sUAS Purpose-Number

Purpose	Number	Instances
Strike	Multiple	3
Strike	Not Stated	3
Propaganda	Multiple	2
Recon	Multiple	2
Recon	Not Stated	2
Propaganda	Not Stated	1
Recon	Indeterminate	1
Strike	Indeterminate	1

Source: Created by author using cross-tabulation analysis in Microsoft Access from coded study data.
NOTE: Codes in one category may be associated with multiple codes in another.

As shown in Table 5, literature describes attacks throughout the battlespace with various types of sUAS, but no clear patterns emerge in the coded data. VEOs employ fixed-wing and rotary-wing sUAS, mostly commercial-off-the-shelf (COTS) systems. Although targets are generally split between maneuver forces and fixed sites, the data is insufficient to draw conclusions regarding which type of sUAS are employed against which type of target.

Table 5. VEO Cross-Category Association: sUAS Type-Target

Target	UAS Type	Instances
Fixed Sites	Fixed-wing	1
Fixed Sites	Not Stated	2
Fixed Sites	Rotary-wing	1
Maneuver Forces	Not Stated	2
Maneuver Forces	Rotary-wing	2
Not Stated	Fixed-wing	1

Source: Created by author using cross tabulation analysis in Microsoft Access from coded study data.
NOTE: Codes in one category may be associated with multiple codes in another.

Comparing the purpose of VEO employment of sUAS against targets in the battlespace, as shown in Figure 5, reveals that no significant patterns emerge from this data, and no conclusions can be drawn beyond the fact that VEOs employ sUAS wherever possible. This is consistent with the generally non-contiguous battlefields on which VEOs operate.

		BATTLESPACE			
		Location Not Stated	Rear Area	Close	Non-Contiguous
TARGET	Maneuver Forces		Recon, Strike	Propaganda (2), Recon (2), Strike (3)	Propaganda, Recon (2), Strike (2)
	Fixed Sites		Recon, Strike (2)	Propaganda, Recon, Strike (2)	Propaganda, Recon, Strike
	Target Not Stated	Propaganda, Recon, Strike			

Figure 5. VEO sUAS Cross-Category Association: Purpose-Location-Target

Source: Created by author using cross tabulation analysis in Microsoft Access from coded study data.
NOTE: Table structure was modified, original table can be found in Appendix A. Numbers in parentheses ( ) indicate multiple instances of a Purpose-Location-Target association.

The complete set of coded data pertaining to VEO sUAS employment can be found in Appendix A.

Nagorno-Karabakh Conflict. The Nagorno-Karabakh conflicts provide unique insight into how sUAS may be employed on the battlefield due to the large role these systems played on the battlefield. When examining sources, however, it was important to identify which effects and employment descriptions referred to sUAS and which referred to the larger Baraktyur TB-2. While technically within the Group 3 UAS range, the TB-2 was employed in a traditional unmanned strike aircraft role and was excluded in the data where identified. Figure 6 reflects the frequency of codes within each category.

Event Type	Operational	9
	Development	0
	Assessment	0
Target	Air Defense	6
	Maneuver forces	5
	Artillery	3
	Fixed Site	2
	C2	1
	Sustainment	1
	Not Stated	1
Purpose	Strike	7
	Reconnaissance	4
	Fires Coordination	3
	Propaganda	3
	Indeterminate	0
	Not Stated	1

Battlespace Location	Close	3
	Rear	2
	Indeterminate	2
	Non-Contiguous	0
	Not Stated	2
Type	Loitering Munition	6
	Fixed-wing	5
	Rotary-wing	0
	Not Stated	3
Number	Multiple	2
	Single	0
	Indeterminate	0
	Not Stated	7
Data consolidated and coded from 9 sources. *A single source may have multiple codes per category		

Figure 6. Nagorno-Karabakh sUAS Employment Overview

Source: Created by author using coded study data.

Azerbaijan employed sUAS extensively in the Nagorno-Karabakh conflict. The frequency of descriptions of strikes and reconnaissance (as shown in Figure 6) stands out, as does the extensive use against maneuver targets and air defenses.[148] While a few sources document the use of multiple sUAS employed sequentially or simultaneously, for the most part the literature does not capture this data. When present, the battlespace location of sUAS employment can generally be described in terms of close or rear areas of the targeted formations, consistent with the clear lines present in the conflict.

Table 6 depicts the associations between targets and the purposes of sUAS employment and predominantly reflects sUAS use against fixed site defenses, maneuver

[148] Mitzer and Oliemans, "The Fight for Nagorno-Karabakh."

forces, air defense and artillery assets. Fixed defenses, command and control elements, and sustainment nodes also experienced attacks from sUAS. Sources most commonly associate strikes with air defense and maneuver force targets. Due to the impact of such attacks, reporting bias may result in overrepresentation of this type of activity as sUAS use for reconnaissance is also frequently described. In this case, use of sUAS for propaganda entails use of sUAS to capture footage of destroyed or damaged formations and equipment, later posted on social media or otherwise published.[149]

[149] Dixon, "Azerbaijan's Drones Owned the Battlefield in Nagorno-Karabakh."

Table 6. Nagorno-Karabakh Cross-Category Association: Target-Purpose

Target	Purpose	Instances
Air Defense	Strike	5
Maneuver Forces	Strike	4
Air Defense	Fire Coord	3
Maneuver Forces	Recon	3
Air Defense	Recon	2
Artillery	Recon	2
Artillery	Strike	2
Fixed Sites	Recon	2
Fixed Sites	Strike	2
Maneuver Forces	Propaganda	2
Air Defense	Not Stated	1
Air Defense	Propaganda	1
Artillery	Not Stated	1
Artillery	Propaganda	1
C2 Nodes	Fire Coord	1
C2 Nodes	Strike	1
Fixed Sites	Propaganda	1
Maneuver Forces	Fire Coord	1
Maneuver Forces	Not Stated	1
Not Stated	Not Stated	1
Sustainment	Fire Coord	1
Sustainment	Recon	1
Sustainment	Strike	1

Source: Created by author using cross tabulation analysis in Microsoft Access from coded study data.
NOTE: Codes in one category may be associated with multiple codes in another.

Examining associations between sUAS purpose and sUAS quantity employed, shown in Table 7, reveals no notable information. While sources describe the overall number of sUAS employed in the conflict, little information appears regarding to what extent sUAS were employed simultaneously or in sequence during a specific event. In the limited cases where sources describe the quantity of sUAS, they always describe the employment of multiple sUAS. The lack of single sUAS descriptions may be a bias in reporting if sources only consider the use of multiple sUAS noteworthy, or it may reflect an actual technique by Azerbaijan. The data, however, is inconclusive.

Table 7. Nagorno-Karabakh Cross-Category Association: Purpose-Number

Purpose	Number	Instances
Strike	Not Stated	5
Fire Coord	Not Stated	3
Not Stated	Not Stated	2
Propaganda	Not Stated	2
Recon	Multiple	2
Recon	Not Stated	2
Strike	Multiple	2
Propaganda	Multiple	1

Source: Created by author using cross tabulation analysis in Microsoft Access from coded study data.
NOTE: Codes in one category may be associated with multiple codes in another.

The Nagorno-Karabakh conflict saw heavy employment of fixed-wing sUAS and loitering munitions. Notably, both were used by Azerbaijan to perform attacks against Armenian air defenses. Associations between target and sUAS type for Nagorno-Karabakh are shown in Table 8. No clear trends or themes appear regarding which type of sUAS prosecuted which targets; fixed-wing sUAS and loitering munitions both appear at generally the same rate.

Table 8. Nagorno-Karabakh Cross-Category Association: Target-Type

Target	UAS Type	Instances
Air Defense	Fixed-wing	4
	Loitering Munition	5
	Not Stated	1
Artillery	Fixed-wing	1
	Loitering Munition	1
	Not Stated	2
C2 Nodes	Loitering Munition	1
Fixed Sites	Fixed-wing	1
	Loitering Munition	1
	Not Stated	1
Maneuver Forces	Fixed-wing	2
	Loitering Munition	3
	Not Stated	2
Sustainment	Fixed-wing	1
	Loitering Munition	1
Not Stated	Not Stated	1

Source: Created by author using cross tabulation queries in Microsoft Access from consolidated study data.
NOTE: Codes in one category may be associated with multiple codes in another.

During the conflict, Azerbaijan employed sUAS throughout the battlespace for a variety of purposes and against a variety of targets. Reporting on strikes dominates the data, but reconnaissance, fire coordination, and propaganda uses all appear. Notably, air defense and maneuver forces were engaged throughout the battlespace, and a broad range of targets were engaged in the close area. Strikes against sustainment and C2 nodes were described only in the rear area. No sources describe sUAS employment in non-contiguous battlespace, consistent with the nature of the conflict. The relationship between sUAS purpose, target, and battlespace location for sUAS employment in Nagorno-Karabakh is shown in Figure 7.

		BATTLESPACE LOCATION			
		Location Not Stated	Rear Area	Indeterminate	Close
TARGET	Air Defense	Effect Not Stated	Fire Coord (2), Recon, Strike (2)	Strike	Fire Coord, Propaganda, Recon, Strike (2)
	Artillery	Effect Not Stated		Propaganda, Recon, Strike	Recon, Strike
	Maneuver Forces	Effect Not Stated	Fire Coord, Strike	Propaganda, Recon, Strike	Propaganda, Recon (2), Strike (2)
	Fixed Sites				Propaganda, Recon (2), Strike (2)
	C2		Fire Coord, Strike		
	Sustainment		Fire Coord, Recon, Strike		
	Target Not Stated	Effect Not Stated			

Figure 7. N-Karabakh sUAS Cross-Category Association: Purpose-Location-Target

Source: Created by author using cross tabulation analysis in Microsoft Access from coded study data.
NOTE: Table structure was modified, original table can be found in Appendix A. Codes in one category may be associated with multiple codes in another. Numbers in parentheses ( ) indicate multiple instances of a Purpose-Location-Target association.

The complete set of coded data pertaining to Nagorno-Karabakh sUAS employment can be found in Appendix A.

Answer to Secondary Research Question #1

Together, the VEO and Nagorno-Karabakh cases answer the first secondary research question: How have sUAS been employed in contemporary operations? The two cases display significant contrasts. While both cases reflect the use of fixed-wing sUAS, VEOs also employed rotary-wing sUAS, whereas loitering munitions figured heavily in the Nagorno-Karabakh conflict. Many of these differences are not surprising, and stem largely from the nature of the actors and the battlefields involved. The conflict in Azerbaijan involved traditional states fighting on a contiguous battlefield.[150] VEOs, by their very nature, are asymmetric actors fighting in a much less contiguous battlespace.[151] Despite these differences, certain similarities are clear. In both cases, actors used sUAS for strike and reconnaissance against maneuver forces across the battlespace. Comparing these cases to those of near-peer threats informs the answer to the next secondary research question.

Peer Threat sUAS Employment

The following cases, along with cross-case analysis of all cases, provide a basis the second of the two secondary research questions: How will sUAS be employed by peer forces during high-intensity combat operations? This section examines two cases: Russia and China.

[150] Minasyan, "The Battle For Shusha Fighting In Nagorno-Karabakh Has Reached A Turning Point."

[151] Warrick, "Use of Weaponized Drones by ISIS Spurs Terrorism Fears."

Russia. Russia poses a peer threat to the US and a viable competitor in large-scale combat. Sources regarding Russian employment of sUAS break down into two primary categories: sUAS exercises or development and sUAS employment in Ukraine and Syria. As shown in Figure 8, most information on Russian sUAS involves their employment in a fires-coordinating capacity.

Event Type	Operational	6	Battlespace Location	Close	2
	Development	3		Rear	1
	Assessment	0		Non-Contiguous	1
Target	Maneuver forces	3		Indeterminate	1
	Fixed Site	1		Not Stated	4
	Air Defense	0	Type	Fixed-wing	6
	Artillery	0		Rotary-wing	0
	C2	0		Loitering Munition	1
	Sustainment	0		Not Stated	0
	Not Stated	5	Number	Multiple	3
Purpose	Fires Coordination	4		Single	1
	Reconnaissance	3		Indeterminate	1
	Strike	2		Not Stated	4
	Propaganda	0	Emerging Control Technology	Swarm	2
	Indeterminate	0		Autonomous	0
	Not Stated	1		Not Stated	7
Data consolidated and coded from 9 sources. *A single source may have multiple codes per category					

Figure 8. Russian sUAS Employment Overview

Source: Created by author using consolidated study data.

Russian employment of sUAS to coordinate fires most frequently associates with targeting of maneuver forces. This association, as shown in Table 9, provides the only notable connection between the targets and purposes for which Russia employed sUAS. Literature on Russian sUAS employment in Ukraine (both before and after the start of the most recent operations) frequently and explicitly highlights Russian sUAS integration with fires assets to provide rapid target acquisition. Artillery units control these systems and maintain direct links between the sUAS conducting observation and the supported fires systems.

Table 9. Russia Data Cross-Category Association: Target-Purpose

Target	Purpose	Instances
Maneuver Forces	Fire Coord	4
Not Stated	Not Stated	3
Not Stated	Recon	3
Artillery	Fire Coord	1
Artillery	Recon	1
Fixed Sites	Strike	1
Maneuver Forces	Recon	1
Not Stated	Fire Coord	1
Not Stated	Strike	1

Source: Created by author using cross tabulation analysis in Microsoft Access from coded study data.
NOTE: Codes in one category may be associated with multiple codes in another.

Table 10 shows the relationships between sUAS purpose and quantity of sUAS employed by Russia. While sources describe the employment of multiple sUAS, the data do not provide a clear link between the number of sUAS and the purpose for which they are employed, and no meaningful conclusions can be drawn from this relationship. Most sources do not describe the number of Russian sUAS employed.

Table 10. Russia Data Cross-Category Association: Purpose-Number

Purpose	Number	Instances
Fire Coord	Not Stated	4
Recon	Not Stated	3
Fire Coord	Multiple	1
Not Stated	Multiple	1
Not Stated	Not Stated	1
Not Stated	Single	1
Recon	Multiple	1
Strike	Indeterminate	1
Strike	Multiple	1

Source: Created by the author using cross tabulation analysis in Microsoft Access from coded study data.
NOTE: Codes in one category may be associated with multiple codes in another.

Relationships between the types of sUAS employed by Russia and the target they were employed against are similarly ambiguous and shown in Table 11. No conclusions can be drawn regarding the relationship between targets and the type of sUAS employed by Russian forces. Most sources that describe the type of sUAS used do not describe the target, and those that do fail to provide detail regarding the type of sUAS employed.

Table 11. Russia Data Cross-Category Association: Target-Type

Target	UAS Type	Instances
Fixed Sites	Loitering Munition	1
Maneuver Forces	Fixed-wing	1
	Not Stated	2
Not Stated	Fixed-wing	5

Source: Created by author using cross tabulation analysis in Microsoft Access from coded study data.
NOTE: Codes in one category may be associated with multiple codes in another.

Russia's demonstrated and developing capabilities indicate that employment will likely be near the forward line of troops in the close area of tactical operations. Sources indicate that sUAS operations will support lethal targeting against maneuver forces, possibly while at a halt or in an assembly area. Russia has demonstrated a limited integration of sUAS into ground combat (specifically in support of Russian SOF forces in Syria), but the techniques demonstrated in exercises and in Ukraine could be employed in conjunction with maneuver.[152] Associations between Russian sUAS employment purpose, target, and battlespace location are depicted in Figure 9.

[152] McDermott, "Russian UAV Technology and Loitering Munitions."

		BATTLESPACE				
		Location Not Stated	Rear Area	Indeterminate	Close	Non-Contiguous
TARGET	Maneuver Forces	Fire Coord	Fire Coord, Recon	Fire Coord	Fire Coord (2), Recon	
	Artillery		Fire Coord, Recon		Fire Coord, Recon	
	Fixed Sites					Strike
	Target Not Stated	Fire Coord, Recon (2), Purpose Not Stated (2)	Purpose Not Stated		Recon, Strike	

Figure 9. Russian sUAS Cross-Category Association: Purpose-Location-Target

Source: Created by author using cross tabulation analysis in Microsoft Access from coded study data.
NOTE: Table structure was modified, original table can be found in Appendix A. Codes in one category may be associated with multiple codes in another. Numbers in parentheses ( ) indicate multiple instances of a Purpose-Location-Target association.

Recent reports highlight effective use of Russian sUAS to coordinate deep fires, and these data are included. The significance of this employment remains to be seen, but it does mark an interesting departure from earlier fire coordination activities which tended toward the close area.[153] Future reporting may reveal ongoing Russian use of sUAS that is similar to previous conflicts. The absence of sUAS use by Russian forces as

[153] Cranny-Evans, "Russian Drones Are Playing a Major Role in the War Against Ukraine."

propaganda to justify pretexts for strikes, however, may indicate that the lack of reporting does indeed indicate reduced use.

Russian forces have experimented with swarming sUAS to perform strikes and reconnaissance, which may indicate an interest in using multiple sUAS for these applications in the future.[154] Russia has also experimented with autonomous sUAS. While the purpose of these sUAS is not clear, de-linked, fully autonomous systems would add little value to fire coordination or reconnaissance missions, which would still require a link with an artillery platform or a ground-based observer. Alternatively, autonomous systems could use a one-way link to transmit data back to a ground station without requiring control, which could enable reconnaissance or fire coordination while exposing the system to EW sensors. The relationship between sUAS employment purpose and emerging control technologies as described in literature is shown in Table 12.

Table 12. Russia Cross-Category Association: Emerging Technology-Purpose

Emerging Control Technology	Fire Coord	Propaganda	Recon	Strike	Not Stated
Autonomous					1
Swarm			1	1	1
Not Stated	4		2	1	1

Source: Created by author using cross tabulation analysis in Microsoft Access from coded study data.

[154] Hambling, "Russia Uses 'Swarm Of Drones' In Military Exercise For The First Time."

The complete set of coded data pertaining to Russian sUAS employment is shown below in can be found in Appendix A.

<u>China</u>. China is both a peer threat to the US and a major producer of commercial and military sUAS. Chinese manufacturers of sUAS command a significant market share of sUAS sold commercially.[155] Furthermore, Chinese-produced armed UAS have been extensively sold to governments in the Middle East.[156] The data analyzed, however, provide limited insight into how China will employ sUAS. As reflected in Figure 10, sources most frequently describe reconnaissance and strike capabilities. China employs a variety of sUAS types, and some sources do highlight an emphasis on multiple sUAS.

[155] Allen, *Understanding China's AI Strategy*.

[156] Milan and Tabrizi, "Armed, Unmanned, and in High Demand."

Event Type	Development	5	Battlespace Location	Close	2
	Assessment	1		Non-Contiguous	1
	Operational	0		Rear	0
Target	Fixed Site	0		Indeterminate	0
	Maneuver forces	1		Not Stated	3
	Air Defense	0	Type	Rotary-wing	3
	Artillery	0		Fixed-wing	1
	C2	0		Loitering Munition	1
	Sustainment	0		Not Stated	1
	Not Stated	5	Number	Multiple	2
Purpose	Reconnaissance	4		Single	0
	Strike	4		Indeterminate	0
	Fires Coordination	1		Not Stated	4
	Propaganda	0	Emerging Control Technology	Autonomous	2
	Indeterminate	0		Swarm	1
	Not Stated	0		Not Stated	3
Data consolidated and coded from 6 sources. *A single source may have multiple codes per category					

Figure 10. China sUAS Employment Overview

Source: Created by author using coded study data.

Most literature on Chinese sUAS activity describes or assesses a specific component of sUAS technology or employment and provides little context across codes. Descriptions of employment targets and battlespace locations are particularly ambiguous. Due to the inconclusive relationships between categories within Chinese sUAS employment descriptions, tables depicting these associations are omitted. This data can be found in Appendix A.

Literature does describe the efforts by China to integrate artificial intelligence and swarm technology into sUAS employment. These technologies may influence how China employs sUAS and could change the manner in which tactical formations need to perform C-sUAS operations. While these emerging technologies warrant deeper examination in future studies, the information analyzed for this study indicates that development of swarm technology supports the use of sUAS for reconnaissance and the development of autonomous sUAS supports use for strikes, as shown in Table 13.

Table 13. China Cross-Category Association: Emerging Technology-Purpose

Emerging Control Technology	Fire Coord	Propaganda	Recon	Strike	Not Stated
Autonomous			1	2	
Swarm			1		
Not Stated	1		2	2	

Source: Created by author using cross tabulation analysis in Microsoft Access from coded study data.

The complete set of coded data pertaining to Chinese sUAS employment can be found in Appendix A.

Cross-Case Analysis

Cross-Case Themes. Comparing sUAS employment across actors provides insight into overall trends regarding employment of sUAS and informs how sUAS will most likely be employed on a large-scale battlefield. Table 14 depicts the overall instances of codes across all cases. The following significant themes emerge in Cross-Case comparison as shown in Table 14:

1. sUAS are most likely to be employed in the close area of the targeted force.
2. sUAS are most likely to be employed in reconnaissance and strike roles.
3. sUAS employment targeting maneuver forces was most common where targets were explicitly stated

Table 14. Overall Instances of Data Codes by Category

	Total	VEO	N-Karbk	Russia	China
Battlespace Location					
Close	10	3	3	3	2
Rear Area	6	3	2	2	
Non-Contiguous	4	2		1	1
Indeterminate	3		2	1	
Not Stated	9	1	2	5	3
Target					
Maneuver Forces	13	4	5	4	1
Fixed Sites	7	4	2	1	
Air Defense	6		6		
Artillery	3		3	1	
C2 Nodes	1		1		
Sustainment	1		1		
Not Stated	11	1	1	6	5
Purpose					
Strike	19	7	7	2	4
Recon	16	5	4	4	4
Fire Coord	8		3	5	1
Propaganda	6	3	3		
Not Stated	4		2	3	
sUAS Type					
Fixed-wing	14	2	5	7	1
Loiter. Munition	8		6	2	1
Rotary-wing	4	2			3
Not Stated	9	3	3	2	1
Number of sUAS					
Multiple	10	3	2	3	2
Indeterminate	2	1		1	
Single	1			1	
Not Stated	17	3	7	6	4

Source: Created by author using coded study data.

sUAS employment in the close area featured significantly and most frequently in each case study. Targets in Nagorno-Karabakh were more varied than in the other cases, and sUAS employment against air defense featured prominently, something that was not present in other cases. Overall, sUAS employment targeting maneuver forces was most common where targets were explicitly stated. The use of sUAS for strike featured significantly in the Nagorno-Karabakh and VEO cases, to a lesser extent in the China case, and were less prominent in the Russia case. Use for reconnaissance was notable across all case studies and use for fires coordination was notable in the Russia and Nagorno-Karabakh cases. Fixed-wing sUAS were most described, followed by loitering munitions.

Across all purposes, most discussion of sUAS employment on Non-Contiguous battlefields is associated with VEOs. In close areas, information across all purposes is associated with multiple cases. Most information regarding employment in rear areas comes from recent conflicts, including the 2020 Nagorno-Karabakh conflict and the 2022 Russian operations in Ukraine. Comparisons of relationships between the purpose of sUAS employment and where they were employed by case is shown in Table 15. The following significant themes emerge in the Battlespace Location-Purpose comparison:

1. sUAS will conduct strikes and reconnaissance throughout the battlespace, but most frequently in the close area.
2. sUAS will coordinate fires in the close area and in the rear area.

Table 15. Cross-Case Comparison: Battlespace Location-Purpose

Battlespace Location	Purpose	TOTAL	VEO	Nagorno-Karabakh	Russia	China
Non-Contiguous	Fire Coord					
	Propaganda	1	1			
	Recon	3	2			1
	Strike	4	2		1	1
	Not Stated					
Close	Fire Coord	4		1	2	1
	Propaganda	4	2	2		
	Recon	7	2	2	2	1
	Strike	8	3	3	1	1
	Not Started					
Indeterminate	Fire Coord	1			1	
	Propaganda	1		1		
	Recon	1		1		
	Strike	2		2		
	Not Stated					
Rear Area	Fire Coord	3		2	1	
	Propaganda					
	Recon	4	2	1	1	
	Strike	5	3	2		
	Not Stated	1			1	
Not Stated	Fire Coord	2			2	
	Propaganda	1	1			
	Recon	5	1		2	2
	Strike	3	1			2
	Not Stated	4		2	2	

Source: Created by author using cross tabulation query in Microsoft Access.

Literature for each case describes sUAS employed in reconnaissance and strike capacities against the targets operating in the close area. This may reflect the simplicity of employing sUAS independently against nearby targets. Literature for the Russia, China, and Nagorno-Karabakh cases each describe sUAS use to coordinate fires in the close area. Sources in the Russia case also describe use against targets in the rear area.

Table 16 shows the frequency with which emerging control technologies appear in the Russia and China cases. Sources on both Russian and Chinese sUAS employment highlight emerging development of autonomous and swarm technologies. Both technologies appear in each case.

Table 16. Emerging Control Technologies by Case

Case	Autonomous	Swarm	Not Stated
China	2	1	3
Russia	1	2	8

Source: Created by author using cross tabulation query in Microsoft Access.

Descriptions of autonomous technology do not discuss the number of sUAS employed but do center on implementations in rotary-wing sUAS. This is consistent with emerging civilian technologies that enable rotary-wing sUAS to autonomously recognize human beings for search and rescue operations.[157] Descriptions of swarm sUAS employment are associated with multiple fixed-wing sUAS. Table 17 further shows relationships between these technologies and sUAS type in these cases.

[157] Lygouras et al., "Unsupervised Human Detection with an Embedded Vision System on a Fully Autonomous UAV for Search and Rescue Operations."

Table 17. Cross-Case Associations: sUAS Type-Quantity-Emerging Technology

sUAS Type	sUAS Quantity	Autonomous	Swarm
Fixed-wing	Multiple	1	3
Rotary-wing	Not Stated	2	

Source: Created by author using cross tabulation query in Microsoft Access.

Answer to Secondary Research Question #2: sUAS Employment Models

From these themes, the models for sUAS employment by adversaries on an MDO battlefield can be described to answer the final secondary research question: How will sUAS be employed by peer forces during high-intensity combat operations? Each integrates the themes above to describe relationships between coding categories and a model for *where* (battlespace location of sUAS employment) and *how* (type of sUAS employed, Number of sUAS employed) adversaries may employ sUAS on the battlefield, *what* (targets of sUAS employment) they will target, and *why* (purpose of sUAS employment) they will employ them. While most of these factors do appear in these models, data regarding the number of sUAS employed are ambiguous, and therefore not reflected on the models.

Model #1: sUAS reconnaissance. sUAS reconnaissance consists of enemy ground forces launching and using sUAS to observe friendly forces and inform operations in a similar manner to other ISR. The ease of operation of sUAS means ground forces can operate these systems and receive immediate information about US force positions that can inform their maneuver.[158] Case study themes identified indicate that this activity will

[158] Hambling, *Swarm Troopers*.

take place in the close and rear areas of U.S tactical forces, but sources describe activity in the close area more commonly. Propaganda closely relates to sUAS reconnaissance. The use of sUAS for propaganda is often functionally indistinguishable from that of reconnaissance, with nearly every case of propaganda use also described as reconnaissance. Intelligence, particularly video, collected by sUAS may not be used only for tactical purposes, but also turned into a weapon in the information space. Figure 11 shows the sUAS reconnaissance model employing a single sUAS with a direct link to ground forces.

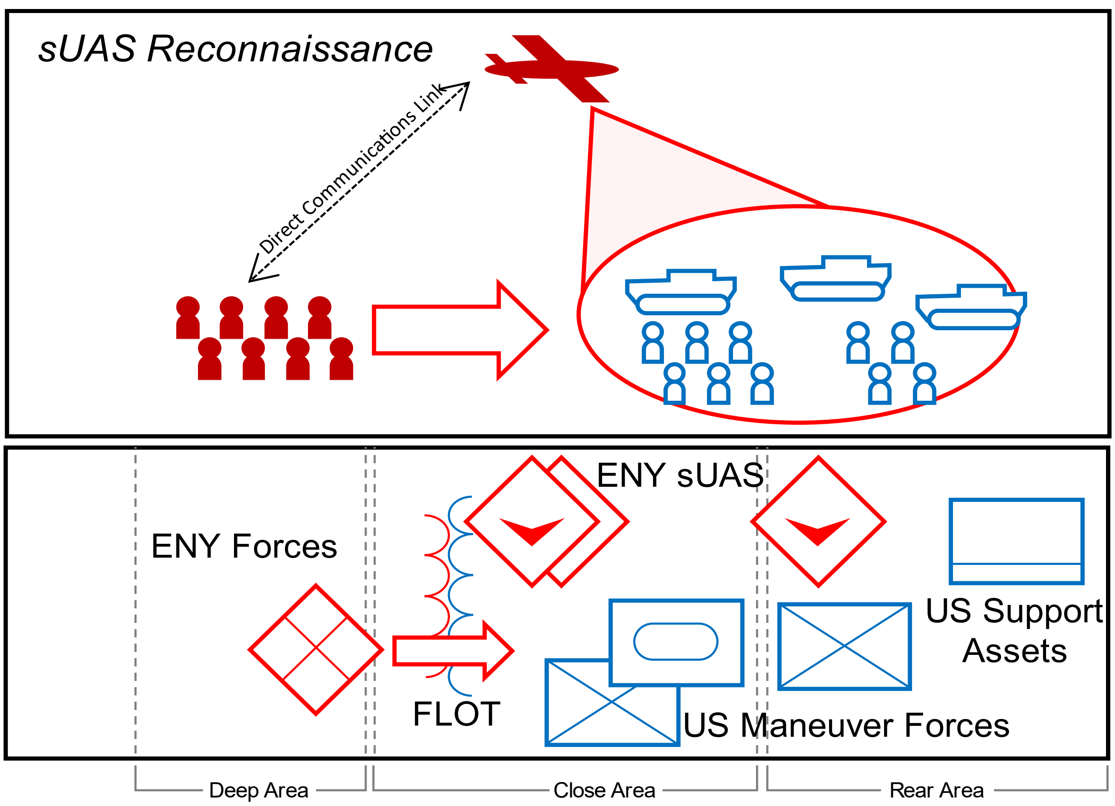

Figure 11. Depiction of sUAS Reconnaissance

Source: Created by author using symbols from Headquarters, Department of the Army, Field Manual 1-02.2, *Military Symbols* (Washington, DC: Army Publishing Directorate, 2020).

Model #2: sUAS-Fires Integration. sUAS integration with fires capabilities figures most prominently in Russia's sUAS employment but is a common thread throughout the cases identified. Employing sUAS in support of kinetic effects through traditional fires capabilities, as shown in Figure 12, is a simple way to incorporate these systems into combat operations, and when integrated into fires C2 architecture serves as an extremely responsive targeting asset. Literature historically describes this activity more frequently in the close area, but sUAS have been used to coordinate deep fires into the rear area in some of the most recent reporting, and the relationship between sUAS fires coordination and location of employment is ambiguous. The use of sUAS for fire coordination does not negate or otherwise impact the utility of counterfire.

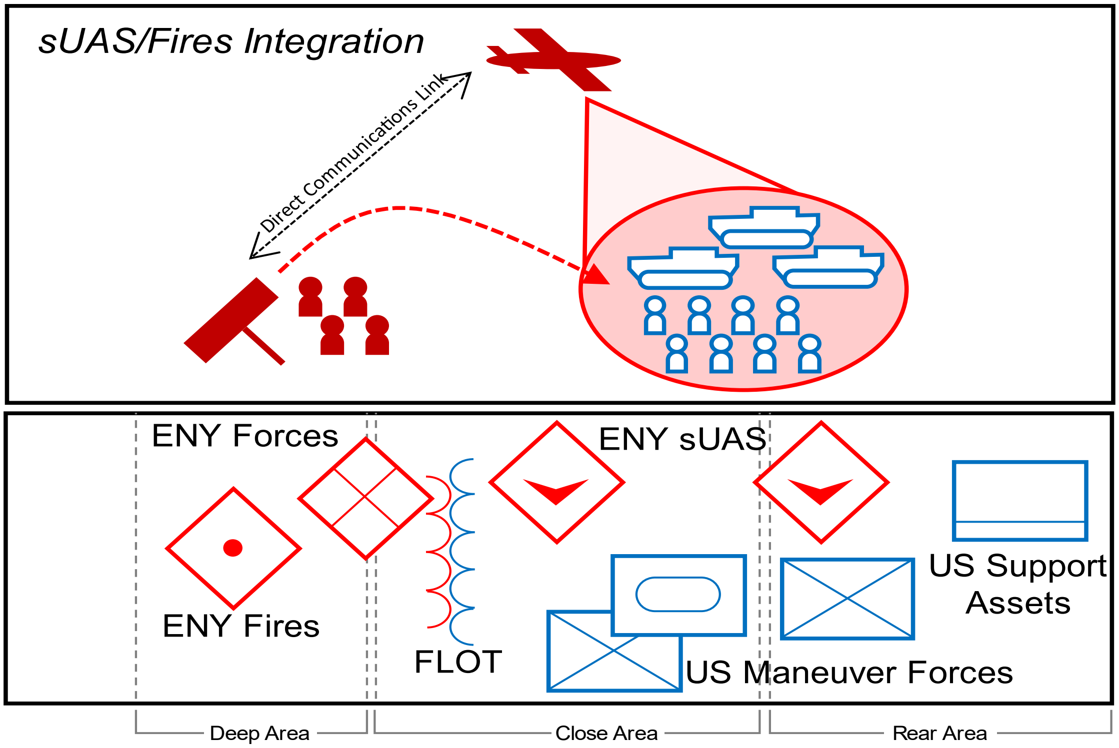

Figure 12. Depiction of sUAS/Fires Integration

Source: Created by author using symbols from Headquarters, Department of the Army, Field Manual 1-02.2, *Military Symbols* (Washington, DC: Army Publishing Directorate, 2020).

Integration of swarm technology, or simply a network of multiple sUAS with peer-to-peer links could enable this model further.[159] By putting multiple sUAS above US forces, adversaries can observe a greater area, provide redundancy of observation, and potentially extend the range of sUAS communications. This capability could be enabled with simple sUAS-to-sUAS link technology, even without the advanced enabling AI technology typically associated with sUAS swarms. Both China and Russia have

[159] Hambling, "Russia Uses 'Swarm Of Drones' In Military Exercise For The First Time."

demonstrated the ability to employ this type of link in exercises and continue to pursue its development.[160]

Model #3: sUAS Strike. Strikes are the most frequent type of sUAS employment described in literature, and are viable across the tactical battlespace, likely targeting maneuver forces. As shown in Figure 13, sUAS strikes involve the use of an sUAS to drop munitions on targets or sUAS piloted into targets to deliver a munition (a technique frequently associated with loitering munitions). As seen in Nagorno-Karabakh, other critical assets such as air defenses, C2 nodes, and lines of communication may be targeted as well. Piloted sUAS rely on a control link with a ground control station.[161] Advances in fully autonomous systems, such as those in development by China, could identify and engage targets without the need for human control.[162]

[160] Hambling, "If Drone Swarms Are the Future, China May Be Winning,"; Bendett, "Strength in Numbers."

[161] DHS Science and Technology Directorate, "Questions to Ask When Researching Counter Unmanned Aircraft Systems."

[162] Lygouras et al., "Unsupervised Human Detection with an Embedded Vision System on a Fully Autonomous UAV for Search and Rescue Operations,"; Allen, *Understanding China's AI Strategy*.

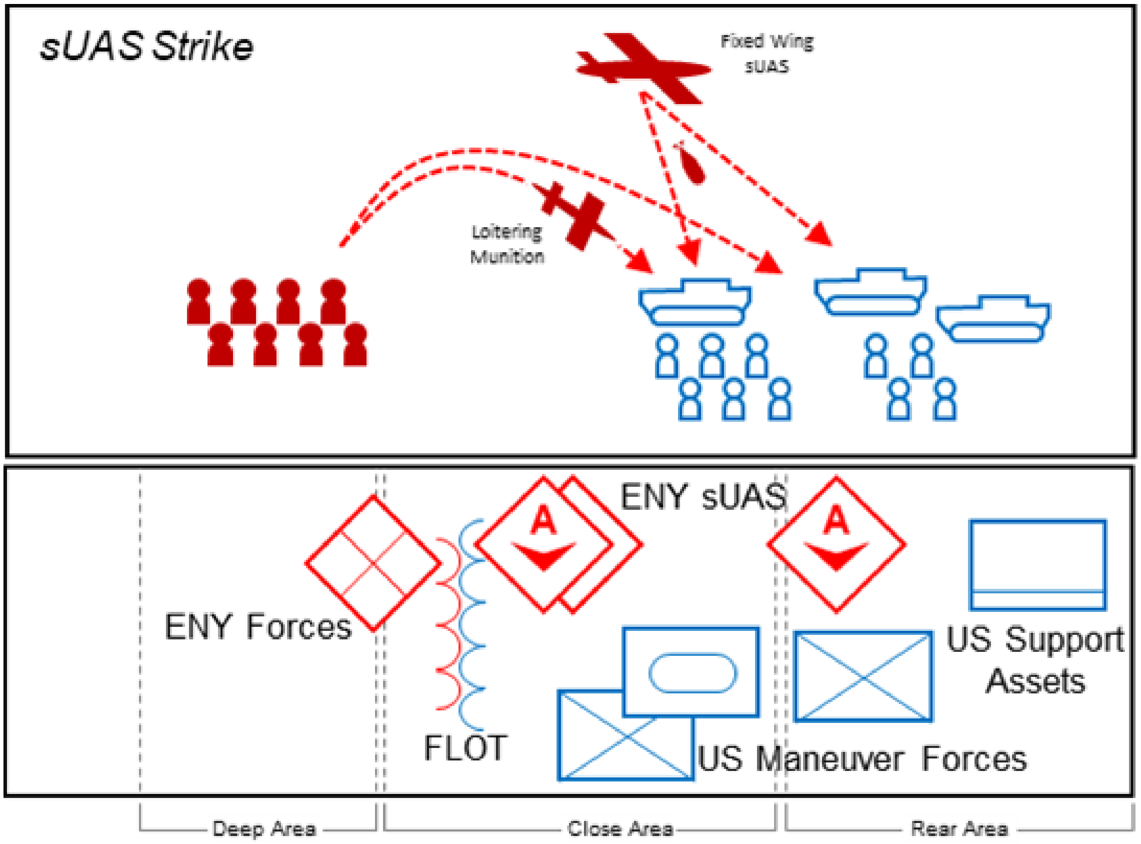

Figure 13. Depiction of sUAS Strike

Source: Created by author using symbols from Headquarters, Department of the Army, Field Manual 1-02.2, *Military Symbols* (Washington, DC: Army Publishing Directorate, 2020).

DOTMLPF-P

DOTMLPF-P analysis will be driven by identifying how the domains of DOTMLPF-P best align with the solution parameters already identified: assets and areas which tactical formations must protect against sUAS, and the manner in which sUAS must be defeated. First, Table 18 below revisits the solution parameters and the threat information that informs each.

Table 18. Threat Information and Solution Parameters

THREAT INFO (CODES)	SOLUTION PARAMETERS
Targets of sUAS employment Purpose of sUAS employment	Assets which tactical formations must protect against sUAS
Battlespace location of sUAS employment	Areas tactical formation must protect against sUAS
Type of sUAS employed Number of sUAS employed	Manner in which sUAS must be defeated

Source: Created by author.

Two aspects of sUAS employment models must be considered when determining which DOTMLPF-P domains to use. First, the battlefield framework employment of these systems requires examination, as does their purpose and target. This informs which assets in which part of the battlefield tactical formations must protect against sUAS. In this case, models depict sUAS employment in the close area with adversaries likely to employ sUAS for strike, reconnaissance, and fire coordination, and to a lesser extent in the rear area. Models further depict sUAS most likely employed against maneuver forces.

Second, emerging technologies that will influence control of these systems must be considered, namely autonomous sUAS employment and swarm sUAS employment. Control mechanisms can heavily influence what weapon system impacts an sUAS the most. An autonomously guided loitering munition could frustrate an electromagnetic warfare effect designed to jam a communications link, necessitating the use of other assets, such as direct fire weapons. On the other hand, electromagnetic warfare measures could be highly effective against swarming sUAS relying heavily on system-to-system communications, even as the large numbers of sUAS deplete on-hand munitions.[163]

The assets a tactical formation must protect against sUAS determine what effects are required and how those effects must be employed. The areas tactical formations must protect against sUAS, or more specifically, where a tactical formation must protect its assets within the deep-close-rear battlefield framework, determine where those effects must be employed. The manner in which sUAS must be defeated determines what types of effects and elements tactical forces must use. Figure 14 shows how DOTMLPF-P domains apply to these parameters of the required solution.

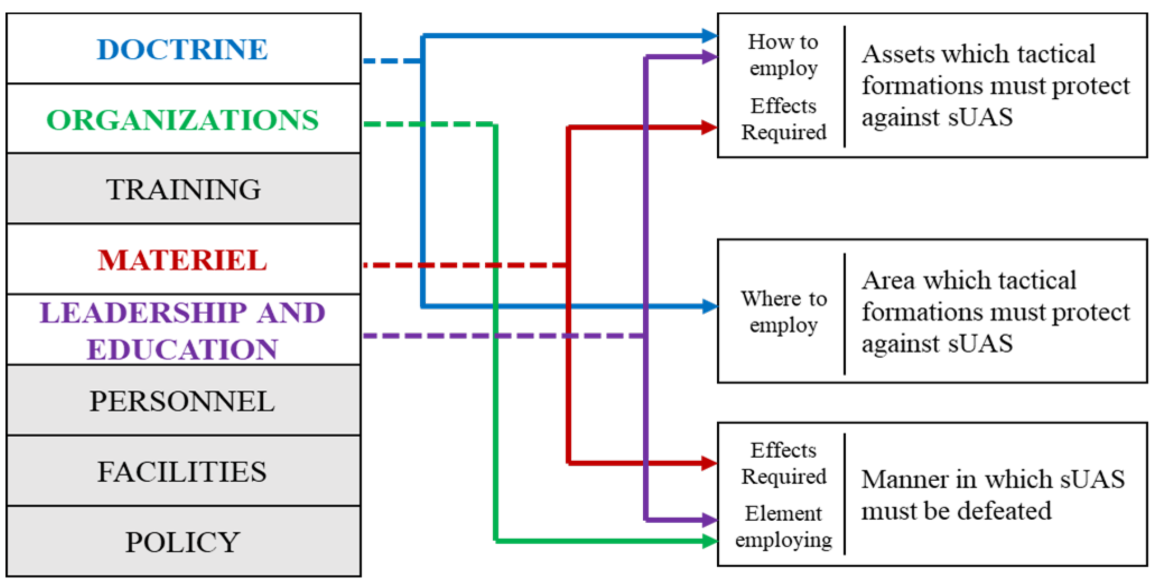

Figure 14. DOTMLPF-P Domains and Solution Parameters

Source: Created by author.

[163] Guelfi et al., "The Imperative for the US Military to Develop a Counter- UAS Strategy."

Materiel provides the effects required. Organizations are the elements that employ these effects. Doctrine describes where and how these effects must be employed. Leadership and Education prepares the personnel to lead elements and ensure they properly employ effects. These are the DOTMLPF-P domains through which the primary research question will be answered: What capabilities do tactical formations need to conduct counter-sUAS operations in high-intensity Multi-Domain Operations?

Materiel. Materiel provides the foundational capability for effects against sUAS. Literature describes two major methods for defeating sUAS: kinetic (or direct fire) and non-kinetic (or electromagnetic warfare) means.[164] Electromagnetic warfare techniques can exploit the link between an sUAS and the ground station controlling it. Employment models that rely heavily on signals emitted from an sUAS may be particularly vulnerable to EW effects. sUAS used for reconnaissance or used to coordinate fires must transmit large amounts of data over radio waves which makes them easier to detect and identify. Swarm sUAS implementations, which rely on communications with adjacent drones, may likewise be highly susceptible to electromagnetic warfare. Additionally, unlike kinetic countermeasures which consume finite ammunition, EW countermeasures can be repeatedly employed against successive or simultaneous targets. The majority of C-sUAS countermeasures are electromagnetic warfare systems, however, these have not been widely fielded to tactical units.

Kinetic countermeasures, or more precisely, direct-fire countermeasures, may be more suitable when simply breaking a communications link is insufficient. Loitering

[164] Sayler, "Department of Defense Counter-Unmanned Aircraft Systems,"; Keller, "The Army Is Officially Adding Missile-Hauling Strykers to Its Arsenal."

munitions may require this response. If a loitering munition has entered terminal approach and no longer requires navigation toward its target, it may detonate even if a control link is broken. Similarly, fully autonomous systems may require no communications link at all to prosecute targets, reducing opportunities for electromagnetic warfare attacks. The M-SHORAD provides an overall, kinetic short-range capability against UAS, but the Directed Energy variant provides a capability tailored specifically to sUAS.

The literature favors a layered approach, involving electromagnetic warfare and kinetic capabilities.[165] The Joint C-sUAS Office (JCO) has largely pursued acquisition of electromagnetic warfare systems for fielding to tactical units.[166] Efforts to align Maneuver-Short Range Air Defense Battalions with tactical formations, on the other hand, provide a kinetic short-range air defense capability.[167] As previously stated, M-SHORAD does not provide an optimal C-sUAS capability, which has necessitated the development of Directed Energy variants of the system that are more capable of engaging group 2 and below sUAS.[168]

<u>Organizations</u>. Even once materiel solutions are identified, limited C-sUAS-focused units exist at the tactical level. The army is building tactical air defense and

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[165] Haider, "A Comprehensive Approach to Countering Unmanned Aircraft Systems | And Why Current Initiatives Fall Short."

[166] Army Public Affairs, "Army Announces Selection of Interim C-SUAS Systems."

[167] Sheftick, "Army Rebuilding Short-Range Air Defense."

[168] DOD, *DOD FY 2021 Budget Estimates*.

electromagnetic warfare formations, but these formations are currently incompletely fielded.[169] As described in the literature, every BCT is allocated an EW platoon with three EW teams. These formations are in BCT MI companies and are not integrated into air defense processes or systems. As described in literature, the Army is also fielding divisionally aligned M-SHORAD battalions. In addition, to the base M-SHORAD platform capable of kinetically engaging UAS, each M-SHORAD battery will, ultimately, have one platoon armed with M-SHORAD directed-energy capabilities specifically designed to target the smallest group 1-2 UAS. [170]

US Tactical formations must be capable of controlling significant battlespace, and threat models indicate sUAS can operate throughout much of that battlespace. Doctrinally in large scale ground combat operations, a US Army division close area can cover over 100 square miles.[171] This study did not find sufficient data to pinpoint where enemy forces will employ specific sUAS effects. However, the data did indicate that overall sUAS employment is most likely in the close area against maneuver forces.

<u>Doctrine</u>. Even once appropriately equipped, tactical formations must still employ C-sUAS capabilities at the right place and time to stop sUAS attacks and defend critical assets. Despite assessed shortfalls of Army C-sUAS doctrine, the sUAS threat as described in Army Doctrine is consistent with the information in this study. Doctrine

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[169] Szoldra, "Army Fires New Missile-Hauling Stryker for the First Time in Europe."

[170] Feickert, *U. S. Army Short-Range Air Defense Force Structure and Selected Programs*, 4.

[171] HQDA, FM 3-94.

recognizes the potential use of sUAS for strikes, reconnaissance, and fire coordination against tactical formations, and identifies a wide range of targets including air defenses, maneuver forces and support nodes.[172] It describes swarm and autonomous sUAS, but only in terms of threat capability.[173]

Doctrine generally does not describe responsibility for C-sUAS in terms of a battlefield framework, but it does define BCT Air Defense and Airspace Management (ADAM) cells as the tactical-level integrating elements for air defense, including C-sUAS.[174] ADAM Cells do not have organic ADA assets, nor does the rest of a BCT.[175] In some cases, C-sUAS capabilities may not even be traditional air defense capabilities, falling under electromagnetic warfare instead.[176] Despite precedent in doctrine for limited air defense control from supported units, current doctrine on air defense engagement control authority leaves ambiguity in terms of authority for maneuver headquarters supported by C-sUAS capable air defense units.[177] Engagement authority for sUAS can be doctrinally delegated all the way to the team leader level, but still is delegated from the Area Air Defense Commander and vested through the Air Defense Task Force chain of command to air defense units conducting C-sUAS operations in support of tactical

[172] HQDA, ATP 3-01.8, 1-8.

[173] Ibid., 3-12.

[174] HQDA, FM 3-01.

[175] Ibid.

[176] DOD, *Counter-Small Unmanned Aircraft Systems Strategy*.

[177] HQDA, FM 3-01, 9-4.

units.[178] Doctrine also provides air defense employment principles (mass, mix, mobility, flexibility, integration, and agility) and tenets (mutual support, overlapping fires , balanced fires, and weighted coverage) for developing air defense designs.

Cyber and EW doctrine, on the other hand, only tangentially addresses C-sUAS operations, despite the central role of EW-based C-sUAS systems and the extensive use of the EMS to enable sUAS. Cyber and EW doctrine acknowledges the use of defensive electromagnetic attack to counter UAS and identifies electromagnetic warfare technicians in CEMA cells to support protection planners when these systems are used. This guidance, however, is cursory and provides no detail into what planning support CEMA cells should provide, who should employ these systems, or the role of EW platoons in C-sUAS.

Leadership and Education. Because sUAS operate in a more distributed manner than traditional air threats and require different countermeasures, both air defense and electromagnetic warfare principles must be considered. Additionally, the challenges of sUAS detection previously discussed, and the distributed nature of their employment reflected in the threat require different skills than traditional electromagnetic warfare or air defense tasks.

Because of the emerging nature of the C-sUAS mission set, electromagnetic warfare, air defense, and traditional maneuver force leaders lack specific education in planning and integrating C-sUAS operations at the tactical level. The removal of divisionally aligned SHORAD battalions in the mid-2000s means current air defense

[178] HQDA, FM 3-01, 9-4.

leaders possess limited experience in conducting short-range air defense operations in support of tactical operations, and maneuver leaders possess limited experience in integrating air defense capabilities. Likewise, the dearth of emphasis on C-sUAS in cyber and EW doctrine as previously described means that EW leaders are not formally equipped to conduct C-sUAS. The JCO recognizes a gap in C-sUAS knowledge and intends to move C-sUAS training to Fort Sill and establish a Joint C-sUAS academy by 2024.[179]

Summary

This chapter examined the manner in which sUAS could be employed by adversaries and the extent to which Army formations are prepared to counter this threat. Contemporary use of sUAS by VEOs and in the Nagorno-Karabakh conflict consisted of diverse sUAS types, but in both cases, actors used sUAS for strike and reconnaissance against maneuver forces across the battlespace. Examination of Russian and Chinese sUAS employment and development, along with comparisons across all cases further revealed that peer forces will likely employ sUAS to coordinate fires, conduct strikes and perform reconnaissance in the close and rear areas, predominantly against maneuver forces. Advancements in swarm and artificial intelligence technologies will likely amplify these effects.

This chapter developed models for sUAS employment for fires, strikes and reconnaissance on an MDO battlefield to describe the threat toward friendly forces. The

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[179] Suits, "Joint Counter-SUAS Strategy to Address Need for Improved Technology."

nature of the sUAS threat on the battlefield means solutions will emphasize particular DOTMLPF-P domains, which were each aligned with solution parameters to identify specific domains for analysis. This chapter then examined how four domains of DOTMLPF-P, Material, Organizations, Doctrine, and Leadership and Education, currently address this threat. The final chapter, "Conclusions and Recommendations" will recommend solutions and attempt to answer the primary research question of this study.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Introduction

This study has examined the use of sUAS on a large-scale, multi-domain battlefield. By examining how VEOs employed sUAS in the CETCOM AOR and the way that Azerbaijan employed sUAS in the Nagorno-Karabakh war, this study addressed how sUAS have been employed in contemporary operations. By examining Russian and Chinese sUAS use, as well as sUAS testing and development, this study established a basis for cross-case comparison and identified how a peer threat might employ sUAS in large scale operations. These were developed into Employment Models to demonstrate what an sUAS threat might look like on the battlefield. This study then applied DOTMLPF-P to identify shortfalls in tactical formations' ability to counter these threats. Four primary recommendations resulted, each covering multiple DOTMLPF-P domains: the use of Brigades as the foundational tactical C-sUAS unit, use of BCT EW platoons as C-sUAS elements, employment of M-SHORAD forces by tactical Brigades and delineation of tactical C-sUAS responsibilities by echelon. This chapter draws conclusions and makes recommendations to best enable C-sUAS operations at the tactical level on a high-intensity MDO battlefield.

Recommendations

This section will propose solutions to mitigate the sUAS threat on an MDO battlefield and answer this study's primary research question: What capabilities do tactical formations need to conduct counter-sUAS operations in high-intensity Multi-Domain Operations?

BCTs as the Tactical Building Block for Synchronizing C-sUAS. The BCT should be considered the foundational element for tactical C-sUAS operations. Doctrine defines the air defense principle of integration as combining "ADA and other joint counterair forces, systems, functions, processes, and information acquisition and distribution required to efficiently and effectively perform the mission."[180] Because the preponderance of sUAS activity occurs in the division close area, centering C-sUAS operations on the BCT and appropriately organizing ADAM cells allows integration to occur where the sUAS fight is most likely to take place. This section makes two primary recommendations: first, doctrinally define BCTs as the C-sUAS unit of action at the tactical level, and vest C-sUAS engagement authority in BCT commanders; second, provide ADAM cells with sufficient expertise to synchronize the C-sUAS fight. Implementing these recommendations requires changes to the Doctrine and Organization DOTMLPF-P domains.

Doctrine. The analysis in Chapter 4 shows that the preponderance of sUAS employment will be targeted against Maneuver Forces operating in the close area. BCTs are the headquarters most appropriate to manage the tactical C-sUAS fight. BCTs have not traditionally played a significant role in managing and employing air defense assets. Furthermore, although C-sUAS is an air defense role, doctrine must define the role of

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[180] HQDA, FM 3-01, 1-5.

electromagnetic warfare systems and practitioners in conducting tactical C-sUAS operations.

Doctrine should define tactical, maneuver commanders as the authority for all types of C-sUAS engagement within their area of operations. Engagement authority for sUAS can be still doctrinally delegated all the way to the team leader level but should be vested in BCT commanders instead of the air defense chain of command.[181] BCT commanders can then delegate that authority to subordinate elements, specifically the BCT artillery or maneuver battalion commanders. The low altitude of sUAS, their targeting of maneuver forces, and the predominance of activity in the close area as described in this study's threat employment models ties C-sUAS closely to the maneuver fight. Furthermore, with both EW and air defense forces capable of C-sUAS effects within a maneuver commander's area of operations, placing engagement authority within the BCT allows commanders to determine which effects are most appropriate and how to layer them.

Organization. At the BCT level, ADAM cells, serving as an integrating cell for C-sUAS, require additional resources. Although ADAM cells have a small number of air defense personnel, they are part of the Brigade Aviation Element (BAE) and have the appropriate integration into the friendly aviation plan to ensure deconfliction and prevent fratricide. [182] ADAM cells do, however, require augmentation with EW expertise and with liaisons from any attached M-SHORAD assets. At the BCT level, a Cyber-

[181] HQDA, FM 3-01, 9-4.

[182] Ibid., 10-3.

Electromagnetic Warfare Officer (CEWO) from the BCT CEMA cell should be assigned to the ADAM/BAE cell and provide EW expertise for C-sUAS operations. This officer would serve as the subject matter expert for targeting sUAS communications and PNT links with EW-based C-sUAS systems and would support EMS site selection and EW system payload coordination tasks. While this reduces the strength of a BCT CEMA cell, it also clarifies responsibilities and keeps the BCT CEMA cell and primary CEWO focused on traditional EW and cyber mission sets.

When allocated an M-SHORAD battery, the battery headquarters should integrate into the ADAM cell and serve as the C2 node for the subordinate platoons, whether they are retained by the BCT or allocated to subordinate Battalions. When attached, the battery commander serves as the senior air defense advisor to the BCT commander and takes the central role in coordinating the BCT's C-sUAS operations, while the ADAM cell supports and integrates C-sUAS operations with the larger air picture. The battery commander, supported by the BCT air defense leaders, should advise the BCT commander regarding the appropriate delegation of authority. If the BCT chooses not to delegate engagement authority to subordinate maneuver battalions supported by M-SHORAD platoons or teams, the battery headquarters can form an Engagement Operations Center for the subordinate platoons augmented by ADAM cell personnel.

The ADAM cell (with the addition of a CEWO) and the battery headquarters would produce the BCT's air defense design using air defense employment principles and tenets and provide guidance for the employment of M-SHORAD and EW assets by subordinate elements in support of that design. This would allow the design to use EW and air defense assets to balance appropriate mass and mix of C-sUAS to weight coverage along anticipated avenues of sUAS approach while retaining the mobility required to support maneuver units. Commanders could further define relationships between M-SHORAD platoons and the supported maneuver units to provide flexibility and agility commensurate the assessed threat and the size of the area of operations.

The BCT EW Platoon as a C-sUAS Element. Electromagnetic warfare platoons should be viewed as a C-sUAS element in tactical operations. Doctrine describes the air defense principle of mix as the "combination of weapons and sensors to protect the force and assets from the threat."[183] Electronic warfare assets provide mix when employed with traditional air defense assets by offering non-kinetic measures to mitigate sUAS when direct-fire engagement is ineffective or untenable. They also provide a distinct method for sUAS detection to corroborate or complement RADAR, optical sensors, and other traditional air defense detection systems. This section makes three primary recommendations: equip EW formations with C-sUAS equipment and develop future EW systems to be C-sUAS capable; doctrinally designate C-sUAS as a secondary mission for EW platoons; and educate EW leaders on C-sUAS at Professional Military Education (PME) and at qualification courses. Using EW platoons in this capacity requires changes in the DOTMLPF-P domains of materiel, doctrine, and leadership and education.

Materiel. Since electromagnetic warfare measures can be used repeatedly without resupplying ammunition and the majority of sUAS activity occurs in the close area, EW C-sUAS assets should be forward postured with BCTs. EW systems are likely to be more effective against the links between sUAS and fires assets, and less effective against

[183] HQDA, FM 3-01, 10-3.

autonomous sUAS conducting strikes. BCTs are already allocated EW platoons which perform reconnaissance and offensive operations in the EMS.[184] Each platoon should be equipped with EW-based C-sUAS systems, such as the FS-LIDS, NINJA, and CORIAN down-selected by the JCO, and where appropriate employ organic EW assets in support of C-sUAS missions. Organic EW equipment designed to perform flexible communications or Position, Navigation and Timing (PNT) denial can perform those functions for C-sUAS as well. That said, developers should design tactical EW systems with C-sUAS employments in mind. The key performance parameters of these systems should include the ability to interface with the FAAD C2 air defense networks and the ability to fire targeted cyber payloads against known adversary sUAS systems.[185] For EW systems already developed, software or hardware modules could serve to retrofit these capabilities.

Doctrine. Dominating the EMS is a core competency of EW Soldiers. Since the preponderance of C-sUAS equipment is based on Electronic Warfare technology, the soldiers in EW platoons are already the de facto C-sUAS practitioners in BCTs. The use of EW platoons for C-sUAS may present decisions for BCT commanders to forego other employment of EW capabilities to use EW platoons in a protection role. It is important to acknowledge that EW platoons are not a dedicated C-sUAS asset and that using them in a cross-functional manner in combat will reduce their ability to perform traditional EW missions. But the ability to use EW platoons in a C-sUAS role offers tactical options to a

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[184] Pomerleau, “Army Shares Details on New Electronic Warfare Units.”

[185] Eric Rowland, “F100 Case Study,” (unpublished coursework, US Army Command and General Staff College, 2021).

BCT Commander. The three EW teams within an EW platoon allow commanders to allocate resources to multiple missions and locations. Attaching an EW platoon to a Battalion to provide C-sUAS protection provides a C-sUAS capability with low coordination requirements and a low risk of fratricide. Jamming frequencies does not create the same level of risk that uncoordinated kinetic fires would present. Deconflicting jamming frequencies can be performed from the published Joint Restricted Frequency Lists (JRFL) and does not require airspace deconfliction through the BCT ADAM cell. When an EW team is attached to a battalion headquarters, Jam Control Authority (JCA) should be delegated to the Battalion level to allow rapid and responsive mitigation of sUAS threats.

The deliberate use of dedicated EW forces for C-sUAS represents a significant departure from existing doctrine and should be captured in future C-sUAS, air defense and cyber doctrine. Cyber and EW doctrine and air defense doctrine should both designate EW platoons as the organic unit of action for C-sUAS within a BCT, and cyber and EW doctrine should recognize C-sUAS as a key secondary mission for EW soldiers in BCTs. The rise of autonomous and swarm technologies may require unique cyber and EW solutions and support, and countering remotely or autonomously controlled systems through the EMS with EW or cyber effects should be a core cyber mission. Deliberate integration of Cyber-Electromagnetic Activities (CEMA) personnel is essential to determining what countermeasures are available and how they should be employed.

Leadership and Education. C-sUAS presents a different set of challenges than either air defense or electromagnetic warfare. Leaders in the air defense and electromagnetic warfare communities need training to understand how to apply these affects and lead these formations. Specifically, this training should include training on air defense design, air defense principles, M-SHORAD capabilities, and site selection for electromagnetic warfare enabled air defense systems. The Cyber Advanced Leaders Course (ALC) at Fort Gordon provides an opportunity to train mid-level 17E Electromagnetic Warfare Non-Commissioned Officers (NCOs) in C-sUAS principles. However, EW NCOs may not attend ALC prior to assuming a team leader position and must be sufficiently familiar with C-sUAS to operate independently. EW team leaders should attend the JCO's Joint C-sUAS academy to receive the multidisciplinary education required to be effective as C-sUAS leaders. Cyber officers should receive this training when designated as 17B Cyber-Electromagnetic Warfare Officers (CEWO) during an addition to the Electromagnetic Warfare Qualification Course (EWQC) received prior to assignment as EW platoon leaders or BCT CEWOs.

Direct-fire C-sUAS Support from M-SHORAD Battalions. The complexity and lethality of sUAS mean tactical units, specifically divisions, require short range air defense capabilities. Kinetic C-sUAS countermeasures can decisively stop sUAS strikes likely to occur throughout the battlespace and placing these assets at the division level allows flexibility and tailored protection. The M-SHORAD program is appropriate for this role if the Army continues to invest in it as a divisionally aligned C-sUAS capability. Doctrine defines the air defense principle of mass as a "concentration of combat power sufficient to achieve the commander's intent."[186] Aligning M-SHORAD batteries with BCTs provides commanders with significant C-sUAS combat power and the opportunity

[186] HQDA, FM 3-01, 1-5.

to mass those capabilities. This section makes three primary recommendations: emphasize development of the M-SHORAD platform capabilities against group 1-2 sUAS; organize M-SHORAD DE platforms into regular M-SHORAD platoons instead of separate platoons; doctrinally define an association between M-SHORAD batteries and BCTs in large-scale combat operations, with ADAM cells serving as integrating cells; provide comprehensive education on C-sUAS and M-SHORAD operations at air defense PME. This section also supports the army's stated intent of aligning M-SHORAD battalions to divisions and recommends that any additional M-SHORAD battalions allocated to higher headquarters be in addition to, not in place of divisionally aligned battalions. These recommendations will require efforts in the materiel, organization, doctrine, and leadership and education DOTMLPF-P domains.

Materiel. The Army should sustain the stated intent to create M-SHORAD battalions in divisions, field a full complement of M-SHORAD DE capabilities within these battalions, and ensure the viability of the M-SHORAD platform against sUAS. The Army will equip specifically C-sUAS capabilities (M-SHORAD DE) at a limited scale. Currently, only one platoon in each battery will be equipped with M-SHORAD DE since M-SHORAD battalions must be capable of engaging a range of threats beyond sUAS, including rotary-wing aircraft and larger, more traditional fixed-wing UAS.[187] The kinetic capabilities of the M-SHORAD may in some cases be poorly aligned to engaging sUAS due to the cost of munitions relative to the value of the target, but future development of this platform must maximize tactical capabilities against all sUAS. The

[187] DOD, *DOD FY 2021 Budget Estimates*.

design of the M-SHORAD must incorporate capabilities to detect and defeat Group 1-2 sUAS. In these cases, tactical commanders must make deliberate decisions about the conditions under which to employ limited munitions against an sUAS threat.

Organizations. As a mobile element that can attach forces to subordinate brigades, divisionally aligned M-SHORAD battalions are well postured to protect the maneuver forces that are most frequently the targets of sUAS. The Army is pursuing divisional alignment of M-SHORAD battalions, however, to date, only one M-SHORAD battalion has been created and that battalion is not divisionally aligned.[188] The Army should assign an M-SHORAD battalion to every division. This is consistent with the original plans for M-SHORAD, but not consistent with the allocation of M-SHORAD units so far which have been designated to higher echelons.[189] Scope creep, funding shortfalls and lack of vision could derail the effectiveness of M-SHORAD C-sUAS support if the sUAS threat to tactical formations is not kept central as the force is modernized. Assigning M-SHORAD battalions to divisions allows M-SHORAD batteries to habitually associate with each subordinate brigade and to conduct training with the BCT ADAM cells to ensure interoperability and effective processes. As the army allocates M-SHORAD battalions to headquarters outside divisions, those battalions should not detract from the intent to field divisionally aligned M-SHORAD battalions that can provide support to BCTs.

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[188] Szoldra, "Army Fires New Missile-Hauling Stryker for the First Time in Europe."

[189] Feickert, *U. S. Army Short-Range Air Defense Force Structure and Selected Programs*, 4.

Additionally, when the Army fields M-SHORAD DE (which provides greater capability against Group 1-2 sUAS), rather than replacing a regular M-SHORAD platoon with DE vehicles, these systems should instead be spread through the existing platoons and replace a platform in each. This provides consistency to supported commanders in the capabilities provided, better accounts for the broad range of possible sUAS threats of various types and groups and provides a mix of capabilities within each platoon.

Doctrine. M-SHORAD batteries and platoons should be attached to brigades in the close and rear areas to support the maneuver plan and protect assets identified on the defended asset list (DAL) or priority protection list (PPL). Tactical formations must task-organize individual M-SHORAD elements at a level where the controlling staff can appropriately and rapidly support airspace deconfliction and commanders can impose effective control measures to prevent fratricide. The BCT, with ADAM cells designed to deconflict airspace, provides appropriate capability. Divisions should establish habitual relationships between M-SHORAD batteries and BCTs, with batteries and BCT ADAM cells training together to ensure rapid clearance for fires. Where support is required in the rear area, a platoon (or a battery if necessary) should be allocated to the formation responsible for the rear area, whether it is a BCT or a maneuver enhancement brigade (MEB). Since the ADAM cell in a maneuver enhancement brigade is small, personnel from the M-SHORAD battalion operations section should augment or replace this cell when an M-SHORAD battery is allocated to a MEB.

Where M-SHORAD capabilities are required in support of battalion operations, they should be provided to the supported battalion while the BCT ADAM cell still supports employment planning and air deconfliction. Authority to dictate where C-sUAS direct-fire engagement authority lies should rest with the supported BCT commander, advised by the brigade aviation officer (BAO) and air defense officer. In a restrictive environment with complex airspace where friendly aircraft could be easily mistaken for enemy sUAS, commanders may choose only to delegate engagement authority to the M-SHORAD battery headquarters, which, supported by the BCT ADAM cell, would form an EOC. In a more permissive environment, BCT commanders could delegate authority to the platoon or team level through their supported maneuver battalion headquarters.

Leadership and Education. Air defense leaders require C-sUAS specific education. This includes leaders in the M-SHORAD battalion, as well as planners on division and brigade staffs and ADAM cells. The return of air defense formations to divisions opens new opportunities for leadership development amongst air defense personnel on division and brigade staffs, and eventually, although it will take some time to become possible, personnel should complete assignments at M-SHORAD battalions prior to serving in an ADAM cell. This provides the appropriate knowledge regarding M-SHORAD and C-sUAS operations prior to serving as a key tactical integrator of these capabilities. Divisionally aligning M-SHOARD battalions, rather than allocating M-SHORAD battalions to other headquarters, enables this organic expertise development. Furthermore, air defense leaders require education on the sUAS threat and the basic principles of countering them with EW capabilities. Professional Military Education (PME) provides the best opportunity to conduct this training. For enlisted 14G and 14P air defense leaders, the Advanced Leaders Course at Fort Sill provides an opportunity to educate mid-level NCOs. For commissioned air defense leaders, the air defense Basic Officer Leader’s Course and Captain’s Career Course provides an opportunity to similarly educate company grade officers. The planned proximity of the Joint C-sUAS Academy, projected to move to Fort Sill in 2024, would facilitate this training. This education should familiarize leaders with the way sUAS employ the EMS for PNT and C2, basic concepts of jamming and radio wave propagation, and electromagnetic warfare site selection. It should also cover the manner in which M-SHORAD formations should conduct direct-fire C-sUAS operations and familiarize leaders with sUAS flight profiles and recognition. Conducting this training during air defense PME at Fort Sill ensures M-SHORAD battery leadership from the NCOs to the company commander receive this education, as well as air defense planners and ADAM cell personnel at the division and brigade level.

Delineation of C-sUAS Responsibilities by Echelon. Finally, C-sUAS responsibilities must be clearly delineated for tactical formations, requiring changes to the Doctrine DOTMLPF-P domain. Doctrine should define the role of a BCT as the controlling headquarters for C-sUAS operations, with the role of the division as one of planning, prioritization, and asset allocation. The corps should play a supporting role through operations in the deep area to detect and identify the fastest, longest range sUAS and their launch points. This section makes three primary recommendations: provide doctrinal models for defining C-sUAS command and support relationships for maneuver BNs; clearly Delineate the roles and responsibilities of BCTs (C-sUAS operations), DIVs (C-sUAS planning) and Corps (C-sUAS shaping); provide C-sUAS education to maneuver leaders at key points of professional military education. Implementing these recommendations involves changes to the Doctrine and Leadership and Education domains of DOTMLPF-P.

Doctrine. The battlespace a tactical formation must control dictates how doctrine informs its C-sUAS roles. The limited C-sUAS capabilities within Army divisions must be flexible enough to allow resources to be prioritized to critical assets within such a large area of operations—a small-scale, dedicated C-sUAS capability organic to battalions, for instance, would fail to provide this flexibility. Having assets at division (M-SHORAD) to allocate to subordinate BCTs based on threat and mission provides this flexibility, while retaining organic, cross-functional C-sUAS capabilities at the BCT level (EW platoons) ensures options for tactical C-sUAS exist across the battlespace. Furthermore, having distinct defeat mechanisms at each echelon provides air defense planners with the appropriate mix of capabilities to prepare defense designs within the guidelines of the air defense employment principles.

Under the proposed model of using BCTs as the foundational element for tactical C-sUAS operations, BCT commanders should task-organize C-sUAS forces, to include aligned M-SHORAD batteries and organic EW platoons, to support maneuver operations. Doctrine should provide the models in Figure 15 as possible command and support relationships for BCT C-sUAS operations.

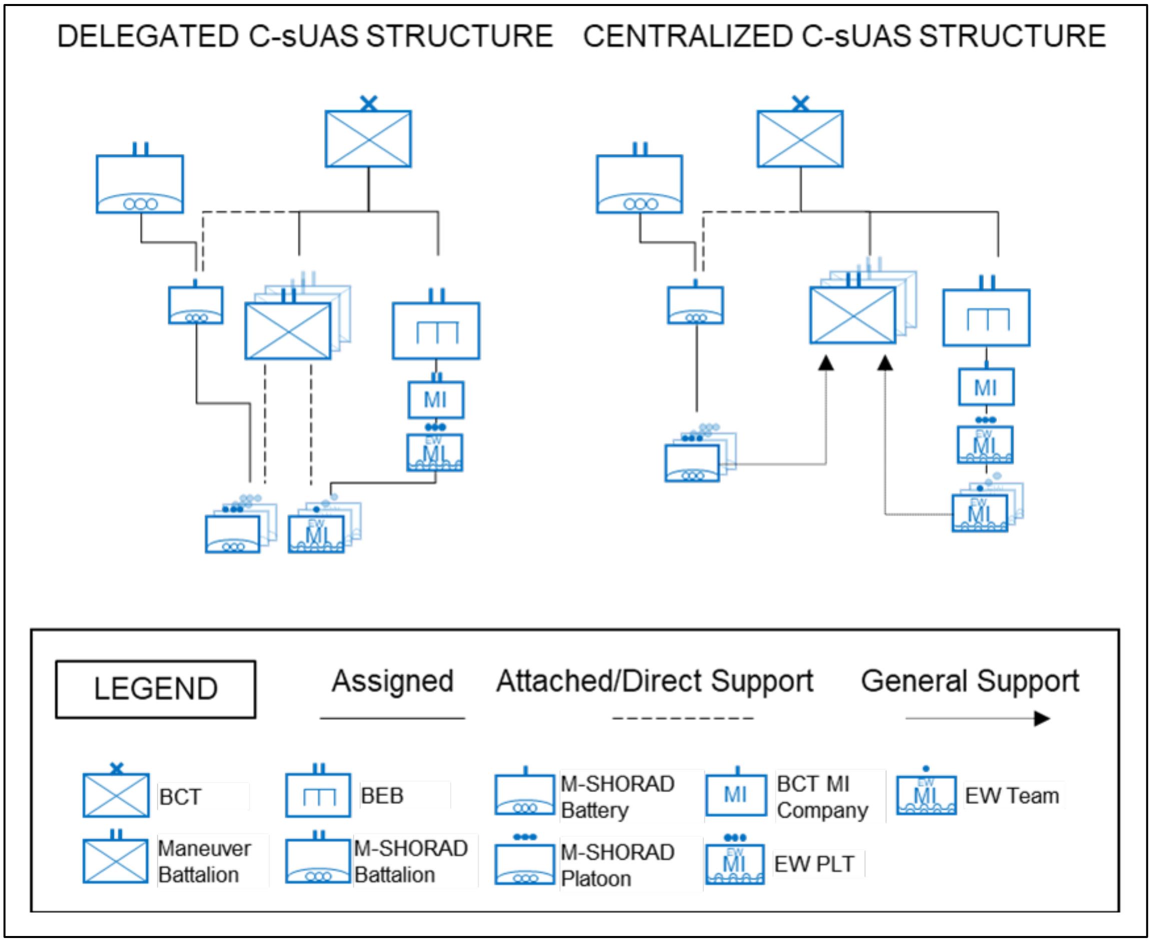

Figure 15. Recommended BCT C-sUAS Command and Support Relationships.

Source: Created by author using symbols from Headquarters, Department of the Army, Field Manual 1-02.2, *Military Symbols* (Washington, DC: Army Publishing Directorate, 2020).

A delegated structure prioritizes the ADA principle of mobility by attaching multiple types of C-sUAS forces directly to maneuver battalions. Under this model, M-SHORAD battery headquarters are attached to BCTs and integrate with ADAM cells to provide planning and coordination support, while BNs employ attached M-SHORAD platoons to support tactical operations. Likewise, EW teams are attached from the EW platoon in the brigade engineer battalion and employed by the maneuver battalion headquarters. This is appropriate for fast-paced offensive operations in the BCT close area, as maneuver battalion headquarters can re-position C-sUAS assets accompanying forces as the FLOT changes.

A centralized structure prioritizes the ADA principles of agility and integration and allows greater opportunity for air defense planners to implement air defense employment tenets into defense designs. It also allows greater flexibility in the use of EW assets to achieve traditional EW effects for the BCT commander. The M-SHORAD battery headquarters still closely integrates with the BCT ADAM cell but exercises greater operational control over M-SHORAD platoons, positioning them to better achieve mutual support and overlapping fires and apply weighted coverage over key projected avenues of sUAS approach assessed by the BCT S2 and the ADAM cell. EW teams similarly remain under the control of the BCT military intelligence company. Greater control and opportunity for overlapping coverage make this model more suitable for employing C-sUAS forces in the BCT close and rear areas during defensive or consolidation operations.

In large scale ground combat operations, the limited number of C-sUAS forces mean tactical formations are unable to provide comprehensive coverage across the entire AO. Figure 16 shows a doctrinal tactical battlefield with C-sUAS assets arrayed with brigades.

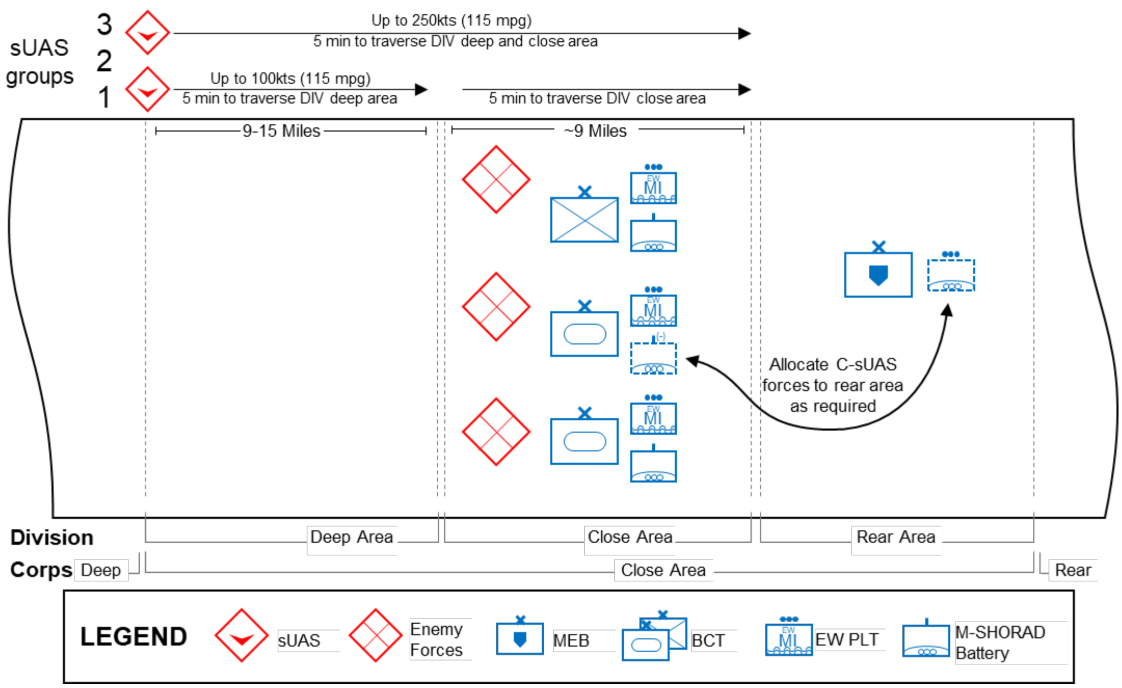

Figure 16. Depiction of C-sUAS Forces on an MDO Battlefield

Source: Created by author using symbols from Headquarters, Department of the Army, Field Manual 1-02.2, *Military Symbols* (Washington, DC: Army Publishing Directorate, 2020).

As shown, division C-sUAS planning must balance a requirement to provide protection in the rear area while still providing sufficient C-sUAS combat power to the forces in contact. Existing air defense and protection planning tools provide appropriate processes for identifying critical assets and applying resources. Planners consider the balance of C-sUAS forces in close and rear areas and should consider to what extent tasking BCTs with forward postured assets to cover likely avenues of sUAS approach into the rear area can mitigate the need for C-sUAS forces in the rear area. When building a Defended Asset Lists (DAL) and developing an air defense design, division staffs must take advantage of the technical expertise specifically available at the division level to apply air defense and electromagnetic warfare planning principles to best provide a balance of distribution and depth of coverage. Experts from the M-SHORAD battalion and the division CEMA cell should work closely with division air defense planners to identify which capability or mix of capabilities is most appropriate to a particular threat.

When employed as a tactical headquarters, the corps role in countering UAS expands as the size, speed, and range of a UAS (as shown in Figure 16) increases. Because larger UAS, such as group 3 and above, are significantly faster than smaller systems, and more likely to be launched from enemy rear areas, corps must shape in the operational deep area to detect and identify incoming UAS and their launch points. This role may, in limited circumstances, apply to large and fast sUAS, in which case these targets should be handed off to subordinate headquarters for engagement with the assets under their control.

Leadership and Education. Despite support from BCT ADAM cells and M-SHORAD battery headquarters, the potential for control of C-sUAS forces at the battalion level means maneuver commanders and staffs at the company and battalion levels need to be educated on basic air defense principles. Maneuver Captain's Career Course (MCCC) and the Command and General Staff Officer Course (CGSOC) provide opportunities to educate maneuver officers on C-sUAS, EW and air defense concepts. A short module in MCCC that covers basic air defense principles and EW concepts would provide sufficient basis for maneuver captains to recognize the techniques employed by these formations. Similar modules for Captain's Career Courses (CCC) of other branches that play a significant role in BCT operations, such as Engineers, Intelligence, Signal, Logistics and Field Artillery would provide a deeper level of C-sUAS knowledge across

BCTs. An elective course at CGSOC would further inform future battalion S3s and eventual battalion commanders on the basics of implementing these concepts into tactical operations. This education would enhance maneuver leaders' ability to effectively communicate with and employ the C-sUAS forces supporting them.

Recommendations for Future Research

This study should be repeated at the classified level. Using classified sources may provide greater insight into the events described in open-source material. Additional information about the events to provide greater context for analysis may reveal, reinforce, or disconfirm relationships between data. Reliance on open-source material limits the extent to which this study can describe the gap between capabilities and requirements in tactical C-sUAS. A study conducted at the classified level or using controlled unclassified information could provide more specific assessments of posture and recommendations for improvement. Finally, using classified material may allow more in-depth discussion of sUAS defeat mechanisms, and allow consideration of detection and defeat ranges. This would better inform where in the battlespace particular assets should be postured, and by extension what echelon to which they should be allocated.

Investment by China in autonomous and swarm technologies may shape the way it employs sUAS in future conflicts. These technologies are closely linked, each tied to advances in artificial intelligence, and may influence how China employs sUAS, changing the manner in which tactical formations must conduct C-sUAS operations. These emerging technologies warrant deeper examination in future studies as existing literature on how these technologies will be employed in war is conceptual and not tied to specific battlefield realities. Using the models established in this study, future researchers could explore what targets on the battlespace may be most vulnerable to autonomous or swarm technologies, and how tactical units must apply countermeasures.

Ongoing sUAS employment by both parties in the ongoing Russian-Ukrainian conflict will likely provide a rich area for future study. This study provides only the most superficial glimpse of the still-evolving role of sUAS in this war. Future study could explore to what extent the lessons of Nagorno-Karabakh were immediately applied by Russian and Ukrainian forces, and the extent to which social media played a role in proliferating techniques. The reasons that Russia employed minimal UAS in the first few weeks of the conflict could also provide an interesting avenue for further study. The reason behind this absence of sUAS is unclear and understanding it may provide insight into how adversaries will make decisions about where and when to employ these systems.

Conclusions

The threat of sUAS presents a new and distinct air defense challenge. The amount of material available can make the field seem more complex than perhaps it is. This study found sUAS employment frequently conforms to intuitive understandings of how sUAS will be used. Simple sUAS uses such as observing maneuver forces appear more frequently than complex ones such as coordinating fires in the deep area. The fact that small drones are reported more frequently in the close area, nearer to their launch points, than deep in friendly rear areas is unsurprising given the nature of the systems. This accessibility may be one of the primary reasons sUAS pose such a threat – if anyone can understand and fly such systems, they can appear anywhere and proliferate rapidly. The DoD has recognized the threat of sUAS, a threat substantiated and clarified by this study. But simply describing the threat is insufficient. C-sUAS cannot simply be viewed as a process of matching a C-sUAS capability to a critical asset. Instead, C-sUAS must be performed as a tactical operation.

The recommendations in this study support operationalizing C-sUAS and nest within ongoing Army efforts to improve the posture of tactical forces against these systems. To enable the use of BCTs as the tactical building block for synchronizing C-sUAS operations, this study recommended that the Army: doctrinally define BCTs as the C-sUAS unit of action at the tactical level and vest C-sUAS engagement authority in BCT commanders; and provide ADAM cells with sufficient expertise to synchronize the C-sUAS fight. To enable the BCT electromagnetic warfare platoon as a C-sUAS element, this study recommended the Army equip EW formations with C-sUAS equipment and develop future EW systems to be C-sUAS capable; doctrinally designate C-sUAS as a secondary mission for EW platoons; and educate EW leaders on C-sUAS at PME and at qualification courses. To support direct-fire C-sUAS support from M-SHORAD Battalions, this study recommended the Army: emphasize development of the M-SHORAD platform capabilities against group 1-2 sUAS; organize M-SHORAD DE platforms into regular M-SHORAD platoons instead of separate platoons; doctrinally define an association between M-SHORAD batteries and BCTs in large- scale combat operations, with ADAM cells serving as integrating cells; and provide comprehensive education on C-sUAS and M-SHORAD operations at air defense PME. This study also supports the army’s stated intent of aligning M-SHORAD battalions to divisions and recommends that any additional M-SHORAD battalions allocated to higher headquarters be in addition to, not in place of divisionally aligned battalions. Finally, to support clear C-sUAS responsibilities by echelon, this study recommended that the Army: provide doctrinal models for defining C-sUAS command and support relationships for maneuver battalions; clearly delineate the roles and responsibilities of BCTs (C-sUAS operations), divisions (C-sUAS planning) and Corps (C-sUAS shaping); and provide C-sUAS education to maneuver leaders at key points of professional military education

While technology and materiel play an important role in defeating sUAS on future MDO battlefields, the processes used to integrate C-sUAS systems (as reflected in doctrine and organizational structures) and the leaders that apply those processes play an even more critical role in taking C-sUAS assets and turning them into capabilities. Opportunities to use EMS and cyberspace effects along with ground-based direct-fire weapon systems against airborne targets make C-sUAS a uniquely multi-domain fight. BCTs with organic, non-kinetic electromagnetic warfare C-sUAS capabilities in EW platoons and task-organized direct fire C-sUAS capabilities from divisionally aligned M-SHORAD battalions provide a compelling tactical C-sUAS building block on an MDO battlefield when supported by division level planning and resource allocation.

APPENDIX A

SUPPORTING TABLES

Coded Case Study Data

Table 19. Coded Study Data: VEO Case Study

Event Type	Target	Battle-space Location	Purpose	Type	Number	Emerging Control Technology	Source
Operational	Fixed Sites	Rear Area	Recon, Strike	Not Stated	Not Stated	Not Examined	1
Operational	Fixed Sites, Maneuver Forces	Close, Non-Contiguous	Propaganda, Recon, Strike	Not Stated	Multiple	Not Examined	2
Operational	Maneuver Forces	Non-Contiguous, Rear Area	Recon, Strike	Rotary Wing	Indet.	Not Examined	3
Operational	Fixed Sites	Rear Area	Strike	Fixed Wing	Multiple	Not Examined	4
Operational	Fixed Sites, Maneuver Forces	Close	Strike	Rotary Wing	Not Stated	Not Examined	5
Development, Operational	Not Stated	Not Stated	Propaganda, Recon, Strike	Fixed Wing	Not Stated	Not Examined	6
Operational	Maneuver Forces	Close	Propaganda, Recon, Strike	Not Stated	Multiple	Not Examined	7

Source: Created by author using annotated sources.

[1] Sterman, "Hezbollah Drones Wreak Havoc on Syrian Rebel Bases."
[2] Guelfi et al., "The Imperative for the US Military to Develop a Counter- UAS Strategy."
[3] Watson, "The Drones of ISIS."
[4] Reuters, "Drone Attack on US Base Foiled, Iraqi Security Sources Say."
[5] Pomerleau, "How $650 Drones Are Creating Problems in Iraq and Syria."
[6] Braun, "Miniature Menace."
[7] Warrick, "Use of Weaponized Drones by ISIS Spurs Terrorism Fears."

Table 20. Coded Study Data: Nagorno-Karabakh Case Study

Event Type	Target	Battle-space Location	Purpose	Type	Number	Emerging Control Technology	Source
Operational	Air Def.	Close	Fire Coord, Propaganda, Strike	Fixed Wing, Loit. Mntn.	Not Stated	Not Examined	1
Operational	Air Def., Artillery, Fixed Sites, Maneuver Forces	Close	Recon, Strike	Not Stated	Mult.	Not Examined	2
Operational	Fixed Sites, Maneuver Forces	Close	Propaganda, Recon, Strike	Fixed Wing, Loit. Mntn.	Mult.	Not Examined	3
Operational	Air Def., C2, Maneuver Forces	Rear Area	Fire Coord, Strike	Loit. Mntn.	Not Stated	Not Examined	4
Operational	Air Def., Artillery, Maneuver Forces	Not Stated	Not Stated	Fixed Wing, Loit. Mntn.	Not Stated	Not Examined	5
Operational	Air Def.	Indet.	Strike	Fixed Wing, Loit. Mntn.	Not Stated	Not Examined	6
Operational	Artillery, Maneuver Forces	Indet.	Propaganda, Recon, Strike	Not Stated	Not Stated	Not Examined	7
Operational	Air Def., Sust.	Rear Area	Fire Coord, Recon, Strike	Fixed Wing, Loit. Mntn.	Not Stated	Not Examined	8
Operational	Not Stated	Not Stated	Not Stated	Not Stated	Not Stated	Not Examined	9

Source: Created by author using annotated sources.

[1] Kasapoglu, "Turkey Transfers Drone Warfare Capacity to Its Ally Azerbaijan."
[2] Synovitz, "Technology, Tactics, And Turkish Advice Lead Azerbaijan To Victory In Nagorno-Karabakh."
[3] Dixon, "Azerbaijan's Drones Owned the Battlefield in Nagorno-Karabakh."
[4] Urcosta, "Drones in the Nagorno-Karabakh."
[5] Mitzer and Oliemans, "The Fight for Nagorno-Karabakh."
[6] Barton, "Loitering Menace."
[7] Minasyan, "The Battle For Shusha Fighting In Nagorno-Karabakh Has Reached A Turning Point."
[8] Shaikh and Rumbaugh, "The Air and Missile War in Nagorno-Karabakh."
[9] Spencer and Ghoorhoo, "The Battle of Shusha City and the Missed Lessons of the 2020 Nagorno-Karabakh War."

Table 21. Coded Study Data: Russia Case Study

Event Type	Target	Battlespace Location	Purpose	Type	Number	Emerging Control Technology	Source
Operational	Not Stated	Not Stated	Fire Coord, Recon	Fixed Wing	Not Stated	Not Stated	1
Operational	Maneuver Forces	Not Stated	Fire Coord	Not Stated	Not Stated	Not Stated	2
Operational	Maneuver Forces	Close	Fire Coord	Not Stated	Not Stated	Not Stated	3
Operational	Maneuver Forces	Indet.	Fire Coord	Fixed Wing	Multiple	Not Stated	4
Development	Not Stated	Not Stated	Recon	Fixed Wing	Not Stated	Not Stated	5
Operational	Not Stated	Not Stated	Not Stated	Fixed Wing	Single	Not Stated	6
Development	Not Stated	Close	Recon, Strike	Fixed Wing	Multiple	Swarm	7
Operational	Fixed Sites	Non-Contiguous	Strike	Loitering Munition	Indet.	Not Stated	8
Development	Not Stated	Rear Area	Not Stated	Fixed Wing	Multiple	Swarm	9
Operational	Artillery, Maneuver Forces	Close, Rear Area	Fire Coord, Recon	Fixed Wing	Not Stated	Not Stated	10
Operational	Not Stated	Not Stated	Not Stated	Loitering Munition	Not Stated	Autonomous	11

Source: Created by author using annotated sources.

[1] Galeotti, Armies of Russia's War in Ukraine.
[2] Freedberg, "Russian Drone Threat."
[3] Woodford, "The Russian Artillery Strike That Spooked the US Army."
[4] Kowrach, "US Army Counter-Unmanned Aerial Systems."
[5] Russian Aviation, "Russian Army Artillery Units Use Takhion Mini-UAV to Perform Reconnaissance Missions."
[6] InformNapalm, "Russian Military UAV Shot down in the War Zone (Updated)."
[7] Hambling, "Russia Uses 'Swarm Of Drones' In Military Exercise For The First Time."
[8] McDermott, "Russian UAV Technology and Loitering Munitions."
[9] Bendett, "Strength in Numbers."
[10] Cranny-Evans, "Russian Drones Are Playing a Major Role in the War Against Ukraine."
[11] Knight, "Russia' s Killer Drone in Ukraine Raises Fears About AI in Warfare."

Table 22. Coded Study Data: China Case Study

Event Type	Target	Battlespace Location	Purpose	Type	Number	Emerging Control Technology	Source
Assessment	Not Stated	Close	Fire Coord, Recon	Not Stated	Not Stated	Not Stated	1
Development	Maneuver Forces	Close	Strike	Loitering Munition	Multiple	Not Stated	2
Development	Not Stated	Non-Contiguous	Recon, Strike	Rotary Wing	Not Stated	Not Stated	3
Development	Not Stated	Not Stated	Recon, Strike	Rotary Wing	Not Stated	Autonomous	4
Development	Not Stated	Not Stated	Recon	Fixed Wing	Multiple	Swarm	5
Development	Not Stated	Not Stated	Strike	Rotary Wing	Not Stated	Autonomous	6

Source: Created by author using annotated sources.

[1] HQDA, ATP 7-100.3.
[2] Hambling, "China' s Mini-Drone Packs a Heavyweight Punch."
[3] Defense News World Bureau, "Chinese Troops Deploy Unmanned Helicopters Near Border With India."
[4] Allen, *Understanding China's AI Strategy.*
[5] Hambling, "If Drone Swarms Are the Future, China May Be Winning."
[6] Tucker, "SecDef: China Is Exporting Killer Robots to the Mideast."

Table 23. Cross-Category Associations by Case: Purpose-Target

Purpose	Target	VEO	Nagorno-Karabakh	Russia	China
Fire Coord	Air Defense		3		
Fire Coord	Artillery			1	
Fire Coord	C2 Nodes		1		
Fire Coord	Maneuver Forces		1	4	
Fire Coord	Not Stated			1	1
Fire Coord	Sustainment		1		
Not Stated	Air Defense		1		
Not Stated	Artillery		1		
Not Stated	Maneuver Forces		1		
Not Stated	Not Stated		1	3	
Propaganda	Air Defense		1		
Propaganda	Artillery		1		
Propaganda	Fixed Sites	1	1		
Propaganda	Maneuver Forces	2	2		
Propaganda	Not Stated	1			
Recon	Air Defense		2		
Recon	Artillery		2	1	
Recon	Fixed Sites	2	2		
Recon	Maneuver Forces	3	3	1	
Recon	Not Stated	1		3	4
Recon	Sustainment		1		
Strike	Air Defense		5		
Strike	Artillery		2		
Strike	C2 Nodes		1		
Strike	Fixed Sites	4	2	1	
Strike	Maneuver Forces	4	4		1
Strike	Not Stated	1		1	3
Strike	Sustainment		1		

Source: Created by author using cross tabulation analysis in Microsoft Access from coded study data.
NOTE: Codes in one category may be associated with multiple codes in another.

Table 24. Cross-Category Associations by Case: Purpose-Number

Purpose	Number	VEO	Nagorno-	Russia	China
Fire Coord	Multiple			1	
Fire Coord	Not Stated		3	4	1
Not Stated	Multiple			1	
Not Stated	Not Stated		2	1	
Not Stated	Single			1	
Propaganda	Multiple	2	1		
Propaganda	Not Stated	1	2		
Recon	Indeterminate	1			
Recon	Multiple	2	2	1	1
Recon	Not Stated	2	2	3	3
Strike	Indeterminate	1		1	
Strike	Multiple	3	2	1	1
Strike	Not Stated	3	5		3

Source: Created by author using cross tabulation analysis in Microsoft Access from coded study data.
NOTE: Codes in one category may be associated with multiple codes in another.

Table 25. Cross-Category Associations by Case: Target-Number

Target	Type	VEO	Nagorno-	Russia	China
Air Defense	Fixed Wing		4		
Air Defense	Loitering Munition		5		
Air Defense	Not Stated		1		
Artillery	Fixed Wing		1	1	
Artillery	Loitering Munition		1		
Artillery	Not Stated		2		
C2 Nodes	Loitering Munition		1		
Fixed Sites	Fixed Wing	1	1		
Fixed Sites	Loitering Munition		1	1	
Fixed Sites	Not Stated	2	1		
Fixed Sites	Rotary Wing	1			
Maneuver Forces	Fixed Wing		2	2	
Maneuver Forces	Loitering Munition		3		1
Maneuver Forces	Not Stated	2	2	2	
Maneuver Forces	Rotary Wing	2			
Not Stated	Fixed Wing	1		5	1
Not Stated	Loitering Munition			1	
Not Stated	Not Stated		1		1
Not Stated	Rotary Wing				3
Sustainment	Fixed Wing		1		
Sustainment	Loitering Munition		1		

Source: Created by author using cross tabulation analysis in Microsoft Access from

coded study data.
NOTE: Codes in one category may be associated with multiple codes in another.

Table 26. Cross-Category Associations by Case: Location-Target-Purpose

Battlespace	Target	Purpose	VEO	Nagorno-	Russia	China
Close	Air Defense	Fire Coord		1		
Close	Air Defense	Propaganda		1		
Close	Air Defense	Recon		1		
Close	Air Defense	Strike		2		
Close	Artillery	Fire Coord			1	
Close	Artillery	Recon		1	1	
Close	Artillery	Strike		1		
Close	Fixed Sites	Propaganda	1	1		
Close	Fixed Sites	Recon	1	2		
Close	Fixed Sites	Strike	2	2		
Close	Maneuver Forces	Fire Coord			2	
Close	Maneuver Forces	Propaganda	2	1		
Close	Maneuver Forces	Recon	2	2	1	
Close	Maneuver Forces	Strike	3	2		1
Close	Not Stated	Fire Coord				1
Close	Not Stated	Recon			1	1
Close	Not Stated	Strike			1	
Indeterminate	Air Defense	Strike		1		
Indeterminate	Artillery	Propaganda		1		
Indeterminate	Artillery	Recon		1		
Indeterminate	Artillery	Strike		1		
Indeterminate	Maneuver Forces	Fire Coord			1	
Indeterminate	Maneuver Forces	Propaganda		1		
Indeterminate	Maneuver Forces	Recon		1		
Indeterminate	Maneuver Forces	Strike		1		
Non-Contiguous	Fixed Sites	Propaganda	1			
Non-Contiguous	Fixed Sites	Recon	1			
Non-Contiguous	Fixed Sites	Strike	1		1	
Non-Contiguous	Maneuver Forces	Propaganda	1			
Non-Contiguous	Maneuver Forces	Recon	2			
Non-Contiguous	Maneuver Forces	Strike	2			
Non-Contiguous	Not Stated	Recon				1
Non-Contiguous	Not Stated	Strike				1
Not Stated	Air Defense	Not Stated		1		
Not Stated	Artillery	Not Stated		1		
Not Stated	Maneuver Forces	Fire Coord			1	
Not Stated	Maneuver Forces	Not Stated		1		

Battlespace	Target	Purpose	VEO	Nagorno-	Russia	China
Not Stated	Not Stated	Fire Coord			1	
Not Stated	Not Stated	Not Stated		1	2	
Not Stated	Not Stated	Propaganda	1			
Not Stated	Not Stated	Recon	1		2	2
Not Stated	Not Stated	Strike	1			2
Rear Area	Air Defense	Fire Coord		2		
Rear Area	Air Defense	Recon		1		
Rear Area	Air Defense	Strike		2		
Rear Area	Artillery	Fire Coord			1	
Rear Area	Artillery	Recon			1	
Rear Area	C2 Nodes	Fire Coord		1		
Rear Area	C2 Nodes	Strike		1		
Rear Area	Fixed Sites	Recon	1			
Rear Area	Fixed Sites	Strike	2			
Rear Area	Maneuver Forces	Fire Coord		1	1	
Rear Area	Maneuver Forces	Recon	1		1	
Rear Area	Maneuver Forces	Strike	1	1		
Rear Area	Not Stated	Not Stated			1	
Rear Area	Sustainment	Fire Coord		1		
Rear Area	Sustainment	Recon		1		
Rear Area	Sustainment	Strike		1		

Source: Created by author using cross tabulation analysis in Microsoft Access from coded study data.
NOTE: Codes in one category may be associated with multiple codes in another.

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