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14. ABSTRACT

Over the last decade, Unmanned Aircraft Systems (UAS) have proliferated from major nation-state militaries to numerous commercial industries, smaller militaries, and non-state actors. A majority of countries in the world now field military UAS systems, and non-state actors have adapted commercial UAS to fulfill military roles. Recent conflicts in the Middle East, Ukraine, and the Caucasus regions demonstrate that state and non-state actors can use military specific or commercial UAS effectively on the battlefield. Artificial intelligence (AI) controlled UAS swarms will provide the next leap in UAS development. The US, China, and Russia are all developing UAS swarms that utilize AI. These UAS swarms will change the character of future wars and have to potential to overwhelm currently fielded air defense systems. This paper seeks to analyze the Joint Force's current posture and identify gaps in doctrine, training, and materiel to address UAS threats. After a long period of neglect, the Joint Force has begun to place a renewed emphasis on short-range air defense to counter currently fielded UAS; however, the Joint Force is disregarding the looming threat of UAS swarms. This paper recommends changes to doctrine, training, and materiel to adequately address this looming threat.

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NATIONAL DEFENSE UNIVERSITY

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JOINT ADVANCED WARFIGHTING SCHOOL

WILL A UAS SWARM OVERWHELM THE JOINT FORCE?

by

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U.S. Department of State

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A paper submitted to the Faculty of the Joint Advanced Warfighting School in partial satisfaction of the requirements of a Master of Science Degree in Joint Campaign Planning and Strategy. The contents of this paper reflect my own personal views and are not necessarily endorsed by the Joint Forces Staff College or the Department of Defense or Department of State.

This paper is entirely my own work except as documented in footnotes.

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ABSTRACT

Over the last decade, Unmanned Aircraft Systems (UAS) have proliferated from major nation-state militaries to numerous commercial industries, smaller militaries, and non-state actors. A majority of countries in the world now field military UAS systems, and non-state actors have adapted commercial UAS to fulfill military roles. Recent conflicts in the Middle East, Ukraine, and the Caucasus regions demonstrate that state and non-state actors can use military specific or commercial UAS effectively on the battlefield. Artificial intelligence (AI) controlled UAS swarms will provide the next leap in UAS development. The US, China, and Russia are all developing UAS swarms that utilize AI. These UAS swarms will change the character of future wars and have to potential to overwhelm currently fielded air defense systems. This paper seeks to analyze the Joint Force's current posture and identify gaps in doctrine, training, and materiel to address UAS threats. After a long period of neglect, the Joint Force has begun to place a renewed emphasis on short-range air defense to counter currently fielded UAS; however, the Joint Force is disregarding the looming threat of UAS swarms. This paper recommends changes to doctrine, training, and materiel to adequately address this looming threat.

DEDICATION

This thesis is dedicated to my wife and daughter. You both have made me a better, more fulfilled, and understanding person.

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I am grateful for the support of my thesis and faculty advisors. The guidance, insight, and advice provided by Dr. Bryon Greenwald and Colonel Jody Owens enabled the accomplishment of this thesis. I thank Captain Frank Castellano for his support and understanding throughout the year. I thank my wife for her patience, strength, and support during this arduous year.

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CHAPTER 1: INTRODUCTION

Over the last decade, Unmanned Aircraft Systems (UAS) have evolved from their military origin to become prevalent in numerous industries. UAS technology has proliferated from major nation-state militaries to numerous commercial industries, smaller militaries, and non-state actors. Commonly referred to as drones, these systems have continuously increased in speed, range, and payload. Since the first commercial UASs became available in 2010, the commercial sector has become a multi-billion-dollar industry. The global commercial UAS market generated $22.5 billion in sales in 2020 and is projected to almost double to $42.8 billion in 2025.[1] The proliferation of commercial UAS has allowed non-state actors easy access to this technology. Military UAS use also expanded in the last decade, with countries worldwide incorporating UAS systems into their armed forces. In 2010, 60 countries had UAS in their military inventories. In 2020, this group expanded to 102, with 58 having or developing armed UASs.[2] Relatively basic UASs operating at low altitudes have shown effectiveness against modern militaries, as demonstrated in the Syrian conflict and the 2019 attack on Saudi Arabian oil infrastructure. Modern UAS proved a critical factor in Azerbaijan's military success against Armenia.

At the same time, advanced militaries have developed new systems. Several advanced countries have begun testing UAS coupled with Artificial Intelligence (AI), intending to create a swarm of multiple UASs acting autonomously in concert to increase

[1] Josh Spires, "Drone Market Is Set to Be Worth $42.8 Billion by 2025," *DroneDJ*, June 24, 2020, https://dronedj.com/2020/06/24/drone-market-is-set-to-be-worth-42-8-billion-by-2025/.

[2] Dan Gettinger, "DRONE DATABOOK UPDATE: MARCH 2020," *Center for the study of the drone at Bard College*, March 2020, https://dronecenter.bard.edu/files/2020/03/CSD-Databook-Update-March-2020.pdf.

the UASs' effectiveness. Moreover, the miniaturization and use of non-radar reflective composite materials to construct these systems make them increasingly difficult for existing air defense systems to detect.[3] Given the expanded use of commercial and military UAS, the U.S. military can no longer assume that it completely controls the skies. The Joint Force has recently recognized the current UAS threat and taken steps to reorient its force structure and development; however, it remains woefully unprepared for the looming threat of UAS swarms and must immediately address deficiencies in doctrine, training, and materiel.

UAS vary in size, weight, range, speed, propulsion, and payload. The Department of Defense (DoD) classifies UAS into five groups based on weight, operating altitude, and speed.[4] Groups four and five function analogously to manned aircraft, with similar size, speed, operating altitude, and performing similar missions. The General Atomics Predator and Reaper, and the Northrup Grumman Global Hawk platforms fall into groups four and five. With similarities to manned aircraft, current air defense systems, training and doctrine adequately address threats from groups four and five.

Groups one, two, and three, consisting of commercial systems and drones like the Boeing ScanEagle, AAI Shadow, and DJI Phantom, are smaller and fly lower and slower. Groups one through three differ significantly from traditional aircraft. Current air defense systems have difficulty identifying, tracking, and targeting these UAS. Army Training Publication (ATP) 3-01.08 refers to groups one through three as "low, slow, and

[3] Bradley Wilson et al., "Small Unmanned Aerial System Adversary Capabilities" (RAND Corporation, 2020), https://doi.org/10.7249/RR3023, 86.

[4] Department of Defense. *FY2009–2034: Unmanned Systems Integrated Roadmap*. (Washington, DC: Government Printing Office, 2009), 96.

small (LSS)" UASs.[5] It states that "Integrated air and missile defense (IAMD) capabilities can effectively counter larger classes of UAS but have difficulty tracking, identifying, and defeating LSS UAS."[6] Furthermore, training and doctrine have yet to catch up to developments in these UAS categories.

Various propulsion systems propel UAS in takeoff and flight. Internal combustion piston or jet engines propel UAS in groups four and five, similarly to manned aircraft. These UAS takeoff and land from traditional aviation runways. LSS UASs have more varied means of propulsion. Internal combustion piston engines, battery-powered electric motors, and rocket motors propel various LSS UASs.[7] These systems have various means to takeoff; they can use traditional runways, be hand-launched by individual soldiers, air-launched from larger aircraft, launched from vehicle-mounted tube launchers, and rotary-wing UAS can take off and land vertically.

The DoD currently does not have standard definitions for AI or UAS swarms. Organizations, authors, and researchers have all proposed definitions as the concepts continue to evolve.[8] For the purposes of this research, simple definitions of these concepts will provide clarity and understanding. As applied to UASs, AI will allow the UAS to act independently of human control by responding to changes in the environment, determining the best course of action, and then executing that action. UAS swarms

[5] US Department of the Army, Army Techniques Publication (ATP) 3-01.81, *Counter-Unmanned Aircraft System Techniques*, Washington, DC: Government Printing Office, April 2017.

[6] Ibid.

[7] Miroslaw Adamski, "Analysis of Propulsion Systems of Unmanned Aerial Vehicles," *Journal of Marine Engineering & Technology* 16, no. 4 (February 2, 2017): 291–97, https://doi.org/10.1080/20464177.2017.1383337.

[8] Travis Kneen, "Defining Unmanned Aerial Systems (UAS) Swarms," *Defense Systems Information Analysis Center*, August 2019, https://www.dsiac.org/services/technical-inquiries/notable-ti/defining-unmanned-aircraft-system-swarms/25496/.

consist of 10 or more AI UASs, with the ability to communicate with each other and act as a coordinated unit either in mass or dispersed.

Recent conflicts in the Middle East, Ukraine, and the Caucasus regions demonstrate that state and non-state actors can use proprietary, state-sponsored, or commercial UAS effectively on the battlefield. These specific conflicts highlight UAS systems in groups one, two, and three in intelligence, surveillance, and reconnaissance (ISR) roles, delivering munitions, or precisely striking targets. CENTCOM Commander General McKenzie highlighted the threat from these classes of UAS when he told the House Armed Services Committee that "we aggressively pursue anything that will improve the capabilities, particularly against those group one and two UAS'…. That is one of the things that worries me the most in the theater every day. It is the vulnerability of our forces to those small UAS."[9]

Due to the lack of an air threat during the Global War on Terror (GWOT), the United States became complacent in its domination of the air domain and began reducing its number of Short-Range Air Defense (SHORAD) systems. In 2000, a SHORAD battalion protected every U.S. Army division. By 2017, none of the ten active divisions had a dedicated, organic SHORAD battalion.[10] Faced with fighting the current war, the Army allowed its SHORAD forces to languish. In explaining the cuts, the Commandant of the Air Defense Artillery School at Fort Sill, Col. Mark A. Holler, stated that the Army traded SHORAD battalions force structure to grow combat maneuver teams to support

[9] House Armed Services Committee, *National Security Challenges and U.S. Military Activities in the Greater Middle East and Africa*: 116th Cong., 1st sess., 2020. https://www.africom.mil/document/32926/transcript-gen-mckenzie-gen-townsend-asd-whee

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

the counterinsurgency fight. He further noted that the Ukraine conflict had given the Army a "wake-up" regarding the need for increased SHORAD.[11]

The acquisition and development of UAS in China and Russia further highlight the threat of advanced UASs. Both peer competitors currently field large quantities of UASs from groups one through five, and along with the U.S., are testing AI-controlled UAS. Increased autonomy will significantly reduce operator workload. Autonomous swarms have the potential for even more dramatic and disruptive changes to military operations. Swarms of UAS systems can function using greater mass and coordination to overwhelm defenses and gain a decisive advantage through numerical superiority.[12] In any future combat deployment, U.S. forces will inevitably encounter numerous hostile UASs. Adversaries currently deploy a diverse range of UAS from groups one through five. Ongoing developments will only increase these UAS's capabilities. To counter the current threat and allow friendly freedom of maneuver, the Joint Force must develop the means to detect, identify, and defeat UAS on the battlefield. To counter the future threat, the Joint Force must develop new technologies and concepts to defeat swarms of UAS. No single solution exists to defeat this threat; it will require the development of various materiel systems, the implementation of new training with an emphasis on emerging technologies, and the updating of doctrine to guide and instruct the Joint Force.

In arguing these points, this thesis will use a gap and risk analysis methodology. The gap analysis in Chapter Two will focus on the real-world examples of UAS and SHORAD warfare in the last five years, including the Ukraine conflict, the Syrian war,

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[11] Ibid.

[12] Paul Scharre, "Robotics on the Battlefield Part II: The Coming Swarm." *Center for a New American Security*, 2014. http://www.jstor.org/stable/resrep06405, 5.

the strike on Saudi ARAMCO facilities, and the Armenian-Azerbaijan conflict. This section will analyze how militaries have responded to threats from various types of UAS and analyze successes and failures in doctrine, training, and materiel. Chapter Three will compare these existing and emerging UAS threats with current and future Joint Force SHORAD capabilities. Chapter Four will analyze UAS systems' development coupled with AI to create autonomous swarms and how these swarms could change the character of war. Considering any gaps that may currently exist, combined with the effects of AI and swarming tactics, Chapter Five will make recommendations to develop aspects of doctrine, training, and materiel to prepare the Joint Force to defeat these threats.

CHAPTER 2: UAS IN USE

State and non-state actors have utilized UAS in recent conflicts in Syria, Ukraine, Saudi Arabia, and Nagorno-Karabakh to varying degrees of effectiveness. These actors deployed UASs in groups one, two, and three. Each of these conflicts present various methods of military UAS employment. Each employment method offers a case to apply a gap analysis to determine the failures and successes of doctrine, training, and materiel in defense of UAS.

The Syrian Civil War began during the Arab Spring in 2011 with popular protests against President Assad's regime. The regime attempted to suppress the peaceful protests violently. The protesters responded in kind, escalating the conflict into a civil war. When protesters, now rebels, began to gain ground against the regime in 2014 and 2015, Russia offered assistance to the Assad Regime. The Russians provided initial assistance in the form of air support, eventually also committing ground forces. Since 2015, Russia's air support assistance to the regime has operated out of the Khmeimim Air Base, located adjacent to the Bassel Al-Assad International Airport in the Latakia governate of Syria.

After establishing the airbase, the Russian military deployed numerous air defense assets, creating an anti-access/area denial (A2/AD) bubble in western Syria.[1] According to a Russian military spokesman, the air defense assets include the S-400 long-range surface-to-air missile system, the Tor-M2 medium-range surface-to-air system, and the

[1] Thomas Gibbons-Neff. "Top NATO General: Russians Starting to Build Air Defense Bubble over Syria." *Washington Post*. September 29, 2015. https://www.washingtonpost.com/news/checkpoint/wp/2015/09/29/top-nato-general-russians-starting-to-build-air-defense-bubble-over-syria/.

Pantsyr-S1 short-range surface-to-air system.[2] From 2018 to 2020, Russian media claimed Syrian rebels and terrorist organizations had attacked the base numerous times, with Russia shooting down over 100 UASs during these attacks.[3] Russian military spokesmen and media outlets have not reported any damage from these attacks, claiming the air defense systems jammed or destroyed the UASs. Open-source analysis has questioned the assertation of the damage reports.[4] Russia has used the Syrian Civil War to demonstrate its military hardware to boost arms sales, calling into question its assertion of the Tor-M2 and Pantsyer-S1 systems' effectiveness.[5] These engagements demonstrate the need for a multi-tiered, defense in depth, air-defense model. Defense in depth gave the Russians the capabilities to defend against multiple aerial threats spanning groups one through five. By deploying long, medium, and short-range systems, the Russians claim to have protected their airbase from UAS attacks. This case presents a potential force structure model to protect fixed facilities from UAS threats.

The conflict in Ukraine began in 2013 with protests against the Ukrainian government's decision to suspend the implementation of a European Union association agreement. The government of President Yanukovych responded violently to the protests. The protesters eventually precipitated a revolution and forced the Ukrainian president to flee the country. The revolution sparked further unrest in the east of Ukraine, where a sizeable Russophone population resided and where Yanukovych drew

[2] TASS. "Russia's Hmeymim Airbase in Syria Strikes over 100 Terrorists' Drones over Past Two Years," *TASS*, September 27, 2019. https://tass.com/defense/1080250.

[3] Dmitry Kozlov. "Russia Says Drone Attacks on Its Syria Base Have Increased." *AP News*, August 16, 2018. https://apnews.com/article/2b07cc798d614d84a32ff83f6abe2e7e.

[4] Nick Waters. "The Poor Man's Air Force? Rebel Drones Attack Russia's Airbase in Syria." *bellingcat*, January 12, 2018. https://www.bellingcat.com/news/mena/2018/01/12/the_poor_mans_airforce/.

[5] Mansur Mirovalev. "Syria's War: A Showroom for Russian Arms Sales." *Al Jazeera*. June 4, 2016. https://www.aljazeera.com/news/2016/4/6/syrias-war-a-showroom-for-russian-arms-sales.

most of his support. The Russian government capitalized on this unrest by annexing Crimea and supporting a rebellion in the Donbas region.

In this conflict, both sides have deployed numerous UAS systems. The rebels, backed by Russia, have employed UASs for intelligence, surveillance, and reconnaissance against Ukrainian troops, who report seeing multiple overflights every day. UAS tactics have evolved to include attacking fuel and ammunition facilities with UAS delivered incendiary devices.[6] Ukrainian troops have identified no less than fourteen different UAS models, falling broadly into three categories. A report on the Ukraine conflict from the U.S. Army Capabilities Integration Center defines these three categories as "very long-range, strategic surveillance, high-altitude UAVs flying along the border and Ukrainian southern coast; long-range higher-altitude fixed-wing drones flying over Ukrainian positions beyond Brigade rear area; and medium-range fixed with drones used in target acquisition and real-time engagement."[7] The first two groups fall into the DoD classification of groups four and five. The last group of UAS, and the most prevalent in the conflict, falls into groups one through three. Both sides of the conflict have deployed numerous air defense systems. In this contested environment, UASs present a lower cost and risk capability to fulfill ISR roles. The extent of UAS use in a Russian proxy war demonstrates the necessity for the Joint Force to prepare to counter UAS in any future engagement.

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[6] Jen Judson. "Army Debuts Missile Defense Framework in Move to Counter Drones, Hypersonic Threats." *Defense News*, March 27, 2019. https://www.defensenews.com/digital-show-dailies/global-force-symposium/2019/03/27/army-debuts-new-missile-defense-strategy-to-address-emerging-threats/.

[7] Phillip Karber. "Lessons Learned from the Russo-Ukrainian War: Personal Observations." In Historical Lessons Learned Workshop, Johns Hopkins Applied Physics Laboratory and US Army Capabilities Center, 2015.

The use of UASs in conflicts is not limited to nation-states and their proxy forces. Non-state actors and terrorists can procure and adapt commercial UAS equipment to fulfill military missions. Audrey Cronin, the founding director of the Center for Security, Innovation and New Technology at American University, advances what she terms "Lethal Empowerment Theory," where commercial innovation has lowered the threshold for non-state actors' access to technologies like UAS, that can be adapted for lethal means.[8] She compares the proliferation of UASs to the earlier technological innovations such as dynamite and the AK-47. While these technological innovations cannot compete directly against technologies developed and deployed by nation-states, they grant non-state actors' asymmetric capabilities against conventional forces. These innovations allow non-state actors to have greater operational reach and reduce the threat to their forces.

The Syrian Civil war discussed earlier created a security vacuum within large areas of Syria. In this vacuum, drawing on the disillusionment of Sunni Arabs, components of Al-Qaeda in Iraq reformed into a new organization, the Islamic State of Iraq and Syria (ISIS). ISIS grew through local and international recruitment and captured large swaths of Syrian and Iraqi territory, intending to create an Islamic Caliphate. In pursuit of this goal, they have fought against Iraqi, Kurdish, Syrian, U.S., and Russian forces throughout Syria and Iraq.

ISIS has predominantly adapted commercial UAS systems for their purposes. ISIS has employed UAS in various roles to film propaganda, conduct ISR, and deliver

[8] Audrey Kurth Cronin, *Power to the People: How Open Technological Innovation Is Arming Tomorrow's Terrorists* (New York: Oxford University Press, 2020), 13.

small munitions.[9] ISIS created a UAS development and engineering group labeled "Unmanned Aircraft of the Mujahideen" to develop UAS and adapt commercial UAS to their purposes.[10] ISIS also created several UAS factories in Syria and Iraq to adapt these UAS.[11]

The first documented use of a UAS by ISIS occurred in May 2014 in a propaganda role. A video produced by the group showed aerial views of explosions and combat operations, cumulating in the fall of the Iraqi city of Fallujah.[12] ISIS conducted surveillance and reconnaissance with a UAS of the Tabqa Syrian Air Force Base in August 2014. With an understanding of the base layout and defenses, ISIS then attacked and captured the base.[13] In 2015, ISIS's UASs determined the location of targets for artillery and then further refined the artillery fire using the UAS imagery.[14] ISIS then developed tactics to deliver munitions with commercial UAS. In December 2015, ISIS employed this new tactic by attacking Kurdish forces in Kobani, Syria, with a commercial fixed-wing UAS laden with explosives in an attack analogous to a crude

[9] Larry Friese, N. R Jenzen-Jones, and Michael Smallwood, "Emerging Unmanned Threats: The Use of Commercially-Available UAVs by Armed Non-State Actors," *Armament Research Services,* 2 (February 2016), 40.

[10] Thomas Braun, "Miniature Menace: The Threat of Weaponized Drone Use by Violent Non-State Actors," *Air University*, September 14, 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/.

[11] Audrey Kurth Cronin, *Power to the People: How Open Technological Innovation Is Arming Tomorrow's Terrorists* (New York: Oxford University Press, 2020), 218.

[12] Alberto M Fernandez, "Here to Stay and Growing: Combating ISIS Propaganda Networks," *Project on U.S. Relations with the Islamic World U.S.-Islamic World Forum Papers 2015* (October 2015): 8, https://www.brookings.edu/wp-content/uploads/2016/07/IS-Propaganda_Web_English_v2.pdf.

[13] Yasmin Tadjdeh, "Islamic State Militants in Syria Now Have Drone Capabilities," *National Defense Magazine*, August 24, 2014, https://www.nationaldefensemagazine.org/articles/2014/8/28/islamic-state-militants-in-syria-now-have-drone-capabilities.

[14] Larry Friese, N. R Jenzen-Jones, and Michael Smallwood, "Emerging Unmanned Threats: The Use of Commercially-Available UAVs by Armed Non-State Actors," *Armament Research Services,* 2 (February 2016), 41.

cruise missile.[15] ISIS continued the development of combining munitions and UAS. The group created attachments to UAS that could remotely drop hand grenades, 40mm grenades, and RPG-7 rounds.[16] ISIS adapted and modified the improvised explosive device concept, building UAS that would explode when dissembled.[17] Often ISIS combined the various roles, using the UAS to identify targets, drop munitions, and film the event to later include in propaganda films. While the employment of UAS did not drastically change the balance of power between ISIS and the various nation-state and rebel actors it fought—Iraqi, American, and Kurdish forces regularly shot down ISIS UAS, often with little more than automatic rifles—UAS did provide the group with increased ISR and operational reach. ISIS continued refining its UAS tactics during operations and, with additional time and resources, could have built up a more extensive, more capable UAS fleet.

ISIS demonstrated the utility of commercial UAS to other non-state actors who have emulated many of the same methods and tactics. ISIS's adversaries in Syria and Iraq, the Kurdish and Syrian militias, adopted commercial UAS to fill the propaganda, ISR, and attack roles.[18] Libyan militias now regularly employ commercial UAS. The Taliban have also begun experimenting with the concept, attacking an Afghan

[15] Thomas Braun, "Miniature Menace: The Threat of Weaponized Drone Use by Violent Non-State Actors," *Air University*, September 14, 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/.

[16] Ben Watson, "The Drones of ISIS," *Defense One*, January 1, 2017, https://www.defenseone.com/technology/2017/01/drones-isis/134542/.

[17] Ibid.

[18] Larry Friese, N. R Jenzen-Jones, and Michael Smallwood, "Emerging Unmanned Threats: The Use of Commercially-Available UAVs by Armed Non-State Actors," *Armament Research Services,* 2 (February 2016), 46.

Governor's compound with an explosive UAS in November 2020.[19] These examples demonstrate the continued proliferation of commercial UAS in non-state actor military roles. As the commercial market grows and UAS use is further disseminated among these groups, this threat will continue to grow. This threat allows non-state actors to use widely available technology in an asymmetric way against conventional forces.

In September 2019, Iran attacked the Saudi Abqaiq petroleum processing facilities and Khurais oil field with a mix of UAS and cruise missiles. The Houthi group in Yemen claimed responsibility; however, open-source reporting and western governments have refuted that claim. The use of large numbers of UAS to overwhelm air defenses and conduct a precision strike validates the utility of attacking in mass and represents the first documented proto-swarm UAS attack. The precision strike destroyed numerous oil processing units, caused a spike in global oil prices, and shut down 5% of the global oil supply.[20] Yemen's Houthi group claimed responsibility for the attack; however, a UN investigation determined that the Houthis did not possess the manufacturing capability to develop the weapon systems used and that the attack did not originate from the direction of Yemen. The U.S. has identified Iran as the culprit.[21] An Israeli missile defense expert has claimed that UAS attacked the Abquiq petroleum processing facility, and cruise missiles attacked the Khurais oil field.[22] Eighteen UAS

[19] Najim Rahim and Thomas Gibbons-Neff, "Deadly Taliban Attack Probably Used Drone, a Worrisome Shift," *The New York Times*, November 1, 2020, https://www.nytimes.com/2020/11/01/world/asia/taliban-drone-afghanistan.html.

[20] Michelle Nichols, "Exclusive: U.N. Investigators Find Yemen's Houthis Did Not Carry out Saudi Oil Attack," *Reuters*, January 8, 2020, https://www.reuters.com/article/us-saudi-aramco-attacks-un-exclusive-idUSKBN1Z72VX.

[21] Nichols, "Exclusive: Exclusive: U.N. Investigators Find Yemen's Houthis Did Not Carry out Saudi Oil Attack"

[22] Uzi Rubin, "Saudi Arabia's Black September," *Jerusalem Institute for Security and Strategy*, October 15, 2019, https://jiss.org.il/en/rubin-saudi-arabias-black-september/.

struck processing equipment at the facility, demonstrating the potential precision and damage UAS operating in mass can deliver.

Before the attack, open-source satellite imagery shows the American-made Patriot missile defense system, German-made Skyguard air defense cannons, and France's Shahine mobile anti-aircraft system all deployed around the Abqaiq facility.[23] The UAS and cruise missiles flew below the systems' engagement zone. None of the three systems were designed to deal with UAS in the group one to three. Raytheon designed the Patriot to engage medium to high-altitude air targets such as fixed-wing aircraft and ballistic missiles. Rheinmetall designed the Skyguard system to defeat low to medium altitude fixed-wing and rotary aircraft, and the Shahine has a similar role. Rheinmetall has developed a new version of the Skyguard system that will engage UAS.[24]

The Saudi military deployed systems best suited to ballistic and medium to high altitude fixed and rotary wing threats, not UAS and cruise missiles. Jack Watling, a land warfare expert at the Royal United Services Institute, questioned the Saudi soldiers' readiness and training. He stated, "The Saudis have a lot of sophisticated air defense equipment. Given their general conduct of operations in Yemen, it is highly unlikely that their soldiers know how to use it," adding that the kingdom's forces have "low readiness, low competence, and are largely inattentive."[25] This attack demonstrates the necessity for

[23] Natasha Turak, "How Saudi Arabia Failed to Protect Itself from Drone and Missile Attacks despite Billions Spent on Defense Systems," *CNBC*, September 19, 2019, https://www.cnbc.com/2019/09/19/how-saudi-arabia-failed-to-protect-itself-from-drones-missile-attacks.html.

[24] DP Staff Writer, "Rheinmetall Wins €120M Contract to Modernize Skyguard Air Defence Systems," *DefPost*, December 9, 2019, https://defpost.com/rheinmetall-wins-e120m-contract-to-modernize-skyguard-air-defence-systems/.

[25] Turak, "How Saudi Arabia Failed to Protect Itself from Drone and Missile Attacks despite Billions Spent on Defense Systems."

air defense systems designed explicitly for the UAS threat. The attack also calls into question the Saudi forces' training, doctrine, and readiness for that threat.

The attack on Saudi oil facilities illustrated the capability of UAS used in a manner analogous to cruise missiles where the operator selects a target before the launch of the UAS. The 2020 Nagorno-Karabakh War between Armenia and Azerbaijan illustrates the capabilities of nation-state-developed loitering munitions. This type of UAS, often referred to as suicide or kamikaze drones, combines a UAS from group two or three with an explosive charge. These UASs can loiter over the battlefield for hours until the operator identifies a target and physically strikes the target setting off the explosive charge.

The 2020 Nagorno-Karabakh War lasted from September 2020 to November 2020. Armenia and Azerbaijan claim sovereignty over the Nagorno-Karabakh region and had previously fought over the territory after the fall of the Soviet Union in the 1990s. After a cease-fire in 1994, numerous skirmishes occurred until the conflict escalated to war in 2020. At the start of the 2020 war, Armenia controlled the Nagorno-Karabakh territory.

Armenia and Azerbaijan's conventional forces consisted predominantly of Soviet-era tanks, aircraft, and air defense systems. Both sides had procured more modern Russian and Chinese ballistic missiles. They sparingly used these missiles due to limited inventories and a desire to contain the conflict to the Nagorno-Karabakh region.[26] With its larger defense budget based on Caspian Sea oil extraction, Azerbaijan procured

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

advanced UAS systems from Israel and Turkey before the start of the 2020 war,[27] including the Israeli Harpy and Harop loitering munitions, which fall into the DoD group 3 classification.

These UAS proved to be a critical factor within the war, with some excited analysts even claiming that it portended the end of the tank.[28] Numerous reports argued that these loitering munitions were game-changing in the conflict.[29] The Harpy UAS provided significant advantages in precision long-range strike capabilities. These UASs allowed Azerbaijani forces to find, target, and destroy enemy forces and equipment far behind the battlefield's front lines.[30] The loitering munition UAS destroyed a large number of Armenian artillery units, fighting vehicles, tanks, and air defenses, including the T-72 tank and S-300 air defense system.[31] The capability to strike behind the front lines also allowed the Azerbaijanis to weaken or destroy Armenia supply lines into

[27] Robyn Dixon, "Azerbaijan's Drones Owned the Battlefield in Nagorno-Karabakh — and Showed Future of Warfare," *Washington Post*, November 11, 2020, https://www.washingtonpost.com/world/europe/nagorno-karabkah-drones-azerbaijan-aremenia/2020/11/11/441bcbd2-193d-11eb-8bda-814ca56e138b_story.html.

[28] Peter Suciu, "Does the Nagorno-Karabakh Conflict Prove the Tank Is Toast?," *The National Interest*, October 5, 2020, https://nationalinterest.org/blog/buzz/does-nagorno-karabakh-conflict-prove-tank-toast-170155.

[29] "The Azerbaijan-Armenia Conflict Hints at the Future of War," *The Economist*, October 8, 2020, https://www.economist.com/europe/2020/10/08/the-azerbaijan-armenia-conflict-hints-at-the-future-of-war; Alex Gatopoulos, "The Nagorno-Karabakh Conflict Is Ushering in a New Age of Warfare," *Al Jazeera*, October 11, 2020, https://www.aljazeera.com/features/2020/10/11/nagorno-karabakh-conflict-ushering-in-new-age-of-warfare; Robyn Dixon, "Azerbaijan's Drones Owned the Battlefield in Nagorno-Karabakh — and Showed Future of Warfare," *Washington Post*, November 11, 2020, https://www.washingtonpost.com/world/europe/nagorno-karabkah-drones-azerbaijan-aremenia/2020/11/11/441bcbd2-193d-11eb-8bda-814ca56e138b_story.html.

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

[31] Robyn Dixon, "Azerbaijan's Drones Owned the Battlefield in Nagorno-Karabakh — and Showed Future of Warfare," *Washington Post*, November 11, 2020, https://www.washingtonpost.com/world/europe/nagorno-karabkah-drones-azerbaijan-aremenia/2020/11/11/441bcbd2-193d-11eb-8bda-814ca56e138b_story.html; Shaan Shaikh and Wes Rumbaugh, "The Air and Missile War in Nagorno-Karabakh: Lessons for the Future of Strike and Defense," *CSIS*, December 8, 2020, https://www.csis.org/analysis/air-and-missile-war-nagorno-karabakh-lessons-future-strike-and-defense.

Nagorno-Karabakh. These UAS not only proved capable in combat, but also supported Azerbaijani Information Operations. Video footage of the UAS strikes flooded Western media and advanced the narrative that Azerbaijan was decisively defeating Armenia.[32] These loitering munitions blur the line between UAS and cruise missiles. Speed, propulsion, and ISR capability provide the main current differences in terminology. The Israeli Harop loitering munition flies significantly slower than a cruise missile due to its propeller-driven propulsion system, allowing it to loiter over an area. The Harop also includes a suite of ISR capabilities to identify targets while loitering. A Center for Strategic and International Studies report noted that air war's "primary lesson" was the importance of full-spectrum air defense.[33] The report noted that Azerbaijan exploited a gap in Armenian SHORAD assets with a large fleet of sophisticated UASs.

Recent conflicts in the Middle East, Europe, and the Caucasus have demonstrated that UAS use has proliferated to numerous groups and has become ubiquitous on the battlefield. Actors have employed UAS to varying degrees of success and impact against opposing forces. As the technology continues to progress and systems increase speed, payload, and other capabilities, the UAS threat will continue to grow. UAS autonomous programming that allows the systems to work in concert without human control may provide the next leap in the technological development of UAS.

[32] Alex Gatopoulos, "The Nagorno-Karabakh Conflict Is Ushering in a New Age of Warfare," *Al Jazeera*, October 11, 2020, https://www.aljazeera.com/features/2020/10/11/nagorno-karabakh-conflict-ushering-in-new-age-of-warfare.

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

CHAPTER 3: THE FUTURE—AI SWARMS

The attack on the Saudi Arabian oil infrastructure, employing numerous drones in a coordinated attack, could be considered the first documented UAS swarm attack. The attacking UAS did not have autonomy, but demonstrated the effect of UAS attacking in mass. Swarms of inexpensive UASs, due to a coordinated effort, could do the work of one expensive multi-purpose aircraft platform. They could expand the observation area using the ability to communicate and combine data. Swarms of autonomous UAS could bring together mass, coordination, intelligence, speed, resilience, and responsiveness on the battlefield, improving belligerents' ability to gain a decisive advantage over opponents.[1] By massing UAS and maneuvering UAS in coordination, the swarm can overwhelm air defense systems by their sheer numbers and act as precision weapons.[2] To create large swarms of UAS acting in concert, the UAS systems require a level of autonomy. Artificial intelligence (AI) will allow the individual UASs to communicate with each other, observe the environment, and adapt to changes within the environment. AI will increase resiliency, allowing adaptation to the destruction or incapacitation of components without affecting the overall swarm. In effect, the swarm will be self-healing. Without AI, large preprogrammed swarms would have difficulty responding to changes in the environment or navigating as a group. Remotely piloting individual UAS would result in difficulty coordinating the swarm and responding to changes in the environment as a group, let alone the manpower requirements to pilot numerous UASs. With advanced autonomous and network capabilities, swarming UAVs could operate

[1] Paul, Scharre, "Robotics on the Battlefield Part II: The Coming Swarm," *Center for a New American Security*, 2014, http://www.jstor.org/stable/resrep06405.

[2] Ibid.

flexibly in non-linear ways. They could adapt to different scenarios by coordinating as small dispersed individuals attacking from different directions, or they could team up to provide mass and attack as a unit.[3] Researchers have worked on the concept for over a decade, with demonstrations of swarm technology now commonplace.[4] Current demonstrations have used groups of homogenous UASs. However, future swarms could deploy heterogeneous components with different tasks synergically contributing to the overall mission objective. The swarming concept is now being implemented thanks to progress in various technologies, including sensing, digitization, networking, and artificial intelligence (AI).

The U.S., China, and Russia have all determined that AI is critical to national security and that the development and implementation of AI systems could bring them competitive advantages in international relations. Russian President Vladimir Putin summarized the potential importance of this technology when he stated that the nation that leads in the development of AI would "become the ruler of the world."[5] While AI has numerous potential military applications, all three nations have begun developing and testing UAS swarms with varying levels of AI autonomy.

The U.S. has emphasized AI's importance to national security by passing the National AI Initiative Act of 2020, creating the National Artificial Intelligence Initiative

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[3] John Arquilla and David Ronfeldt, "Swarming -- The Next Face of Battle," *The RAND Blog*, September 29, 2003, https://www.rand.org/blog/2003/09/swarming----the-next-face-of-battle.html.

[4] Rachel Cohen, "Air Force to Test Weapons Swarming Software in October," *Air Force Magazine*, September 21, 2020, https://www.airforcemag.com/air-force-to-test-weapons-swarming-software-in-october/; Franz-Stefan Gady, "Drone Swarms: How the U.S Navy Plans to Fight Wars in 2016," *The Diplomat*, April 23, 2015, accessed August 27, 2016, http://thediplomat.com/2015/04/drone-swarms-how-the-us-navy-plans-to-fight-wars- in-2016/; Dyllan Furness, "The Sound of 103 Micro Drones Launched from an F/A-18 Will Give You Nightmares," *Digital Trends*, January 11, 2017, http://www.digitaltrends.com/cool-tech/perdix-drone-swarm/

[5] Radina Gigova, "Who Vladimir Putin Thinks Will Rule the World," *CNN Digital*, September 2, 2017, https://www.cnn.com/2017/09/01/world/putin-artificial-intelligence-will-rule-world/index.html.

Office, and including AI as a protected technology within the U.S. National Strategy for Critical and Emerging Technologies. The DoD released a Department of Defense Artificial Intelligence Strategy in 2018. The U.S. Department of Defense and U.S. defense contractors have researched UAS swarms for over a decade and have moved into the testing of numerous systems.

The Navy Post Graduate School conducted a UAS swarm test, controlling 50 UASs with a single human operator in 2015.[6] The school's Advanced Robotic Systems Engineering Laboratory (ARSENL) created a basic follow the leader programming that allowed the UAS to communicate with each other and maintain spacing during the flight. A human operator controlled the overall navigation of the swarm. While this test lacked full autonomy, it demonstrated the progress academic institutions can make in the field.

The Office of Naval Research also conducted a swarm test in 2015, releasing a video of the LOCUST program test, or the Low-Cost Unmanned Aerial Vehicle Swarming Technology. LOCUST consists of a tube-based launcher-type mechanism with 30 tubes containing 30 UAS. The launcher can eject the UAS in rapid succession. Once launched from the tubes, the UAS can communicate with each other and perform ISR or attack targets. "The breakthrough technology … utilizes information-sharing between the UAVs, enabling autonomous collaborative behavior in either defensive or offensive missions," an ONR press release stated.[7] The press release stressed the low cost of each UAS and forcing adversaries to expend resources to defend against them,

[6] Lewis Hunsaker, "ARSENL Reaches Its Ultimate Goal of 50 Autonomous UAVs in Flight - Naval Postgraduate School," *Today@NPS*, August 31, 2015, https://nps.edu/-/arsenl-reaches-its-ultimate-goal-of-50-autonomous-uavs-in-flight.

[7] Franz-Stefan Gady, "Drone Swarms: How the US Navy Plans to Fight Wars in 2016," *The Diplomat*, April 23, 2015, https://thediplomat.com/2015/04/drone-swarms-how-the-us-navy-plans-to-fight-wars-in-2016/.

stating, "Lowering costs is a major benefit of UAVs …. Even hundreds of small autonomous UAVs cost less than a single tactical aircraft — and … having this capability will force adversaries to focus on UAV swarm response."

In 2016, the Strategic Capabilities Office, in partnership with the Naval Air Systems Command, demonstrated a swarm of 103 Perdix UAS.[8] Three F-18 aircraft launched the Perdix UASs from pods during the exercise. The UASs are also designed to fit into and be deployed from standard flare dispensers on fighter aircraft. The UASs then formed into a group and performed coordinated maneuvers.

The Air Force Research Laboratory realized that the actual UAS system in a swarm is less important than the autonomous control programming. The laboratory designated the Golden Horde program as one of three vanguard programs.[9] The vanguard programs will pull resources from across the research spectrum to speed development and testing. Golden Horde strives to apply autonomous software to existing platforms. In the first test, the laboratory incorporated the Golden Horde programming into Boeing's small diameter bomb, intending to have the multiple bombs identify targets and select the highest value target mid-flight, and then attack the target in a swarm.[10] The initial test failed when the software failed to transmit guidance data to the navigation system. The program plans further tests in 2021. The Air Force used a similar concept during Operation Iraqi Freedom, when the Air Force added GPS guidance kits to "dumb"

[8] Aaron Mehta, "Pentagon Launches 103 Unit Drone Swarm," *Defense News*, August 8, 2017, https://www.defensenews.com/air/2017/01/10/pentagon-launches-103-unit-drone-swarm/.

[9] Rachel Cohen, "Skyborg, Weapon Swarms, Satellites Chosen as First 'Vanguards,'" *Air Force Magazine*, November 22, 2019, https://www.airforcemag.com/skyborg-weapon-swarms-satellites-chosen-as-first-vanguards/.

[10] Valerie Insinna, "US Air Force's 'Golden Horde' Swarming Munitions Program to Get Second Chance," *Defense News*, February 10, 2021, https://www.defensenews.com/air/2021/02/04/air-forces-golden-horde-swarming-munitions-program-to-get-a-second-chance-this-month/.

bombs to increase the available number of precision-guided weapons.[11] If successful, the Golden Horde software could be incorporated into numerous existing platforms to give them swarming capabilities, including UAS.

The Defense Advanced Research Projects Agency (DARPA) is testing a project to release and recover UAS swarms from a transport aircraft using semi-autonomous Gremlin UASs.[12] DARPA has not successfully recovered the UAS to date, but research and testing continue to address this issue. The concept uses a C-130 as a mothership, extending the range and reach of the swarm.

China has also determined that AI is crucial to its future military and industrial power and has aggressively pursued AI development to become the global leader in the field. "China seeks to become a leader in key technologies with military potential, such as AI, autonomous systems," according to the 2020 DoD China Military Power Report.[13] China, understanding the global impact of this problem, has initiated a plan for comprehensive, state-sponsored research and education in AI fields. The Chinese State Council published a document in July 2017, entitled Next Generation AI Plan, to explicitly illustrate the importance of developing these technologies. By 2030, China intends to become the global leader in AI innovation. China's government structure, laws and regulations, public perceptions regarding privacy, and the relationship between the government and private companies all provide advantages to China in developing AI.

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[11] John R. Allen and Amir Husain, "AI Will Change the Balance of Power." *United States Naval Institute Proceedings* 144, no. 8 (08, 2018), http://search.proquest.com.nduezproxy.idm.oclc.org/trade-journals/ai-will-change-balance-power/docview/2123715220/se-2?accountid=12686.

[12] Valerie Insinna, "The First 9 Attempts to Retrieve Swarming Gremlins Drones Failed. Here's What's next.," *Defense News*, December 11, 2020, https://www.defensenews.com/air/2020/12/11/the-first-nine-attempts-to-retrieve-swarming-gremlins-drones-failed-heres-whats-next/.

[13] Office of the Secretary of Defence. *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2020*. Washington DC: Department of Defense. August 21, 2020.

China's AI strategy has already paid dividends, as Chinese companies are the global leaders in facial and speech recognition AI software.[14]

China's large industrial base already leads the world in commercial UAS production. China's leading commercial drone manufacturer, DJI, dominates the market, producing 70% of all commercial drones sold worldwide.[15] China also desires to become the global leader in military UAS. The Department of Defense has estimated that China plans to field 41,800 UAS by 2023.[16] Secretary Esper warned of the threat Chinese UAS pose stating,

> As we speak, the Chinese government is already exporting some of the most advanced military aerial drones to the Middle East, as it prepares to export its next-generation stealth UAVs (unmanned aerial vehicles) when those come online… In addition, Chinese weapons manufacturers are selling drones advertised as capable of full autonomy, including the ability to conduct lethal, targeted strikes.[17]

With significant investments in AI and the industrial base to support UAS development, China is advantageously positioned to develop AI UAS. In 2018, China broke the record for the largest UAS formation flown simultaneously, flying 1,108 UAS during an entertainment exhibition.[18] China has publicized several other demonstrations

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[14] Graham Allison, "Is China Beating America to AI Supremacy?," *The National Interest*, December 22, 2019, https://nationalinterest.org/feature/china-beating-america-ai-supremacy-106861.

[15] Laura Wood. "China Drone Market Report 2019: Market Will Grow from $14 Billion in 2018 to Over $43 Billion in 2024 at a CAGR of 20.5." *Business Wire*, November 1, 2019, https://www.businesswire.com/news/home/20191101005200/en/China-Drone-Market-Report-2019-Market-will-Grow-from-14-Billion-in-2018-to-Over-43-Billion-in-2024-at-a-CAGR-of-20.5---ResearchAndMarkets.com.

[16] Office of the Secretary of Defence. *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2016*. Washington DC: Department of Defense. April 07, 2015.

[17]Melissa Leon, "China Exporting Lethal Drones to Middle East, Esper Says," *Fox News*, November 6, 2019, https://www.foxnews.com/us/china-lethal-drones-middle-east-mark-esper-pentagon-warning.

[18] Scott Romaniuk, "China's Swarms of Smart Drones Have Enormous Military Potential," *The Diplomat*, February 3, 2018, https://thediplomat.com/2018/02/chinas-swarms-of-smart-drones-have-enormous-military-potential/.

of UAS swarms flying with autonomy.[19] China has also developed a system similar to the U.S. LOCUST system, a mobile launcher capable of releasing a swarm of UAS. The Chinese test differed in that the swarm consisted of 48 CH-901 type loitering munitions.[20]

As the Putin quote from above illustrated, Russia believes that AI development will significantly impact the balance of power between nation-states. Russia released its national AI strategy, "National Strategy for the Development of Artificial Intelligence Through 2030," in 2019.[21] Russia has a tradition of strong academics in science and technology and effective development of its current technologies. But with a technology industry smaller than China or the USA, Russia must set and achieve such ambitious goals to stay competitive. Like China, the centralized Russian government has more influence over how AI will develop in the country. Russia currently lags behind both the U.S. and China in AI development.[22]

As a result of the Russian-Georgian war of 2008, Russia developed a comprehensive military modernization plan. Russia identified a lack of UAS during the conflict as negatively impacting its military performance.[23] Russia's subsequent operations in Ukraine and Syria demonstrate that they have corrected this deficiency and

[19] Joseph Trevithick, "China Is Hard At Work Developing Swarms Of Small Drones With Big Military Applications," *The War Zone*, January 16, 2018, https://www.thedrive.com/the-war-zone/17698/chinas-is-hard-at-work-developing-swarms-of-small-drones-on-multiple-levels.

[20] Joseph Trevithick, "China Conducts Test Of Massive Suicide Drone Swarm Launched From A Box On A Truck," *The War Zone*, October 14, 2020, https://www.thedrive.com/the-war-zone/37062/china-conducts-test-of-massive-suicide-drone-swarm-launched-from-a-box-on-a-truck.

[21] Elena Chernenko and Nikolai Markotkin, "Developing Artificial Intelligence in Russia: Objectives and Reality," *Carnegie Moscow Center*, May 8, 2020, https://carnegie.ru/commentary/82422.

[22] Ibid.

[23] Keir Giles, "Assessing Russia's Reorganized and Rearmed Military," *Carnegie Endowment for International Peace*, May 3, 2017, https://carnegieendowment.org/2017/05/03/assessing-russia-s-reorganized-and-rearmed-military-pub-69853.

increased their UAS capabilities.[24] Like the U.S. and China, Russia has also begun testing UAS swarms. During the annual Kavkaz military exercise in 2020, Russia demonstrated UAS swarms consisting of various UAS platforms acting in unison to support conventional forces.[25]

Cutting-edge weapons systems' development and procurement costs continue to rise. Systems like the F-22 Raptor and Zumwalt class destroyer program highlight the issue of rising costs for advanced systems. The Air Force planned to purchase 750 F-22s, but budgetary concerns reduced the procurement to only 187 aircraft. Similarly, the Navy planned to purchase thirty-two Zumwalt class destroyers, but rising costs reduced the procurement to only three ships.[26] These situations resulted in the Joint Force obtaining exquisite platforms, but in severely limited quantities. Swarms can provide an alternative to this procurement model. The development of the programming, algorithms, and software is the most challenging aspect of swarming. The development and procurement of the physical platforms do not require significant investments. A nation-state can procure tens or hundreds of thousands of UASs for the price of a single advanced ship or aircraft. The Golden Horde project attempts to decouple the software from the platform. Golden Horde has the potential to be applied to current and future Military UAS, commercial UAS, and even legacy manned platforms. Previously manned systems, such as the F-16, may be adapted into swarms on future battlefields.

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[24] Ibid.

[25] Joe Varner, "Swarms Over Kavkaz," *Modern War Institute*, October 27, 2020, https://mwi.usma.edu/swarms-over-kavkaz/.

[26] T.X. Hammes, "The Future of Warfare: Small, Many, Smart vs. Few & Exquisite?," War on the Rocks, July 16, 2014, https://warontherocks.com/2014/07/the-future-of-warfare-small-many-smart-vs-few-exquisite/.

UAS have proliferated to 102 countries' militaries worldwide in 2020, with 52 countries now fielding armed UAS.[27] In addition to the U.S., China, and Russia, several other countries are actively pursuing military UAS swarms.[28] With numerous countries developing multiple systems, drone swarms will end up on the battlefield in the near future. These systems will likely proliferate worldwide through foreign military sales as unarmed and armed UASs have already spread. Future conflicts will inevitably incorporate swarms of UAS with some level of autonomy.

[27] Dan Gettinger, "DRONE DATABOOK UPDATE: MARCH 2020," *Center for the study of the drone at Bard College,* March 2020, https://dronecenter.bard.edu/files/2020/03/CSD-Databook-Update-March-2020.pdf.

[28] Dave Makichuk, "Test of RAF Drone Swarm 'a Game Changer,'" *Asia Times*, October 13, 2020, https://asiatimes.com/2020/10/test-of-raf-drone-swarm-seen-as-game-changer/; David Hambling, "Indian Army Shows Off Drone Swarm Of Mass Destruction," *Forbes*, January 19, 2021, https://www.forbes.com/sites/davidhambling/2021/01/19/indian-army-shows-off-drone-swarm-of-mass-destruction/; Joseph Trevithick, "Turkey Now Has Swarming Suicide Drones It Could Export," *The War Zone,* June 18, 2020, https://www.thedrive.com/the-war-zone/34204/turkey-now-has-a-swarming-quadcopter-suicide-drone-that-it-could-export.

CHAPTER 4: U.S. RESPONSE TO THE UAS THREAT

Senior Department of Defense Officials have warned of the threat UAS pose to the Joint Force for several years. In 2014, General James Mattis warned, "The proliferation of low-cost, tactical unmanned aerial systems demand we think about this potential threat now....We must understand the threat these systems present to our joint force and develop the tactics, techniques, and procedures to counter the problem."[1] However, only recently has the joint force reoriented procurement, training, and doctrine to this threat. Furthermore, this reorientation only addresses the previous and current generation of UAS threats. As discussed in the previous chapter, UAS swarms will rapidly become a reality on the battlefield and must also be addressed.

At the end of the Cold War, a SHORAD battalion protected every U.S. Army division. By 2005, the U.S. Army reduced the SHORAD force to two battalions of active component Avenger and counter-rocket, artillery and mortar (CRAM) batteries, and seven National Guard Avenger battalions.[2] In 2017, none of the ten active Army divisions had a dedicated SHORAD battalion. The use of UAS in recent conflicts highlighted the lack of an organic counter-UAS SHORAD capability within Army divisions. The Commandant of the Air Defense Artillery School at Fort Sill, Col. Mark A. Holler, noted that the Ukraine conflict had given the Army a "wake-up" regarding the need for SHORAD.[3] The Department of Defense has addressed this deficiency against current UAS threats in several ways.

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[1] F. Patrick Filbert and Darryl Johnson, "Joint Counter Low, Slow, Small Unmanned Aircraft Systems Test," *Fires* PB644-14, no. 4 (July-August 2014): 21.

[2] Andrew Feickert, "U.S. Army's Interim Maneuver, Short-Range Air Defense (IM-SHORAD) System," *Congressional Research Service*, Library of Congress, July 18, 2018. https://crsreports.congress.gov/product/pdf/IN/IN10931/2.

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

The U.S. Army has developed the Interim Maneuver Short-Range Air-Defense (IM-SHORAD) platform that mirrors the basic concept of the Pantsyr-S1. Both the Pantsyr-S1 and IM-SHORAD employ a radar, short to medium-range surface-to-air missiles, and a machine gun attached to a wheeled vehicle. The Pantsyr-S1 is mounted on an 8x8 military truck, while the IM-SHORAD will be mounted on a Stryker. The IM-SHORAD concept originated with an Avenger air defense system mounted to a Stryker. The concept has since progressed to a General Dynamics developed multi-purpose unmanned turret that includes two Hellfire missiles capable of hitting ground and air targets; four Stinger missiles for aerial targets; a 30mm automatic cannon; a 7.62mm machine gun; an electronic warfare package; and a multi-mission radar capable of tracking both ground and air targets.[4] In October 2020, the Department of Defense awarded General Dynamics a $1.2B contract to procure 144 IM-SHORAD systems spread among four battalions by fiscal year 2023.[5] In addition to the IM-SHORAD, the U.S. Army is also pursuing a Directed-Energy Short-Range Air-Defense (DE-SHORAD) system that will use a 50kW laser to disable air threats.[6]

Both the IM-SHORAD and DE-SHORAD systems will increase the capability of the Joint Force against UAS threats. However, these systems will not become operational until at least 2023 for the IM-SHORAD and even later for the DE-SHORAD. Neither system fully addresses the swarm threat, with the IM-SHORAD having a fixed amount of ammunition and the DE-SHORAD requiring laser dwell time on a target to destroy it. As

[4] Ibid

[5] Arun, Mathew. "U.S. Army Awards General Dynamics $1.2 Billion IM-SHORAD Contract." *DefPost*, October 1, 2020. https://defpost.com/u-s-army-awards-general-dynamics-1-2-billion-im-shorad-contract/.

[6] Devon Suits. "Army Gets Closer to Fielding New Air Defense Systems." *Army News Service*, August 10, 2020. https://www.army.mil/article/237878/army_gets_closer_to_fielding_new_air_defense_systems.

a precursor to the interim solution, the Army has removed the previously discussed Avenger systems from storage and refurbished 72 units to return to operational use.[7] With only 72 available systems, the Army must prioritize the Avenger's use in operations where the UAS threat is most likely.

The IM-SHORAD, DE-SHORAD, and Avenger systems may all be vulnerable to being overwhelmed by a swarm. The Joint Force must begin research and development on Electronic Warfare Systems designed to disrupt UAS systems guidance and communication to add another defeat mechanism to the force structure. The Joint Force must also investigate cyberwarfare capabilities to disable UAS systems. General John Allen has theorized a concept he refers to as "hyperwar."[8] In this concept, AI has reduced the time to observe, orient, decide and act to near-instantaneous. To respond quickly enough against AI swarms, defensive systems must also utilize AI. Designs for SHORAD systems must include aspects of AI automation to have the ability to respond to UAS swarms.

The Department of Defense designated the Army as Executive Agent for Counter small Unmanned Aircraft Systems (C-sUAS) in 2019 and created the Joint C-sUAS Office (JCO) in January 2020.[9] The JCO has coordinated efforts among the services, narrowing the development of 40 separate defensive radio-frequency jamming C-sUAS

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

[8] John R. Allen and Amir Husain, "ON HYPERWAR." *United States Naval Institute Proceedings* 143, no. 7 (07, 2017), http://search.proquest.com.nduezproxy.idm.oclc.org/trade-journals/on-hyperwar/docview/1919092891/se-2?accountid=12686.

[9] Caitlin Kenney. "Army General to Lead New Pentagon Unit to Counter Drone Strikes on the Battlefield." *Stars and Stripes*, January 17, 2020. https://www.stripes.com/news/army/army-general-to-lead-new-pentagon-unit-to-counter-drone-strikes-on-the-battlefield-1.615210.

systems to the eight most viable.[10] This coordinating effort demonstrates the necessity for a Joint entity to reduce redundancy and inefficiency and focus the services on Joint solutions to the UAS problem. The JCO will develop a "common core C-UAS program of instruction, publish joint tactics, techniques, and procedures, and update existing doctrine to refine and improve educational baselines across the force."[11]

The JCO drafted and Acting Secretary of Defense Christopher Miller approved the *Department of Defense Counter-Small Unmanned Aircraft Systems Strategy* in January 2021.[12] The strategy provides the framework to address the UAS threat across the Doctrine, Organization, Training, Materiel, Leadership, and Education, Personnel, Facilities—Policy (DOTMLPF-P) spectrum. The strategy provides three strategic objectives and three strategic approaches to achieve the objectives:

1. Enhance the Joint Force through innovation and collaboration to protect DoD personnel, assets, and facilities in the homeland, host nations, and contingency locations.
2. Develop materiel and non-materiel solutions that facilitate the safe execution of DoD missions and deny adversaries the ability to impede our objectives.

[10] Thomas Brading. "Army Selects Countermeasures against Drones." *Army News Service*. June 29, 2020. https://www.army.mil/article/236839/army_selects_countermeasures_against_drones.

[11] Jen Judson. "The Pentagon Is Building a School to Teach the Force How to Defeat Drones." *Defense News*, October 30, 2020. https://www.defensenews.com/digital-show-dailies/ausa/2020/10/30/pentagon-is-building-a-school-to-teach-the-force-how-to-defeat-drone-threats/.

[12] U.S. Army Public Affairs, "Army Announces Release of DoD Counter-Small UAS Strategy," *Army News Service*, January 7, 2021, https://www.army.mil/article/242241/army_announces_release_of_dod_counter_small_uas_strategy.

3. Build and broaden our relationships with allies and partners to protect our interests at home and abroad.[13]

The Joint Force must immediately and diligently work to implement this strategy. While the strategy adequately addresses the current threat, it lacks a plan to deal with the emerging swarm threat. The document only provides two sentences regarding swarms included in the Security Environment section, stating that this emerging threat will introduce another change to the character of war.[14] While working to implement this strategy, the Joint Force must consider the threat of UAS swarms.

In October 2020, the Pentagon announced the creation of a C-sUAS academy at Fort Sill, Oklahoma, with an initial operational capability in fiscal year 2024. Lt. Col. David Morgan of the JCO stated, "There are currently no joint linkages or commonality to counter-UAS training across the department, every service is executing service-specific training. The average soldier, airman, or Marine lacks adequate counter-UAS training. It's not fully embedded in the [program of instruction] from basic training onward."[15] The Joint Force must address this lack of training immediately. The current timeline to create an operational training center in 2024 will not prepare forces for the current threat of group one through three UASs. The services should immediately incorporate interim training, approved by the JCO, to fill the gap until the C-sUAS

[13] U.S. Department of Defense, "DEPARTMENT-OF-DEFENSE-COUNTER-SMALL-UNMANNED-AIRCRAFT-SYSTEMS-STRATEGY" (Washington, D.C., January 7, 2021), https://media.defense.gov/2021/Jan/07/2002561080/-1/-1/1/DEPARTMENT-OF-DEFENSE-COUNTER-SMALL-UNMANNED-AIRCRAFT-SYSTEMS-STRATEGY.PDF, 5.

[14] Idib,6.

[15] Jen Judson. "The Pentagon Is Building a School to Teach the Force How to Defeat Drones." *Defense News*, October 30, 2020. https://www.defensenews.com/digital-show-dailies/ausa/2020/10/30/pentagon-is-building-a-school-to-teach-the-force-how-to-defeat-drone-threats/.

academy is fully operational. Interim training and the eventual courses of study at the academy must address UAS swarm threats as these systems continue development and become operational.

The JCO and the *Counter-Small Unmanned Aircraft Systems Strategy* identify the need to update doctrine to enhance the Joint Force's operational effectiveness and create a shared understanding between the Services. To date, only the Army has released one doctrinal publication on Counter UAS. The Army released the two most recent versions of this publication in 2016 and then updated it in 2017. The Army Technical Publication (ATP) 3-01.8 *Techniques for Combined Arms for Air Defense* published in 2016 identifies the UAS swarm attack as "perhaps the most dangerous" against ground forces, although not highly probable. The Army changed the title in the 2017 publishing of ATP 3-01.8 to "Counter-Unmanned Aircraft System Techniques." The 2017 ATP 3-01.8 focuses directly on UAS, whereas the 2016 version also included missile, rocket, artillery, and manned aircraft. Despite the focus on UAS, the 2017 ATP removes all references to UAS swarms and substitutes "Mass UAS employment by threat forces can produce overwhelming effects on maneuver forces," as the only passing mention of the threat.[16] The 2017 ATP occasionally provides guidance that does not appear to take into consideration the current environment. Suggesting that commanders "identify Soldiers to act as observers (air guard) throughout all phases of the operation" follows the 1999 Field Manual 44-8 passive and active air defense techniques verbiage, initially

[16] US Department of the Army, Army Techniques Publication (ATP) 3-01.81, *Counter-Unmanned Aircraft System Techniques*, Washington, DC: Government Printing Office, April 2017, 1-1.

created for identifying Soviet-style fighter and bomber jets during the Cold War.[17] The JCO and the services must draft and publish complementary updated doctrine to advance the Joint Force's operational effectiveness.

An Air Force contract solicitation demonstrates the lack of C-sUAS doctrine, material, and training. The Air Force released a $925 million contract solicitation to provide airbase defense in Europe against Russian cruise missiles and Chinese UAS.[18] The contract stipulates that in addition to cruise missile defense, the proposal must provide capabilities to defeat up to 15 Da-Jiang Innovations variant UAS capable of attacking from any direction. Da-Jiang Innovations, or commonly known as DJI, are commercially available hobbyist UASs. The contract requests the material solutions to deal with the threats and a concept of operations and plans on how to employ the material solutions. The capability to defend fixed facilities from the threat of UAS does not only apply to airbases, but all Joint facilities. This contract demonstrates the lack of Joint materiel, doctrine, and concepts of operations in the protection joint function and how serious the Air Force considers the problem, and how critically the Joint Force needs a solution to this problem.

As with the Army Brigade level divestment of SHORAD after the Cold War, this contract reveals that the Joint Force has also divested of air defense and specifically SHORAD protection materiel and doctrine for fixed facilities such as airfields. During the Cold War, the Army and Air Force shared responsibility for airbase defense in

[17] Jason M. Kowrach, "US Army Counter-Unmanned Aerial Systems: More Doctrine Needed," (Monograph, School of Advanced Military Studies US Army Command and General Staff College, Fort Levenworth, 2018), 18.

[18] John Vandiver, "Air Force in Europe Seeks Defense against Chinese Drones and Russian Cruise Missiles," *Stars and Stripes*, December 16, 2020, https://www.stripes.com/news/europe/air-force-in-europe-seeks-defense-against-chinese-drones-and-russian-cruise-missiles-1.655492.

Europe. The Air Force provided air-air defense, and the Army provided ground-to-air defense. With the collapse of the Soviet Union, the Army air defense assets were removed from the European theater and repurposed to other missions or divested.[19]

[19] Alan Vick et al., "Air Base Defense: Rethinking Army and Air Force Roles and Functions" (RAND Corporation, 2020), https://doi.org/10.7249/RR4368.

CHAPTER 5: CONCLUSION

Once used by only advanced militaries, UAS technology has proliferated to numerous smaller militaries, commercial industries, and non-state actors. Currently, the militaries in 102 out of 195 countries now employ UAS; this number will only continue to increase in the future. Terrorists and rebel groups in the Middle East have employed UAS in various roles, and similar groups worldwide have the same ability to adapt commercially available UAS for military ends. The Joint Force has integrated UAS into the lowest tactical echelons and must realize that adversaries ranging from near-peer competitors to violent extremist organizations have done the same. The effective use of UAS in recent conflicts in the Middle East, Ukraine, and the Caucasus regions demonstrate the ubiquitous nature of UAS in modern war and that future conflicts will undoubtedly employ UAS in ever-increasing numbers and mission sets. The employment of loitering munition UAS by Azerbaijani's proved a critical factor in their overwhelming success against Armenian forces. The devastating attack on the Saudi oil facility demonstrated the effectiveness of drones attacking precisely and in mass, analogous to a swarm attack.

The Joint Force has identified gaps in material, doctrine, and training to counter UAS threats and has progressed in closing these gaps. The Joint Force must build on the work already done to address current UAS threats adequately. The current threat requires the Joint Force to accelerate this work. The Joint Force has progressed by establishing the JCO office. As demonstrated by the numerous Counter-UAS materiel solutions pursued by the Services, the DoD requires a Joint office to coordinate efforts to gain efficiency. The UAS threat affects all services and requires a Joint response. The DoD

C-sUAS strategy, released in January 2021, identifies the strategic objectives, strategic approaches, and lines of effort, allowing for a coordinated effort throughout the Department to build a capable C-sUAS Joint Force.

The planned creation of a Joint C-UAS training academy will allow the Joint Force to establish linkages and commonality across the force. The current timeline to create an operational training center in 2024 does not prepare joint forces for the current threat. The services should immediately incorporate interim training, approved by the JCO, to fill the gap until the C-sUAS academy is fully operational. Interim training and the eventual courses of study at the academy must address UAS swarm threats as these systems continue development and become operational. The Joint Force should make training a leadership priority and use exercises, experimentation, and wargaming to validate C-sUAS concepts and solutions.

Congressional appropriations for C-sUAS materiel development and procurement will ensure that the Joint Force has the equipment to counter this threat. These steps represent a new emphasis on countering the UAS threat after allowing the SHORAD program to languish during the GWOT. Development of the IM-SHORAD and DE-SHORAD systems will begin to provide the Joint Forces with the means to Counter sUAS. As the recent conflicts have demonstrated, a defense in depth air-defense model is required. The Joint Force must immediately begin developing counter-swarm air defense systems and test current systems for this emerging threat.

The Joint Force currently has only one doctrinal publication dedicated to C-sUAS, and sections of the publication present outdated concepts. The Joint Force must validate new C-UAS concepts. Once validated, the Joint Force should issue new Tactics,

Techniques, and Procedure publications. Derived from the C-sUAS strategy, validated exercises, and training results, the Joint Staff must update Joint doctrine on countering sUAS threats.

Advances in UAS technology and AI will significantly increase the current UAS threat. The U.S., China, Russia, and other countries are developing and testing UAS swarms with different levels of AI. This new development will significantly increase UASs' operational effectiveness on the battlefield. The Joint Force has taken steps to address the current UAS threat, but is unprepared for UAS swarms. To date, the C-sUAS efforts completed or planned by the Joint Force disregard UAS swarms. The Joint Force must immediately include this threat in C-sUAS efforts. New C-sUAS doctrine training and material must address the swarm threat, or U.S. forces will suffer the same fate as the Saudis, Ukrainians, and Armenians.

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