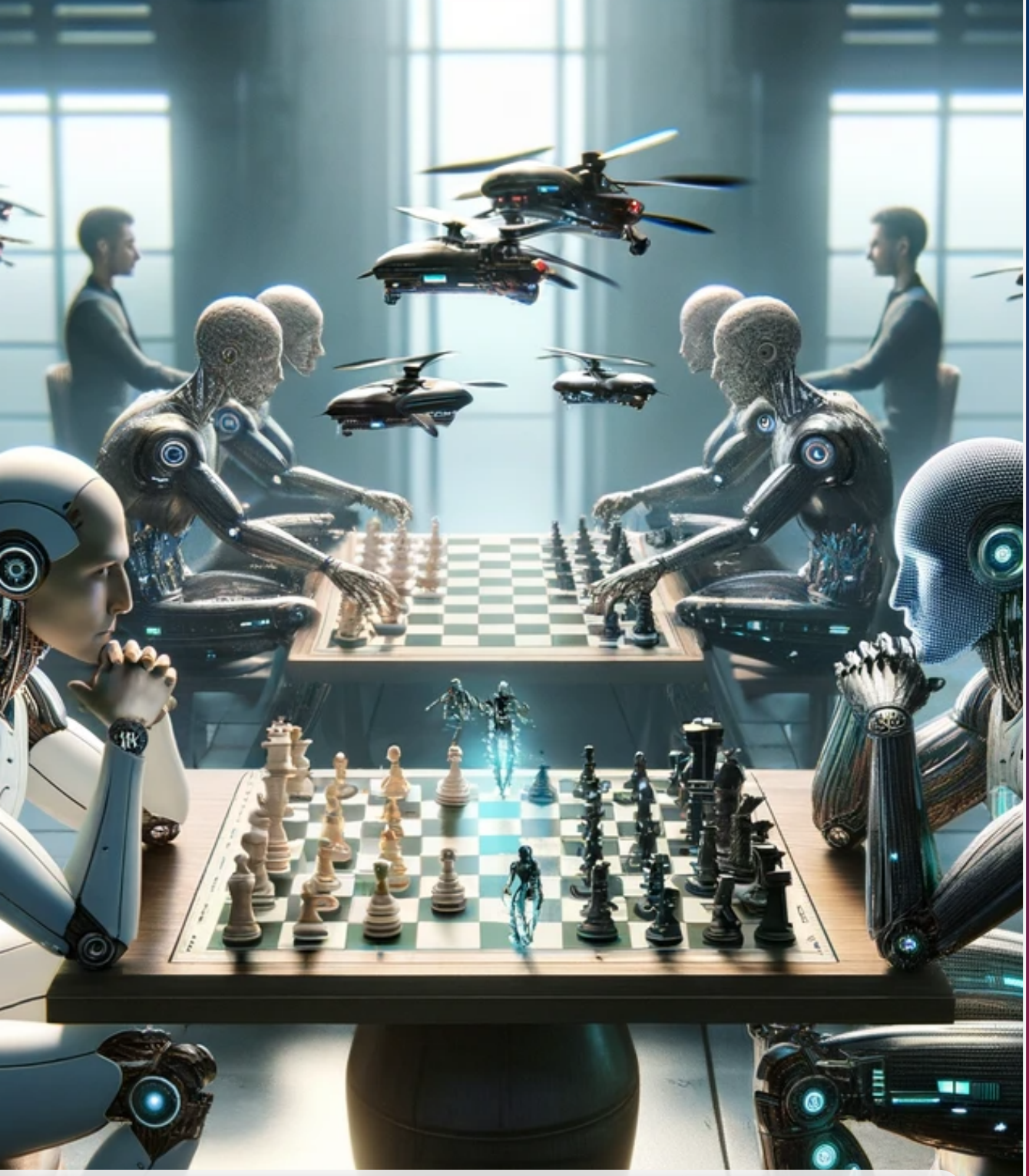

SPECIAL COMPETITIVE STUDIES PROJECT

Empowering the Edge

Uncrewed Systems and the Transformation of U.S. Warfighting Capacity

Lieutenant General (ret.) Clint Hinote, U.S. Air Force
Major General (ret.) Mick Ryan, Australian Army

Authors

Lieutenant General (ret.) S. Clinton Hinote
U.S. Air Force

S. Clinton Hinote is a retired Air Force lieutenant general and the first leader of Air Force Futures. Throughout his career, he served at the leading edge of change–developing novel tactics, revising dated battle plans, reinventing staid organizations, leading complex alliances, and disrupting dated doctrine. In his role as the Deputy Chief of Staff for the Air Force, he led a 400-person organization to become "Air Force Futures," responsible for planning and integration for the future Air Force. His intellectual leadership resulted in a fundamental reconsideration of how the Department of Defense can succeed in the competition with China, connecting military power to political objectives.

The general has extensive diplomatic experience, serving as a commander both in NATO and Korea, and also serving on the Country Team at US Embassy Baghdad, where the Ambassador tapped him to act as Deputy Chief of Mission in his absence. After retirement, he has transitioned to advising, coaching, and encouraging change-oriented leaders in national security across the government, business, finance, and non-profit sectors. General Hinote is a senior defense advisor to the Special Competitive Studies Project, a field expert at Dcode, and a principal at Pallas Advisors. General Hinote graduated first in his class at both the Air Force Academy and Air Command and Staff College. He holds a Master's in Public Policy from Harvard's Kennedy School and a PhD. in military strategy from Air University.

Major General (ret.) Mick Ryan
Australian Army

Mick spent 35 years in the Australian Army and had the honour of commanding soldiers at troop, squadron, regiment, task force and brigade levels. He has a long-standing interest in military history and strategy, advanced technologies, organizational innovation, and adaptation theory. He was inaugural President of the Defence Entrepreneurs Forum (Australia) and is a member of the Military Writers Guild. He is a keen author on the interface of military strategy, innovation, and advanced technologies, as well as how institutions can develop their intellectual edge.

In February 2022, Mick retired from the Australia Army. In the same month, his book War Transformed was published by USNI Books. He is an adjunct fellow at the Center for Strategic and International Studies in Washington DC, a non-resident fellow of the Lowy Institute in Sydney, and a senior defense advisor to the Special Competitive Studies Project. In January 2023 Mick was also appointed as an Adjunct Professor at the University of Queensland in Brisbane, Australia.

He runs his own strategic advisory company and is a regular columnist in the Sydney Morning Herald and ABC Australia. He also has frequent commentary appearances on ABC TV, the BBC and CNN. His latest book, White Sun War: The Campaign for Taiwan, was published on 4 May 2023 by Casemate Books. His next book, about strategy and adaptation in the Ukraine War, will be published in 2024.

> **"Under future labor and cost constraints, and with technological alternatives available today, continuing to fight with legacy fleets of expensive, labor-intensive systems is an economically dubious proposition. It may already be a war-losing strategy, as enemies target concentrations of power and people with their own masses of precision weapons."**[1]

New technologies often require updating old ideas, old strategies, and old ways of preparing humans for war. The influx of new technologies into military institutions is continuous, occurring since the dawn of war, albeit with increased frequency since the First Industrial Revolution. Every now and then, however, a new technology forces a disruptive shift in how wars are started, fought and ended. Uncrewed systems—which are now undergoing a form of Cambrian Explosion in capability, quality and quantity—appear to be such a technology. These systems are disrupting how combatants are considering risk, cost and authority on the modern battlefield.

U.S. Deputy Secretary of Defense Kathleen Hicks has confronted this challenge when she noted that "to stay ahead, we're going to create a new state of the art—just as America has before—leveraging attritable systems in all domains—which are less expensive, put fewer people in the line of fire, and can be changed, updated, or improved with substantially shorter lead times."[2] This is an admirable goal, and an essential foundation of the new *Replicator Program*.[3] Hicks' assertion is consistent with the evidence of modern battles from Nagorno-Karabakh to Ukraine to Gaza and northern Israel. The proven utility of uncrewed systems in the aerial and maritime environments portends a transition to a transformation of military operations across all domains, in many different types of integrated human-machine-AI teams. These uncrewed systems vary widely in cost and capability, and they are operated in remote-controlled, semi-autonomous and autonomous operating modes. We have yet to discover the full potential, and the entire range of different mission sets, that will open up because of this technology.

While we still have much to learn, it is evident that this widespread use of uncrewed systems—primarily in the air but increasingly in the ground and maritime domains—is disrupting the conduct of war. But despite the disruptive nature of uncrewed aerial systems, by themselves they are not transforming war. It is only when drones are combined with the democratization of digitized command and control systems and new-era meshed networks of civilian and military sensors that

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[1] James Hasik, Economy, Autonomy, and Rethinking the Military, CEPA (2023).
[2] Deputy Secretary of Defense Kathleen Hicks Keynote Address: 'The Urgency to Innovate' (As Delivered), U.S. Department of Defense (2023).
[3] The Replicator Program has been covered widely in the press and by think tanks since August 2023. See Michael O'Connor, Replicator: A Bold New Path for DoD, Center for Security and Emerging Technology (2023).

transformational change will occur. These three elements comprise a transformative trinity explored later in this paper, and it is only within this construct that drones will fully realize their potential for defense and other national security applications.

The most important impact of this transformation is that information in the battlespace—traditionally controlled by limited numbers of high-demand sensors and hierarchical distribution of analyzed information—has shifted from paucity to information profligacy. Consequently, the democratization of higher-quality information and its spread "to the edge" changes how military institutions command and control forces, how they group and regroup joint and combined arms teams, how tactics and the operational art are applied, and how people are trained and educated.

Crucially, this transformation must occur at a pace not seen for decades in Allied defense. institutions.

Technology is at the heart of this transformative trinity, and most of the technological components of the trinity are sourced from commercial entities. But, like all technologies, they require the innovation and agency of humans. Thus, people, process, and procurement elements – which are largely within the remit of the Department of Defense – are required for this transformative trinity to play a central role in developing effective deterrence and warfighting capabilities in the 21st century.

Crucially, this transformation must occur at a pace not seen for decades in Allied defense institutions. The imperative of a threat to democracies from an authoritarian 'quad' – Russia, China, Iran and North Korea – compels urgent change and adjustments as described in this paper.

Uncrewed Systems and War Under Modern Conditions

The character of war is not static. It changes in response to social, political and technical developments. As human perspectives change and new technologies emerge, effective militaries learn and adapt. Military organizations that combine the best of human performance and advanced technology often enjoy an advantage. At times, that advantage is decisive. During the post-Cold War era, for example, several one-sided battlefield contests occurred where Allied militaries quickly dominated adversaries stuck in older paradigms.[4]

[4] Unfortunately, quick battlefield victories did not lead to enduring political solutions in Iraq or Afghanistan.

Unfortunately, this advantage—what some have called "overmatch"—has eroded, and has done so rapidly. As the U.S. competition with China and Russia grows, we seek new ways of fighting. One new approach is the widespread use of uncrewed systems. These systems are changing how we perceive risk in the battle space. Risk is ever-present in war. For centuries, wartime leaders have accepted that a portion of one's military forces—the people doing the fighting—will have to face high risk to accomplish the mission. Attrition of humans and machines is the inevitable cost of fighting.

As the U.S. competition with China and Russia grows, we seek new ways of fighting.

In recent decades, however, our perspective has changed. Modern Allied militaries reflect a fundamental principle of Allied thought: every human being is valuable. We do everything possible to drive down risk to the individual. Fighter aircraft, tanks, warships, and submarines are the gold standard for protecting the people in them. So too is realistic training and detailed threat replication. In recent decades, when a new threat emerges in combat, we have developed protective capabilities at great cost.

Taken to an extreme, however, this approach is self-defeating. In recent decades, we have found ourselves expending ever-increasing resources for decreasing protection for our people, with increasing costs to our modern weapons systems. Leaders, rightly, want to buy down risk, and they are willing to spend a lot to do it. Modern military equipment is so valuable that it creates a strong disincentive to use it in battle. Besides the massive human and capability impacts, this development would have significant political effects as well. Allied militaries have few forces that can be considered attritable without high political cost, which undermines the conventional deterrent value of our militaries.

Our competitors know this; they have spent two decades developing sensors and weapons designed to find and destroy these costly assets. Relatively cheaper technologies that make exquisite modern weapons vulnerable have proliferated to our potential adversaries. This is the definition of cost imposition, and we have been on the wrong side for many years.

Uncrewed systems change that equation dramatically. While they can range from cheap highly-expendable commercial systems (such as DJI drones) to mid-tier systems (such as the Iranian Shaheds) to expensive and highly capable military platforms such as Reaper and Global Hawk, they are all considered more expendable than crewed systems. These systems—especially those on the lower end of the cost scale—can be used to impose costs on the adversary who may be

focussed on crewed systems or more expensive uncrewed vehicles, as they can be used to force their hand in different ways. When confronting large numbers of minimally capable uncrewed systems, adversaries face a difficult choice. They can expend expensive weapons to shoot at inexpensive systems, knowing that more waves are coming. Or they can hold onto their expensive weapons and suffer the consequences of the attack.

This dynamic has made the offensive use of uncrewed systems both attractive and effective. In turn, this has generated a warfighting requirement for cost-effective defense against them. In Ukraine, Israel and elsewhere, we are now seeing an accelerating adaptation battle between uncrewed systems used for attack and the technologies and techniques designed to disrupt or destroy these systems, their communications links, their navigation subsystems, and the people operating them.

A recent CEPA study highlighted the need for NATO "to turn the cost-of-intercept curve in favor of the defenders."[5] The adaptation battle in uncrewed systems currently favors attackers; this must change if the United States and its allies are to develop appropriate conventional deterrence strategies and protect military forces that are deployed and at their home stations.

In Ukraine, as both sides rapidly adopted uncrewed systems into their plans, technologies to counter these systems lagged. Similarly, Allied militaries have been slow to deploy counter-autonomy systems, especially those that can be dispersed and decentralized. This must change, and quickly. The U.S. Army's Joint Counter-small Unmanned Aircraft Systems Office, established in 2020, is a promising start. But it will need to be expanded in scope, budget and authority—and collaborate more deeply with allies—to provide timely and capable injections in this adaptation battle.[6] Most importantly, the pace of change must accelerate. In doing this, we can learn important lessons from the Ukrainian experience, especially in the importance of electronic warfare (EW) in negating these systems.

In response to the success of Ukrainian drone employment, Russian forces have instituted an integrated system that employs a mix of electronic warfare, missile systems, and connected sensors to degrade Ukrainian use of drones and loitering munitions.[7] This Russian system not only

Greater investments in EW will be a key part of any counter against the threat of drones.

[5] Federico Borsari & Gordon B. "Skip" Davis, Jr., An Urgent Matter of Drones, CEPA (2023).
[6] Joint Counter-small Unmanned Aircraft Systems Office, U.S. Army (2021).
[7] Oleksandr Stashevskyi & Frank Bajak, Deadly Secret: Electronic Warfare Shapes Russia-Ukraine War, Associated Press (2022); Alia Shoaib, Ukraine's Drones Are Becoming Increasingly Ineffective

interferes with Ukrainian drones but also with critical communications links. Disrupting these links harms unit cohesion and slows down the Ukrainian fire-strike complex, which became an important factor in thwarting the Ukrainian plans for a large-scale counter-offensive in the summer of 2023. Russian forces have been able to pinpoint Ukrainian headquarters, cut the link between drones and their operators, find drone operator stations, and importantly, jam or degrade the effectiveness of Ukraine's drones and precision weapons. The Russian side has learned from these successes and scaled their EW capabilities through a focus on increased industrial production of EW equipment. In doing so, the Russians have leveraged a traditional strength in EW systems and improved these through collaboration with their strategic defense industry. The widespread use of electronic attacks to counter drones could be answered with defensive capabilities such as hardening and smart links, but these capabilities add cost and weight, making them less feasible for the drones on the lower-end of the cost spectrum. Because of this, it is clear that investments in EW could offer an effective counter against the threat of drones.

Effective electronic warfare is not limited to employment against the drones themselves. In Ukraine, both sides have developed the capability to detect the radio emissions coming from forward drone operations centers, and both can direct rapid, precise fires against them. This has driven the requirement for highly mobile, low-signature drone operations centers with encrypted communications links. Thus, we see the need to invest in signature-decreasing technologies, especially because the People's Liberation Army is certain to develop similar approaches and field the technologies to underpin them.

In this area, we have seen the adaptation / counter-adaptation cycle repeat itself many times in Ukraine. Both Ukraine and Russia have learned that uncrewed systems can impose great cost on their forces, and they have adjusted their tactics and equipment accordingly.[8] A key lesson from this adaptation battle is that military forces require a new generation of counter-autonomy systems that are cheaper to purchase and deploy widely. [9] Just as uncrewed systems were cost-imposing because they were much less expensive than traditional defenses, the goal should be for the next generation of counter-autonomy approaches to be roughly equal to or cheaper than the uncrewed systems they are facing.[10] Militaries

as Russia Ramps Up Its Electronic Warfare and Air Defenses, Business Insider (2022); Mick Ryan, How Ukraine Is Winning in the Adaptation Battle Against Russia, Engelsberg Ideas (2022).

[8] Mick Ryan, How Ukraine is Winning in the Adaptation Battle Against Russia, Engelsberg Ideas (2022)

[9] Mick Ryan, Winning the Adaptation Battle, Futura Doctrina (2022).

[10] These will probably involve some amount of electronic attack combined with gun defenses, cheap interceptor drones, and a doctrine of movement.

that master this combination will be successful in future conflicts. Those that don't will suffer extreme attrition.

Uncrewed Systems Contribute to a Larger Transformation: Offset X

In May 2023, the Special Competitive Studies Project published a major report titled *Offset-X: Closing the Deterrence Gap and Building the Future Joint Force.* This report identifies ten key offset technologies that can provide an effective conventional strategic deterrent against adversaries. If adversaries cannot be deterred, these new technological injections in the joint force will provide a range of asymmetric advantages over potential enemy networked forces such as China's People's Liberation Army.[11]

Well designed human-machine teaming will underpin generating future military advantage.

One of the key recommendations of the Offset-X strategy is that human-machine teaming could offer a potentially large advantage in the future. The strategy encourages leadership in Human Machine Collaboration (HMC) and Human Machine Teaming (HMT), and it describes how HMC will be critical to optimizing decision-making in warfare, while HMT will be essential for more effective execution of complex tasks, especially higher-risk missions, with lower human cost. The U.S. military must be the leader in both.[12]

The Offset-X strategy also describes several important near- and medium-term requirements that would allow the leveraging of this technology in U.S. deterrence and warfighting concepts. The widespread use of uncrewed systems is fully compatible with Offset X, especially when combined with other technologies and capabilities.[13]

Within the array of capabilities identified in Offset X, a trinity of systems is transforming the battlefield in central Europe and beyond. These are:

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[11] As a range of reports, including the most recent Military and Security Development Involving the People's Republic of China, 2023, the Department of Defense (2023), have described the PLA is developing a joint and informatized military that is – in theory – capable of very systemic and integrated approaches to warfare.

[12] Offset-X: Closing the Deterrence Gap and Building the Future Joint Force, Special Competitive Studies Project (2023).

[13] Offset-X: Closing the Deterrence Gap and Building the Future Joint Force, Special Competitive Studies Project (2023).

- Democratized and digitized battle command-and-control (C2), which allows uploading and distribution of militarily valuable information by everyone in the battlespace.
- Meshed civil-military sensor networks, which sees an unprecedented combination of open source and classified data, as well as meshing of civilian, commercial and government analysis, to provide an unprecedented (but not transparent) view of the battlespace and enemy strategic systems.
- The uncrewed systems – counter-uncrewed systems complex in the air, land, and sea.

When these systems are combined with other key technologies, their use is transformative. Specifically, when uncrewed systems are combined with meshed civil-military sensor networks and digitized command and control, they accomplish something new. These capabilities make it possible for real-time information to be available at the forward edge of military operations. If leaders at the edge are empowered to act on this information, it will transform how we think about the command and control of military operations.

When uncrewed systems are combined with meshed civil-military sensor networks and digitized command and control, they accomplish something new.

We have entered a military paradigm where tactical operations must be conducted quickly and in a dispersed way, where operational planning must evolve to support faster and more vulnerable tactical operations, and where the operational defense is currently stronger and much less costly. Accordingly, a successful approach to command and control must account for these operational and tactical challenges, producing military operations that underpin a longer-term political solution. This requires a nuanced mix of centralization and decentralization. There remains a need for centralized development of the commander's intent, operational planning, and assessment of current operations. At the same time, there is a need for rapid, decentralized action at the tactical level, taking advantage of the information made available by the trinity.

For the combatants in Ukraine, Gaza and beyond, this trinity is having a profound effect. Unlike wars past, where only a privileged few had access to accurate information about the battlefield, military leaders at lower echelons now have access to the powerful combination of digitized C2 and a diverse sensor network fed in large part by a myriad of different uncrewed systems. They use this knowledge to direct lethal uncrewed systems, which they use to attack the adversary rapidly and at lower levels of risk to their forces. At the same time, the

adversary has access to many of the same technologies, and tactical advantages are fleeting due to the adaptation / counter-adaptation cycles.

Drones in the Transformative Trinity

While all wars feature the aggregation of many old ideas, they often add a small number of new technologies and ideas to older elements. For example, in Ukraine, traditional approaches such as the use of armored vehicles, artillery, and infantry have been supplemented with uncrewed systems. But just as important has been the meshing of civil and military sensor networks—largely fed by uncrewed platforms—and the connection to new-era digital command and control systems.

It is the combination of these technologies that has made new, more effective approaches to warfare possible. For this reason, our consideration of multi-dimensional drone employment must be done with the context of this transformative trinity.

The knowledge developed through the meshed civil-military intelligence system is shared across the digital C2 system to the lowest levels to inform military decisions. In battle, this informed C2 system helps leaders direct rapid manoeuvre and focus diverse fires on the adversaries' critical vulnerabilities. When combined with military units that are equipped and trained to take advantage, there is real potential to apply rapid, accurate effects at scale against adversary forces. The full potential of the trinity, however, cannot be realized unless a military force embraces a fundamental principle—greater (but not uncontrolled) decentralization. The trinity makes it possible for militaries to adopt a powerful division of labor in decision-making. Operational leaders can translate political and strategic guidance into a commander's intent supported by operational-level planning. Tactical leaders can apply this planning to their specific situations and make real-time adjustments, limiting the damage of a bad decision and exploiting opportunities as they present themselves.

It is important to emphasize here that the information needs of tactical leaders at the edge is not the same as that needed for operational planning and assessment. There are important differences between the space and time dimensions of the battlefield. That said, the trinity combination feeds the information needed at both the tactical and operational levels, and the widespread application of various classes of uncrewed systems can support tactical execution as well as the creation of operational—and even strategic—effects. As we see the trinity evolve in places like Ukraine, it is apparent that an AI-driven integrated environment that delivers shared knowledge and enables machine-aided (uncrewed) planning, tasking, deconfliction, is crucial if Allied militaries are to achieve true

transformative capability. This will provide a capability into which all leaders and planners can connect, and it will be the core capability that allows for successful integration and deconfliction of military operations.[14]

It is no longer true that the best information is necessarily at the headquarters or operations center.

What has occurred in Ukraine—and what will occur on future battlefields—is that most levels of the combat force have access to the benefits of the trinity. It is no longer true that the best information is necessarily at the headquarters or operations center. Instead, it may well be true that the leaders at the edge have a situational awareness that is superior to that enjoyed in the headquarters, because they have access to the same digital information augmented with localized awareness of what is happening around them. This doesn't negate the role of headquarters, which is still necessary for operational intent, planning, and assessment. It does, however, demand a reimagination of the division of labor between leaders at the tactical and operational levels.

With the information produced by the meshed civil-military network coupled with generalized C2 across the battlespace, leaders at the edge can make rapid, lethal decisions and conduct a successful localized operation in the context of a broader effort. This development is transforming how leaders approach combat in Ukraine. For example, the Ukrainian *Delta* digital C2 system has significantly shortened decision cycles in many situations. *Delta* was developed in collaboration with NATO prior to 2022, and it combines real-time mapping with pictures and locations of enemy units, which can be input by anyone with access to a smart device with the *Delta* app and connection to a network.[15] Artificial intelligence is also part of Delta and is used to speed relevant information to the right users.[16] The Ukrainians also employ a system called *GIS Arta,* which uses a bottom-up approach to select battlefield targets. Most users of *GIS Arta* do so through an Android app on their smartphones. This app provides rapid target verification, generation of options according to commander

Combining uncrewed systems with the other trinity technologies has ensured a more pervasive sensor network over the battlefield.

[14] We appreciate Lieutenant General Mike Groen (retired) making this point.
[15] Ukrainian Military Innovations Proved Effective – And They're Changing Modern Warfare. Here is How, Brand Ukraine (2023).
[16] T.X. Hammes, Game-changers: Implications of the Russo-Ukraine War for the Future of Ground Warfare, The Atlantic Council (2023).

priorities, and suggestions for engaging the target.[17] Additionally, Ukraine has undertaken the integration of data about the flight of small UAVs into its command and control systems called *Graphite*.[18]

The access to information and streamlined command and control provided by these systems permits tactical leaders to better employ uncrewed systems (although the full potential of this reality remains to be realized due to cultural and technical challenges in implementation…these are discussed later in this paper). Such systems, particularly in the air, are used for reconnaissance and correcting indirect fires from artillery, mortars and tanks. They are also employed as loitering munitions. Recently, there has been a major push to employ them for longer-range strikes.

Combining uncrewed systems with the other trinity technologies has ensured a more pervasive sensor network over the battlefield. The information gathered is used to either call in fires or to use the drones themselves as attack systems by dropping munitions or as 'kamikaze' drones. The tactical result is a drastically reduced time between detection and destruction. Times for detecting and engaging a target are about 3-5 minutes.[19]

This radical contraction of the kill web begets a harsh reality. Any concentration of combat forces—and those that support them—has become much more perilous. Concentrated and/or fixed forces are easily detectable, and the ability to direct rapid fires on them is achievable by all sides. Therefore, combat forces must adopt distributed tactics that lower the overall signature of a force across multiple domains. These forces must also embrace movement as a key aspect of defense. The result is the need for junior leaders to take an active role in directing the distribution and movement of forces under threat of attack. This has major implications for leadership, training, equipment and tactics.

Until recently, uncrewed systems were a scarce resource; there were never enough of these capabilities to go around. There were not enough fighter aircraft, artillery batteries or reconnaissance aircraft to assign to individual ground units below a certain echelon. In the air, there were not enough air refueling or C2 aircraft to assign to each mission commander. Because the allocation of these scarce resources most resembled an economic problem, militaries adopted economic principles, with authority over scarce resources held at high levels.

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[17] Mark Bruno, Uber for Artillery – What is Ukraine's GIS Arta System?, The Moloch (2022).
[18] Valerii Zaluzhnyi, Modern Positional Warfare and How to Win in It, The Economist (2023).
[19] Mykhaylo Zabrodskyi, et al., Preliminary Lessons in Conventional Warfighting from Russia's Invasion of Ukraine: February–July 2022, Royal United Services Institute (2022).

Ukraine has procured large numbers of commercially-sourced drones—which are relatively cheap and widely available. The Ukrainian forces have deployed these drones on the front lines, where the large numbers and increasing level of capability have made it possible for drone operations to be very effective in reconnaissance, surveillance and strike operations.[20] For instance, large numbers of drones manufactured by the Chinese company DJI have been deployed, so many that the Ukrainian Prime Minister Denys Shmyhal has said that Ukraine has procured over 60% of DJIs global output of Mavic quadcopter drones, despite a company policy not to sell directly to militaries.[21]

Many drones are used as stand-alone elements of attack. There is an operator assigned to each drone who uses First-Person View (FPV) to individually direct the mission. Battlefield swarming is in its infancy, despite its widespread use in the civil industry, particularly for light shows and replacing fireworks. Once swarming becomes commonplace in all domains, there will be another shift in the density of drones and humans in military operations. Swarming will allow for an individual operator to direct many drones, multiplying the potential effect for both offense and defense (see the implications of this below). This will likely drive the need for more and more drones to join the swarm, especially as the cost of individual drones continues to fall.

With the falling costs and increasing capabilities of uncrewed systems, there can be enough to go around. With the right investments, militaries can provide a substantial number of these systems to individual leaders of front-line units, who can take full advantage of real-time awareness provided by the trinity and the sense of the battlefield that resides at the edge. Large numbers of cheap, good-enough systems can enable edge leaders to move quickly and inflict losses on the enemy with lower risk to friendly forces. When combined with a smaller number of more capable crewed and uncrewed systems—and even a few exquisite ones—the combined effect will be profound, even game-changing.

Opportunities for the Strategic Development of Uncrewed Systems

This paper has explored how uncrewed systems offer significant advantages to those military institutions that employ them within the clever and constantly evolving system described as the transformative trinity. To realize the full strategic potential of this approach, changes in people, process and procurement are necessary.

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[20] How Ukrainians Modify Civilian Drones for Military Use, The Economist (2023).
[21] Elisabeth Gosselin-Malo, Ukraine Continues to Snap up Chinese DJI Drones for its Defense, C4ISR.net (2023).

People

People are at the heart of all military capability. In what may seem like a paradox, people are crucial to realizing the full benefit of uncrewed systems. As militaries seek people who can make this possible, they will need to consider how the widespread use of uncrewed systems will affect recruiting, training (individual and collective), education, culture, promotion and leadership development models.

Military institutions must provide conditions of service that are competitive with outside industry for those who will operate autonomous systems, maintain them, and conduct research to increase their capability. Beyond the ability to attract and retain talent across the range of needs in the uncrewed system workforce, rapid examination of greater automation in the planning and execution of uncrewed system missions is needed. A large proportion of uncrewed systems, such FPV and maritime semi-submersible systems, still require at least one – and often more – operator per platform. This construct is suboptimal; it is overly expensive, difficult to fully resource with the right people, and tactically vulnerable.

To that end, the attraction of the right talent must be complemented with the introduction of software that allows for the operation and collaboration of multiple uncrewed systems by individuals. While technological solutions are now appearing on the market for this—described as *robotic or drone orchestration*[22]—this type of employment will drive the need for new approaches in personnel. Militaries will need to recruit, train and empower people who can operate in an environment where multiple uncrewed systems are conducting missions concurrently, either by themselves or within larger human-machine teams.

Many Allied militaries have regular and reserve components within a voluntary or semi-voluntary construct. This represents a significant opportunity vis-à-vis uncrewed systems. Reserve components often have personnel who possess contemporary technological skills relevant in operationalizing the transformative trinity. These people need to be identified and placed in positions where they can apply these skills. Where the necessary skills cannot be found—or sustained—within regular or reserve military workforce models, these militaries will need to supplement their forces with contractors. This integrated workforce model for regular, reserve, and contractor personnel will be fundamental to bringing the technological skills as well as a diversity of new ideas to realize the full potential of the transformative trinity. This will be especially true as militaries look to develop their junior leaders for service at the edge.

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[22] Companies such as Microsoft and Votix Offer Solutions for Drone Orchestration. See VOTIX – Drone Orchestration and Automation, VOTIX (2024); Unmanned Life - Robotic Orchestration Platform, Microsoft (2024).

Empowered leaders – at every level - who have been trained and trusted to execute mission command can dominate the cognitive and temporal aspects of future combat. They can leverage the trinity to distribute and move their forces while inflicting major losses on the enemy at greater speed and lower risk. In this way, the trinity rewards the initiative of timely battlefield actions exercised in a decentralized way within a broad intent. Put another way, the trinity rewards trust up and down the chain of command, and this trust makes true mission command possible. The military force that takes advantage of these developments, trusting and empowering people at every echelon, will enjoy a tremendous tactical advantage that can translate into operational and strategic advantage. To gain this advantage, militaries must evolve their training and education to reinforce trust-building, with the goal of constructing trusted subordinate-superior relationships at home and on the battlefield. This training and education will be successful if it results in the kinds of leaders that can leverage uncrewed systems and the transformative trinity that they operate within.

The military force that takes advantage of these developments, trusting and empowering people at every echelon, will enjoy a tremendous tactical advantage that can translate into operational and strategic advantage.

This is a crucial opportunity for Allied militaries, in a way that favors these militaries over those formed under traditional Communist principles. Allied militaries have a long history of growing and developing combat leaders at the junior officer and non-commissioned officer levels. These leaders are capable of exercising judgment and initiative, even when cut off from higher command. By the time a member attains the rank of field-grade officer or senior non-commissioned officer, their countries have invested many hours of training and education in them. More than their contemporaries in forces based on Communist doctrine, these leaders are capable of independent decision-making within an overall intent. This is often described as *mission command*, and it is made much more achievable by the trinity. Moreover, Allied militaries can now realize mission command at scale by leveraging the trinity with leaders capable of directing multi-domain operations in their specific situations, always within the overall intent. This full potential of mission command is only realized when edge leaders combine the trinity of technologies with informed initiative and aggressiveness.

This will demand an evolution in military leadership models. While older requirements to provide purpose, direction, and cohesion for human teams remains, new-era leaders will also need to develop the knowledge and skills to lead teams that have an increasing proportion of semi-intelligent machines and decision-support algorithms. This not only requires improving the technological literacy of leaders at all levels, it may also require a fundamental evaluation of the leadership required for effective human-machine teaming.

As with any transformation in war, cultural reform is both crucial and difficult.

As with any transformation in war, cultural reform is both crucial and difficult. The big question regarding uncrewed combat systems remains unanswered for Allied militaries, especially that of the United States: can these militaries learn from the experiences of Ukraine—as well as the results of their experimentation and wargaming—and adopt their widespread use? Until now, they have not. There have been many promising experiments, to be sure. To date, however, no unit of the United States military has conceptualized, fielded, and trained with drones on the scale seen in Ukraine. Why not? The evidence points to multiple reasons.

Some in the United States have assumed that our forces would fight differently than those in Ukraine, and so there is a limit to what we can learn from the fighting there. Closely related is a lack of urgency that is still haunting the U.S. military and some key allies, despite the strong signals that warfare is changing rapidly and that potential adversaries will inflict unacceptable attrition using emerging technologies such as drones. Added to this, large defense companies do not perceive that there are sufficient profit incentives for them to go “all in” on drone development, and the barriers to entry for new drone makers are significant. Finally, despite statements to the contrary, many U.S. military leaders do not believe in mission command, and they are not incentivized to field systems—such as the technology trinity discussed in this paper—in ways that empower leaders at the edge. Despite these cultural difficulties, the U.S and allied militaries will change, either of their own accord or because they are forced to by circumstances.

Process

Transformation in military affairs is largely about transformation in process. Key military processes include tactics, doctrine, organization, support agencies, learning and adaptation in military institutions. Through transformation in these processes, Allied militaries have an opportunity to shape these emerging technologies, and provide foundations for their use, in ways that favor their strengths, with the result being a significant advantage in combat. Allied militaries

need to be proactive in shaping technologies, doctrine and training so that they work together to empower leaders at the edge. In doing this, Allied militaries must acknowledge that it is unlikely that these leaders will have uninterrupted connectivity with a higher headquarters. There will be times when relatively junior leaders will need to take independent action.

Therefore, Allied militaries have a choice to make. They can choose to adopt practices that make distributed, independent action the primary way of warfare for their forces, or they can treat this approach as a contingency when communication with headquarters is lost. The development of distributed warfighting concepts within joint operations must be a priority. These concepts should then inform subsequent rapid procurement as well as training and education.

Allied militaries have a natural advantage in building and trusting junior leaders, and they have every reason to expect that these junior leaders can operate more effectively and independently under combat conditions than potential adversaries. Added to this is the near certainty that battlefield communications will be hindered and sporadic for all involved.

The changing density of humans and uncrewed systems, particularly in what has previously been regarded as close combat, may fundamentally change the nature of military institutions.

As argued above, doctrine needs to be adjusted to emphasize the importance of initiative and independent action within the broad commander's intent as the 'new normal' on the modern battlefield, with a corresponding commitment to prepare units for this requirement. Each of these units should be equipped with key capabilities in multiple domains as dictated by the expected environment. The technologies should be shaped to push real-time awareness so that it can be interpreted quickly by leaders at the edge, and these leaders should be able to direct localized action through their digitized C2 systems.

An important element of the process is the command and legal authorities invested in leaders. This has doctrinal, educational and training implications. Allied militaries will leverage the transformative trinity best when they empower leaders with the authority to command uncrewed systems in relevant domains and the ability to control them as needed, guided by general direction from higher headquarters. This should be the primary paradigm for employment. For example, leaders of front-line ground units should have access to uncrewed ground and air systems to enable an effective combination of maneuver and fires. Leaders in the air should

have access to ground-based uncrewed surface-to-air missile batteries to increase their magazine depth. Leaders at sea should have access to uncrewed underwater, surface, and air systems. Leaders in training should have the authority to use uncrewed systems in civil airspace and be able to use GPS jammers and electronic warfare more extensively in home station training exercises.

Importantly, the changing density of humans and uncrewed systems, particularly in what has previously been regarded as close combat, may fundamentally change the nature of military institutions. Indeed, in the coming decade, military institutions may realize a situation where uncrewed systems outnumber humans. At present, the tactics, training, and leadership models of military institutions are designed for military organizations that are primarily human, and those humans exercise close control of the machines. Soon, the ratio of humans to uncrewed systems will flip, and many of those uncrewed systems will be capable of **partnering with humans, not just being used by them**. Changing education and training to prepare humans for partnering with machines—not just using them—is a necessary but difficult cultural evolution. A world of truly smart machines is here, and it requires major adjustments to military institutions and their processes, including how people are recruited, trained, educated and incentivized.

This cultural evolution must be a foundational mission for military services, core to personnel and procurement policies. It cannot be a mission that is delegated to reserve components because regular forces are too busy for innovation. This requires leadership, collaboration, risk-taking, and most importantly, nurturing imagination about a different future for military institutions.

One of the most difficult cultural challenges standing in the way, however, is the current culture surrounding procurement and acquisition.

Procurement

In order to field large numbers of uncrewed systems within the trinity, as well as defensive systems to degrade enemy use of these systems, military institutions must identify equipment requirements, apply funds for procurement action, and agree to contracts for the right equipment and services. In each of these areas, uncrewed systems drive unique challenges.

In the Ukrainian conflict, experience has shown that for many classes of uncrewed systems, there is a very high attrition rate. Both the Ukrainians and Russians employ dozens of these vehicles for every kilometer of the front line. A large percentage are expended as weapons, and many others are lost to both enemy action and accidents. A recent report from the Royal United Service Institute described an

attrition rate for the Ukrainian Armed Forces of approximately 10,000 per month.[23]

In an environment where the losses of these systems can run into thousands per week on each side, the rapid procurement of drones is as crucial as mobilization of industry. The Ukrainian government has been intentional about addressing bureaucratic obstacles to the development and production of drones. In March 2023, the government of Ukraine issued a decree[24] to remove some of the red tape associated with bidding for Ukrainian armed forces contracts for drones. Deputy Prime Minister Mykhailo Fedorov, who oversees innovation and technology, noted that "Instead of spending months on unnecessary paper and bureaucratic work, (we will have) accelerated admission of drones to operation, their purchase, and delivery to the front."[25] These measures have been accompanied by the widespread procurement of 'off the shelf' commercial drones.

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Dr. Kathleen Hicks
Deputy Secretary of Defense

Many drones have been sourced from commercial drone companies direct to Ukrainian brigades on the front lines, which has also increased access to affordable and effective drone systems.[26] This trend is likely to continue in future conflicts. T.X. Hammes writes, "The increasing capabilities of commercial drones are changing the game of how militaries will use this technology…. An increasing range of long-endurance, commercial drones carrying commercial surveillance payloads such as these will allow even smaller states access to affordable intelligence, surveillance, and reconnaissance (ISR) and attack."[27]

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[23] Jack Watling & Nick Reynolds, Meatgrinder: Russian Tactics in the Second Year of Its Invasion of Ukraine, Royal United Services Institute (2023).
[24] Resolution on the Implementation of an Experimental Project on Defense Procurement of Domestically Produced Unmanned Systems, Ukrainian Ministry of Defense (2023).
[25] Ukrainian Government Facilitates Mass Drone Production, The Kyiv Independent (2023).
[26] At the same time, the Ukrainian Ministry of Defence has raised large amounts of money, donated by private individuals, to fund the purchase of drones. One campaign—a Ukrainian government-sponsored program called Army of Drones—has provided over 3000 drones for the Ukrainian Armed Forces since the start of the war. Joe Tidy, Ukraine Rapidly Expanding its 'Army of Drones' for Front Line, BBC Online (2023); Jake Epstein, A Ukrainian Donation Drive built an 'Army of Drones' and Picked Up an Unusual System Called a 'Shahed Hunter' for Kyiv's Forces, Business Insider (2023).
[27] T.X. Hammes, Game-Changers: Implications of the Russo-Ukraine War for the Future of Ground Warfare, Atlantic Council (2023). Additionally, commercial drones have been purchased privately and provided to the Ukrainian military, which can avoid restrictions that drone manufacturers may

There are signs that Allied militaries are learning from Ukraine's experience. As mentioned above, the United States Department of Defense has recently revealed the "Replicator" initiative. This effort was announced by Deputy Defense Secretary Kathleen Hicks, who said: "We've set a big goal for replicator: to field attritable, uncrewed systems at a scale of multiple thousands [and] in multiple domains within the next 18-to-24 months.[28] Replicator appears to be entirely consistent with insights from Ukraine as well as wargaming and experimentation accomplished by the U.S and its allies, and it offers a pathway for the United States to push uncrewed systems to the edge, empowering leaders on the front lines through mass, low-cost, all domain, attritable systems and various degrees of autonomy.

However, there are key issues that remain for militaries looking to adopt drones at scale. For example, there is a trade-off between the sophistication (including electronic hardening), capability, cost and quantity in uncrewed system fleets. There is no 'one size fits all missions' approach available with uncrewed systems. Allied militaries will need a wide variety of different systems—from low-end, cheap tactical systems to more high-end expensive systems. Not all of these uncrewed systems can be sourced commercially or rapidly acquired. Some will require longer endurance, faster speeds, and/or more advanced capabilities. Achieving the right balance across an uncrewed system fleet will require additional experimentation and a tolerance of some failure in that process in order to learn lessons about the trades between capability and capacity in uncrewed fleets. Additionally, there are questions about the optimal levels of existing inventory vs. just-in-time production as part of national mobilization, also about the right balance of internally developed versus commercially-sourced systems.

This balance of internal versus commercial development also extends to exploring better Defense-commercial relationships that will increasingly influence the capacity and quality of the meshed sensor network that underpins the capability of uncrewed systems as well as the distribution of intelligence sourced from them. Collaboration with commercial firms is central to realizing the strategic and tactical advantages of the transformative trinity explored in this paper.

Recommendations

While uncrewed systems have been present in the military for decades, we are still in the early stages of fully realizing their potential within the wider array of

impose on purchases by military forces. Most recently, Ukraine has applied private funds to purchase the "Shahed Hunter" system which can defend against Iranian-made loitering drones that are attacking Ukrainian forces. Jake Epstein, A Ukrainian Donation Drive built an 'Army of Drones' and Picked Up an Unusual System Called a 'Shahed Hunter' for Kyiv's Forces, Business Insider (2023).

[28] Jim Garamone, Hicks Discusses Replicator Initiative, U.S. Department of Defense (2023).

disruptive technologies that help with sensing, sense-making, and decision-making. The capabilities of uncrewed systems have increased dramatically over the last two years. Additionally, the quantity of fielded systems has increased, and the cost has gone down. We have every reason to believe these trends will continue. They may accelerate.

The following are recommendations for the U.S. Department of Defense (DoD). Other Allied militaries would also benefit from similar concrete steps to imagine a different future for their institutions and how they conduct integrated warfighting, as well as how they might adopt widespread use of uncrewed systems within the context of the technology trinity. Importantly, we recommend that these recommendations be implemented at a rapid pace, and that institutional leaders accept more risk in order to ensure the DoD is able to out-compete adversaries such as China and Russia in the adaptive cycle that has resulted in the transformative trinity, and which constantly evolves it.

- **The Secretary of Defense should establish a temporary, cross-service task force** to explore the warfighting implications for service and joint personnel as well as new training models to enable a much different ratio of uncrewed systems in military operations. This work should also include exploration of different organizational constructs in the air, sea, and land domains that draw on contemporary lessons. This should be integrated into the current DoD Replicator initiative, which is co-led by the Deputy Secretary of Defense and the Vice Chairman of the Joint Chiefs of Staff.[29] Replicator cannot be a stovepiped acquisition initiative pursued independently from warfighting concepts, doctrine, organization and training. Instead, the initiative would benefit from a small, high-speed team—comprised of military, civil service, scientific and commercial personnel—that can rapidly co-develop concepts of operation, new talent management and promotion pipelines, and use cases for both regular and reserve workforces. Perhaps most importantly, this team would work concurrently with the Defense Innovation Unit and other acquisition entities to identify software and platform solutions that pursue the potential of the transformative trinity described in this paper.

- **The Undersecretary of Defense for Acquisition and Sustainment should consider acquisition strategies that separate the design of uncrewed systems, as well as a range of hard- and soft-kill systems to counter them, from the ability to manufacture them in the procurement process**. The traditional process seeks contracts for large deliveries of complete platforms, which assumes that the same company that designs the platform

[29] Jon Harper, Pentagon About to Pick Systems for Replicator Initiative, DefenseScoop (2023).

should also be the one to manufacture it at scale. This puts smaller, agile companies at a disadvantage vis-à-vis the prime integrators, because even if they offer a superior design, it is unlikely that they have the manufacturing capability to deliver large numbers of systems. It is possible, even likely, that the best designs for these systems will come from non-traditional participants in the defense industry. The government should be able to choose the best design and then allow companies to compete to manufacture at scale. Furthermore, there would be a great advantage to buying a superior design and sharing it with allies, allowing their manufacturing capacity to contribute to the overall number of systems available, with interoperability built in by default, which leads to the next recommendation.

- **DoD should explore the development of an alliance variation of the transformative trinity** under an AUKUS-like model. Invariably, U.S. forces will be deploying, training, operating and warfighting alongside allies in Europe and the Indo-Pacific regions. Ensuring that the trinity of meshed sensors, digitized C2 and uncrewed systems is integrated not only across Services but across alliances is a compelling priority. This should include the development of redundancies in uncrewed systems manufacturing as well as the development and application of alliance doctrine on uncrewed systems. It also should include collaboration on the imperative to counter uncrewed systems fielded by potential adversaries, including hard- and soft-kill opportunities. Finally, this collaboration should also explore the impacts of a lower ratio of human-operated systems in the battlespace and how this affects situational awareness and the generation of operational insights.

- **The Deputy Secretary of Defense should create a single common-access portfolio for uncrewed systems** to allow different organizations to share classified information and collaborate on the development of these systems. This portfolio should include members from the Services, defense agencies, and allied militaries. Allied militaries should be asked to include their initiatives in this portfolio.

- **The Secretary of Defense and the Chairman of the Joint Chiefs of Staff should direct the Joint Requirements Oversight Council (JROC) to oversee the Joint portfolio of uncrewed systems,** ensuring that Joint concept-required capabilities from the Joint Warfighting Concept are pursued across the whole of DoD. The JROC should be given authority to direct the development of a diverse portfolio and limit redundancies between the Services.

- **DoD organizations, including the Services, should fund and execute experimentation with prototypes to develop new warfighting concepts** for uncrewed systems, as well as their hard- and soft-kill counters, that draw on the lessons of Ukraine and Israel, as well as anticipate technological developments in the wider application of uncrewed systems within the transformative trinity. The Deputy Secretary of Defense should use the Joint Rapid Development and Experimentation Reserve for this purpose. The results of these experiments should drive new service-level doctrine as well as combatant command plans.

- As part of the DoD 'Hedge Portfolio,' **the Secretary of Defense should direct the Office of Strategic Capital (OSC) to incentivize private investment in companies that design and produce uncrewed systems.** The OSC would be even more effective if Congress provided it with limited budget authority to invest in risk-reduction for private companies and signal DoD interest in future procurement decisions.

- In concert with evolving warfighting concepts, **DoD organizations, including the research laboratories, should experiment with the orchestration of uncrewed systems (i.e. 'swarming') across the domains**. This effort should be focused on gaining several potential advantages. First, the operation of multiple uncrewed systems under the oversight of an individual or small team will increase the capability per person and decrease the number of trained operators required. It will also decrease the need for large numbers of vulnerable operations centers. In addition, when uncrewed systems operate in groups, they can be designed in ways that allow for the division of labor between the individual systems. Some can carry exquisite payloads like advanced sensors to gather actionable information and share it, while the majority can carry relatively simple payloads like munitions. Some could even be decoys. The loss of one or a few of these systems would not seriously harm the formation, but it could impose great cost on an adversary who employs expensive weapons against inexpensive drones. For some missions, it will be advantageous to orchestrate uncrewed systems across domains. As an example, uncrewed ground systems sent to neutralize an enemy fortification will benefit from systems in the air offering real-time threat information. Likewise, airborne systems that can sense and identify adversary naval vessels can vector submersible systems to attack. Swarming and autonomy will mean that fewer operators are required, but the operators who direct these systems will need to be proficient in creating multi-domain effects.

- **Instead of specific requirements, DoD acquisition executives should adopt trade-off ranges to evaluate the performance of uncrewed systems.** There are too many potential designs of uncrewed systems for any one DoD organization to track them all. In addition, key enabling technologies—including microelectronics, advanced manufacturing and alternative fuels—are advancing rapidly. The result is that it is exceedingly difficult to publish optimal requirements for uncrewed systems, as well as their hard- and soft-kill counter systems. Instead, DoD should explain, in detail, the military problem to be solved, and ask potential providers to design systems that solve the problem. As they present their solutions, companies should also be required to provide detailed explanations for the trade-offs in various attributes, including operational considerations. For example, many short-range systems may cost and perform the same as a few long-range systems. The short-range systems may require launch and recovery from the territory of an uncertain partner, while the longer-range systems may require air refueling closer to the threat, increasing vulnerability for the manned tanker fleet. The explicit identification of trade-offs allows for an informed decision on which designs to buy. These trade-offs may include weight, speed, range, endurance, materials, signature against key threats, power and cooling for modular components, ease of manufacture and assembly, sustainability in the field—including the possibility of repairing systems with parts produced near the edge, complexity of operation, degrees of autonomy, flexibility in updating software, safety considerations, and built-in redundancy.

- Closely related to the consideration of key trade-offs, **DoD acquisition executives should adopt a key performance parameter for uncrewed systems that compares the fully-burdened cost of mission achievement with cost imposition.** The employment of uncrewed systems can drive exchanges between military forces that result in very different costs for each side. Sometimes the cost is wildly asymmetric, as in a case where a defender expends several expensive interceptor missiles to shoot down a cheap drone (both sides have done this in Ukraine). When one considers the fully burdened cost of sending many cheap drones to destroy a target vs. that of fielding and operating an advanced air defense capability with sensors and trained personnel, the cost difference is even more incongruent (and likely unsustainable for the defender). Uncrewed systems can and should be employed with the specific objective of forcing an adversary to choose between incurring high costs or accepting loss of capability. While the question of cost currently favors the side using inexpensive drones for attack, we are seeing key technologies being applied to lower the cost of

defense and make the use of one-way attack drones much less attractive.[30] This development could be critical for the United States and its allies who need options to "turn the cost-of-intercept curve in favor of the defenders."[31] Whether choosing which attack drones to procure or what defensive capabilities to field, acquisition executives should consider a holistic cost comparison between mission achievement and cost imposition. In most cases, this comparison should drive acquisition decisions.

- **In collaboration with Congress, DoD should intensify the use of non-traditional procurement authorities** to allow for more rapid procurement of commercial drones or commercial drone service providers that provide warfighting capability as well as home station training and experimentation. It is not required that these systems be the same as those planned for future employment. Operational units can gain useful learning and training with the systems available now, and the experience gained will make it easier to adopt increasingly capable versions of uncrewed systems. These procurement authorities should also include the authorization to partner with external entities in the commercial and academic sectors that might accelerate the development and mass manufacturing of indigenous uncrewed systems.

- **The Joint Staff Director for Joint Force Development should compile and publish an accessible repository of lessons from operations with uncrewed systems**. By documenting and publishing the learning associated with uncrewed systems within the transformative trinity, the DoD can encourage adaptation in military units as well as procurement organizations. Additionally, this repository data should be made available for experimentation in the use of algorithmic learning—including generative artificial intelligence—to ensure continuous adaptation and improvement in recruiting, training, infrastructure requirements, and warfighting concepts.

Conclusion – Meeting the Challenge

For the United States and its allies, success in battle will require a powerful and potent blend of humans and technology. The best evidence—including real-world experiences in Ukraine and Gaza as well as wargaming and experimentation—suggests that the elements of the transformative trinity of technologies discussed in this paper, including uncrewed systems, will be fundamental to this blend. Neither technology nor humans alone can provide the strategic edge required by the United

[30] A Startup Called Anduril has Unveiled a Reusable Missile, The Economist (2023).
[31] Federico Borsari & Gordon B. "Skip" Davis, Jr., An Urgent Matter of Drones, CEPA (2023).

States and its allies in deterring aggression and winning conflicts in the future security environment.

Only in the optimal blending of new-era technologies with new ideas, new organizations, and empowered leadership can the Allied militaries integrate drones into their approach to maintaining a strategic edge over potential adversaries in a dangerous and uncertain period. And, it must be done at a pace not seen in Allied military organizations since the end of the Cold War. The speed at which Russia, and especially China, can develop, deploy and evolve their warfighting capabilities at scale must drive the DoD to implement a different strategic tempo if we are to build and sustain a future warfighting advantage.