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Ground Combat Systems

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Executive Summary

The United States ground combat vehicle industry is soon reaching a crossroads between the production of legacy ground combat systems, which remain in high demand, and the need for new autonomous ground combat capabilities. These new systems and capabilities will not only be developed in an environment of constrained budgets, but in a time of increasing international insecurity with peer competitors. In preparation for a possible future conflict, the Department of Defense has introduced the Replicator initiative, which seeks to encourage the production and adoption of large quantities of attritable autonomous systems. Congressional committees, elements within the Department of Defense, particularly the US Army, and the defense industrial base have come together to tackle the difficult technological challenges and develop candidate systems for Replicator. Our Industry Study has met with leading firms in the current ground combat vehicle industry, studied the issues, and identified several recommendations to help focus the stakeholders on a clearer path for the development and adoption of more attritable and autonomous ground combat systems. We assess that the US Army should develop an overall resourcing strategy focused on autonomous systems and develop a strategy to engage directly with Congress to discuss the implications of Replicator. The Ground Combat Systems Industry study has also identified the Robotic Combat Vehicle (RCV) as the most likely candidate for the Replicator initiative, and we would recommend the allocation of additional funding for multiple RCV variants to create the greatest amount of technological diversity. From our study we also recommend the Next Generational Combat Vehicle Cross-Functional Team assume greater risk in RCV technology by getting them into the hands of the warfighter sooner. We go on to suggest that the Program Executive Office Ground Combat Systems initiate additional rapid prototyping efforts with industry to drive innovation in unmanned ground combat vehicles. Our final

recommendation to industry is the continued support of the modular open systems approach. Machine learning and artificial intelligence will be the true enabler of any candidate technology determined for Replicator and additional investment in the research and development behind this necessary capability are necessary to create enduring operational advantage. Without this key technology, we expect a slow adoption of RCVs and an inability to realize the benefits of integrating RCVs into military formations to enhance all six Army warfighting functions: command and control, intelligence, fires, maneuver, protection, and sustainment.

Introduction: Developing Robotic Combat Vehicles (RCV)

In March 1941, developers broke ground on an empty field near Warren, Michigan to build the Detroit Arsenal Tank Plant. This factory housed the means to produce one of the war-winning weapon technologies of World War II, the M3 Lee tank.[1] Historians consider the ability of Detroit's automaking industry to scale production of critical ground combat systems and produce war materiel as fundamental to the Allies' victory. Paired with government funding, the capability and capacity of the domestic industrial base enabled the United States to lead the world in weapons development through the late-20th century.

Today, the Department of Defense (DoD) anticipates that autonomous systems will provide war-winning capability on future battlefields. Interest in unmanned ground combat vehicle (UGCV) systems grew during the Global War on Terror, with drone warfare and mine removal systems becoming integral to the counterinsurgency fight in Afghanistan and Iraq. Since 2022, the Ukrainian Armed Forces have proven adept at leveraging drones and ground-based automated systems as sensor and fires platforms, often with the expectation that they will be destroyed. In the Pacific, the increasingly aggressive posture of the People's Republic of China (PRC) toward Taiwan further heightens the requirement for the United States to produce UGCVs, despite flattening U.S. defense budgets. Indeed, autonomous systems can be seen as a strategic option to do more with less, especially as technology matures and they become more affordable.

This evolution from manned platforms to artificial intelligence (AI)-enabled automated systems is at the forefront of weapons development. To remain the world's premier fighting force, each military service should develop long-term strategies for the procurement and integration of UGCVs which perform a multitude of roles on the battlefield. Advancements in

UGCVs can potentially transform the way the Joint Force acquires cutting-edge technological capabilities to conduct maneuver, fires, intelligence, and sustainment operations. This will require updates to policies and doctrine that will give commanders the ability to leverage UGCVs, particularly autonomous or semiautonomous Robotic Combat Vehicles[2], to achieve military objectives.

However, investments in RCVs pose great financial risks for the defense industrial base (DIB) unless the government provides a steady demand signal and rewards firms for their innovation with contracts. In September 2023, the Department of Defense introduced the Replicator initiative, in part to signal the DIB, but also to encourage the military services to identify the best candidate technology to develop under the constraints of being "attritable" and autonomous.[3] **By securing long-term congressional funding and creating opportunities for industrial competition, the U.S. Army will accelerate the development of more advanced and affordable RCVs to enhance unit effectiveness.**

This report describes the strategic environment driving the need for a technological transformation and identifies how DoD, Congress, and industry partners could contribute to the development and procurement of more attritable and affordable RCVs. Political, economic, social, and technological (PEST) considerations that are analyzed briefly in the report appear in greater depth in the appendix. The report includes Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities, and Policy (DOTMLPF-P) considerations for integrating RCVs into Army units. It concludes with specific recommendations for: 1) DoD to develop a resourcing strategy, engage Congress about Replicator, and execute affordable and attritable prototyping with industry; 2) Industry to provide transparent assessments of feasible technological development and production schedules, and invest in research and development

(R&D); 3) Congress to support the Replicator initiative by underwriting risk and funding an RCV variant program.

The Strategic Environment

The United States is at a generational security crossroads in a multipolar world. Highspeed, increasingly autonomous, multifunctional technology incorporated for commercial and military use has redefined what it means to be "state of the art." As American society shapes and, at times, struggles to define what that future will look like, long-time adversaries have become more assertive about challenging the American-led global order to pursue their own interests. The Democratic People's Republic of Korea continues to improve its nuclear missile program meant to contest American military dominance on the Korean peninsula and strike the American continent.[4] In partnership with violent extremist organizations, Iran increased attacks on United States' interests through coordinated assaults and missile and drone attacks across the Red Sea and Middle East.[5] Seeking to re-establish its great power status from czarist and Soviet ages, Russia aggressively pursued reacquiring Ukraine through irregular and conventional warfare, and waged a full-scale military invasion in 2022.[6] Through modernization of the People's Liberation Army (PLA), the PRC hopes to displace the United States as a regional power in the Indo-Pacific.[7] Since taking power, Xi Jinping doubled the PRC's defense budget, and it is trending to go higher based on the goal of achieving reunification with Taiwan.[8]

The United States no longer maintains an international manufacturing edge since globalization diminished its ability to outproduce economic competitors with the highest quality and quantity of material. Additionally, the deliberate downsizing of defense manufacturing after the conclusion of the Cold War led to the elimination of 2.1 million jobs in the domestic DIB.[9] Today the uncertainty of defense spending in a predictable manner frustrates the ability for small firms to compete with the DIB's "Big 5" for defense contracts.[10] Due to political polarization and economic politicization, Congress has not provided consistent fiscal budgets and relies instead on its Continuing Resolution (CR) Authority, with 37 CRs passed between 2014 and 2023 fueling instability.[11] CRs, shared with measures like the Budget Control Act, cause "fluctuations (that) challenge the viability of suppliers within the industrial base by diminishing their ability to hire and retain a skilled workforce, achieving production efficiencies, and in some cases, staying in business."[12] The tangible effect of CRs on the DIB impacts DoD's ability to fund new programs because CRs limit spending to sustaining current programs, further delaying prototyping and testing of potential technologies.[13]

Amid these ongoing challenges, the DoD Replicator initiative intends to accelerate the mass production of new systems that units can employ in conjunction with existing platforms. Replicator may generate affordable all-domain, attritable, autonomous platforms, like unmanned watercraft and aircraft, at a scale in 18 to 24 months that could overwhelm a potential adversary.[14] The introduction of unmanned ground platforms in significant numbers with teleoperated or remote human control would allow commanders to accept a higher degree of risk than they might accept with manned platforms, thus challenging an adversary's plans and act as a deterrent through technological supremacy.[15]

Stakeholders: The Iron Triangle

An Iron Triangle describes the relationship between government agencies, Congress, and interest groups who influence the budget and policy of various public programs.[16] For the RCV acquisition program, the DoD, congressional armed services authorization and appropriation committees, and select industries in and out of the DIB form the Iron Triangle.

Within the DoD, the U.S. Army serves as proponent for developing the RCV capability as one of the Army's signature modernization efforts.[17] Informed by earlier prototyping and experimentation, the Next Generation Combat Vehicle (NGCV) Cross Functional Team (CFT) developed the initial concept and requirements that informed the abbreviated Combat Development Document (CDD) for RCV-Light (RCV(L)) in 2022. Collaborating with the NGCV CFT, the Program Executive Office for Ground Combat Systems is responsible for the RCV acquisition program. The next iteration of prototyping follows the Middle Tier Acquisition – Rapid Prototyping (MTA-RP) pathway for hardware in parallel with a Software Acquisition Pathway (SWP) for software development. The MTA-RP uses an iterative design-upgrade-test approach and will integrate software developed from SWP activities. Each cycle culminates with a Knowledge Point and Soldier Touchpoint that informs the complete system prototype as well as operational concept maturation, CDD refinement, and doctrine development. The MTA-RP will be completed in fiscal year 2027 for an estimated cost of $498 million, and it is fully funded in the Future Years Defense Program.

Within Congress, the primary stakeholders are the four Congressional Defense Committees: House Armed Services Committee, Senate Armed Services Committee, House Appropriations Committee – Defense, and Senate Appropriations Committee – Defense. The Armed Services Committees, or authorizers, focus on DoD's strategy and requirements for the RCV capability. The Defense Appropriations Committees, or appropriators, focus on the funding needed to execute DoD's strategy. The Defense Committees supported RCV Research, Development, Test, and Evaluation (RDT&E) funding requests in fiscal years 2023 and 2024 – $108 million and $142 million, respectively. The President's Budget Request for 2025 shows a lower request of $93 million with a total of $905 million programmed through 2029. Procurement funding has not yet been requested.

Within the industrial component of the RCV Iron Triangle, participation expands beyond General Dynamics and BAE Systems, the two companies accounting for 45% of the armored combat vehicle market. In September 2023, the Army awarded four companies – McQ, Inc., Textron Systems Corporation, General Dynamics Land Systems, and Oshkosh Defense – with agreements for the design and build of RCV(L) prototypes in Phase I of a multiphase program of record competition. Each company is expected to build and deliver two platform prototypes by August 2024. Concurrent with the development of the physical platform, the Army contracted several companies to develop software for autonomous navigation, machine learning and autonomy, and software system integrators. Forterra, Kodiak Robotics, Neya Systems, and Overland AI are competing for autonomous navigation. Applied Intuition and Scale AI are competing for machine learning and autonomy. Anduril and Palantir are competing to be the software system integrators.

Political, Economic, Social, and Technological (PEST) Analysis

This research uses the PEST analytical framework to better understand and highlight the key external factors that would affect industry's decision to participate in or abstain from the development of autonomous or semi-autonomous UGCVs. The framework represents a macro - environmental scan that seeks to identify both the opportunities and threats driving industry decision-making at the enterprise level. PEST factors influence the long-term investment decisions and conduct of U.S. manufacturers, and the appendix expands upon the analysis summarized below.

Political: *Geopolitical Tensions Driving Industrial Policy Priorities and Actions*

Today's tense geopolitical environment is a strong driver for the development of UGCVs. Dangerous hotspots dominate the news and reflect increasing global complexity and uncertainty. U.S. adversaries have significantly strengthened their industrial and military capabilities and are challenging America's technological dominance. The United States is in a period of intense security competition with the PRC marked by fast-evolving technologies such as AI, quantum computing, biotechnology, automation, and robotics, which are already shaping modern warfare and promise to give the technologically stronger power the battlefield advantage.

To incentivize innovation within the DIB, DoD released its inaugural National Defense Industrial Strategy (NDIS) in January 2024. The strategy serves as a roadmap for prioritizing and modernizing the DIB, placing special emphasis on advanced manufacturing, automation, robotics, and machine-learning. Driven by the military-technological arms race with the PRC, rising global tensions, and fast technological developments, both DoD and Congress appear to be sending clear signals to industry that there is a growing awareness, interest, and support for the development of UGCVs.

Economic: ***Steady U.S. and Global Economic Recovery and Disinflation***

The U.S. economy has already surged past its pre-pandemic level and is on a path of a steady growth and disinflation. The global demand for dollar-denominated assets strengthens the U.S. dollar and boosts American manufacturers' ability to source foreign materials. The normalization of international business has abated supply chains problems, and increased fuel supplies lower transportation costs. Absent an unforeseen exogenous shock to the U.S. and global economies, the macroeconomic fundamentals – Gross Domestic Product growth, inflation, interest rates, exchange rates, commodity prices, labor markets, and consumer demand

– appear favorable for ongoing and new industry investments in advanced technologies, including the development of UGCVs.

Social: ***Public Acceptance of "Killer Robots"***

The anticipated role and utility of UGCVs as valuable assets in modern warfare is not without controversy. Fundamentally, it is a question of trust. As the technology matures and its use in combat increases, public perceptions and government regulation will no-doubt evolve. Use of unmanned platforms may become increasingly necessary as the U.S. military struggles to meet recruiting and retention goals to maintain and man the Joint Force. U.S. firms interested in the UGCV development should pay close attention to both the regulatory environment, as well as the public perceptions and attitudes as those may influence congressional support.

Civilian authorities will need to comprehend the implications of employing RCVs for military purposes before choosing to approve requirements and provide resources. As momentum for using autonomous and unmanned weapons increases, so too does momentum toward establishing an international treaty restricting their use.[18] On November 1, 2023, the United Nations (UN) General Assembly began deliberations on a resolution highlighting the dangers of allowing an algorithm to ultimately control decisions involving killing. In April 2024, the UN Secretary General asked stakeholders, including industry and private firms, for input on their position about restricting said weapon systems.[19] Since the United States often sets the pace for international defense production and R&D, the sooner the U.S. government articulates UGCV policy the easier it will be to speak persuasively in forms like the UN.

Technological: ***War Lessons and Rapid Experimentation***

Great and smaller powers alike are in competition for technological advantages on the battlefield, and UGCVs of different sizes and capabilities are being fast-developed and employed. Two years into the war in Ukraine, the Ukrainian government is ambitiously calling for the production and fielding of an "army of robots."[20] UGCVs fulfill an array of tasks on the battlefield for the Ukrainian Armed Forces: logistical UGCV's carry supplies; evacuation UGCVs move injured people; "kamikaze" UGCV's disarm enemy trenches and minefields. Most of these are remote-controlled by people and operate within a few kilometers range. Similarly, the Israeli Defense Force (IDF) uses UGCVs to carry heavy loads, perform difficult maneuvers, and fire weapons systems.[21] Put simply: chips, sensors, and robots will likely determine who wins the next war, and the United States must prevail technologically to either deter or win.

PEST Assessment: ***Generally Conducive Macroenvironment, but . . .***

The PEST analysis suggests that the macroenvironment generally supports UGCV development. Industry would expect stronger signals from the government in the form of dedicated budgeting, RDT&S, strategic acquisition programs, and realistic prototyping, testing, and fielding timelines. Such government decisions and actions will help catalyze broader private sector interest, generate greater competition, and accelerate the development of UGCVs. Industry expects the government to lead, offset the "valley of death" risk, and incentivize private sector engagement in this space. If the U.S. objective is to achieve deterrence by technological superiority, boost the warfighter's capabilities, and minimize the loss of life, then now would be the time to develop the necessary programs, expand UGCV experimentation, adopt the lessons from Ukraine and Gaza, and deny China the technological advantage.

Replicator Initiative Terminology

As the U.S. Army defines the requirement for developing UGCVs and integrating them into units, senior leaders must develop a procurement strategy that will lead to a competitive advantage to exploit and defeat an adversary's critical vulnerabilities. Introducing unmanned platforms into a conflict requires changing how military commanders understand, visualize, describe, and direct action to achieve military objectives. Several key terms related to the Replicator initiative require definitions and inclusion in the accepted terms of reference relied upon by requirements and doctrine writers, as well as the acquisition officials who will share responsibility for the duration of the RCV program's lifecycle.

Unmanned. Over the past two decades, military commanders have used unmanned platforms to perform resupply, close air support, and intelligence, surveillance, and reconnaissance (ISR). The performance of these missions by unmanned systems allowed commanders to remove humans from the battlefield in counterinsurgency operations against non-state actors. Unmanned systems do not have a human operator onboard and are operated remotely, while optionally manned systems are configured to have a human operator onboard or operated autonomously. Unmanned systems can be smaller than optionally manned systems that must accommodate humans and their gear.[22]

Autonomous. Incorporating autonomous UGCVs into maneuver formations requires careful thought, regardless of how quickly technology evolves. Investments in autonomous capabilities must be decided through rigorous analysis to ensure that they remain synchronized with all other efforts to achieve a military objective. In "Pros and Cons of Autonomous Weapons Systems," the authors propose a definition of autonomy: "a machine that has the ability to make decisions based on information gathered by the machine and to act on the basis of its own deliberations, beyond the instructions and parameters its producers, programmers, and users provided to the machine."[23]

One emerging view presents autonomy along a spectrum that accounts for different levels of autonomy.[24] This spectrum could be described in three categories: 1) human remote teleoperation (human in the loop); 2) human oversight of one or more independent system operations (human on the loop); 3) full independent operation without human operator action (human out of the loop). A fully autonomous UGCV could sense, decide, and act independently, meaning that humans could not intervene promptly.[25] In this case, the UGCV has the necessary components to complete the entire Observe Orient Decide Act loop: searching for and detecting enemy targets, deciding whether to engage them, and then engaging the target.[26] Investing in a UGCV that can act independently would involve programming an algorithm determining the value of human life.

Attritable. Recently senior military leaders have used the term "attritable" in various venues without an agreement on its meaning to codify into doctrine. Joint Publication 1 defines attrition as gradually reducing the enemy's effectiveness or strength.[27] As an adjective, "attrit-able" means something "can undergo attrition or something that a commander is comfortable throwing away."[28] Another military term that is useful in understanding attritable systems is the term "expendable," which means "something that can be lost without much impact" like a munition fired from a weapon.[29]

Affordable. What would make an RCV "affordable"? At a minimum, a Replicator system should cost some meaningful percentage less than the cost of the manned system that provides that capability today. Perhaps it should be commensurate with the cost of other expendable technical capabilities, such as missiles. With a higher quantity of systems ordered, the manufacturing cost per platform should decrease. The use of Cost Benefit Analysis is another way that DoD assists leaders make resource informed decisions by laying out detailed cost estimates and the expected benefits that will be derived from the capability.[30]

Framing the Operational Concept

UGCV development should drive revisions to the U.S. Army's operational doctrine and the introduction of new tactics, techniques, and procedures (TTPs) for integrating the RCV into future formations to gain a strategic advantage. In his second message to the Joint Force as chairman of the Joint Chiefs of Staff, General Charles Brown identified three focus areas: balancing risk, aligning strategic processes, and advancing Joint Force design, modernization, and development.[31] RCVs must have the following capabilities to ensure the U.S. Army aligns itself with General Brown's strategic priorities.

The Army's Future Operational Environment posits that emerging technologies will create increased operational complexities, necessitating a holistic approach to protection that includes physical, cyber, and cognitive domains. General James Rainey, commander of Army Futures Command (AFC), supports blending machine and human optimization which underscores the importance of developing effective operational concepts for UGCVs. As described in an AFC publication discussing the protection warfighting function, UGCVs can serve as force multipliers, executing dangerous missions and reducing risks to soldiers while enhancing operational effectiveness.[32]

To effectively integrate UGCVs into future formations, the Army should consider mixed-unit structures where UGCVs operate alongside conventional forces. In armored brigades, a robot platoon could provide additional firepower and serve as a vanguard in high-risk environments, as highlighted in discussions about the Army's plans for UGCVs. In infantry formations, UGCVs could enhance situational awareness, mobility, and lethality, as demonstrated in the "10X" concept.[33] Lessons learned from conflicts in Ukraine and Gaza should inform TTPs. In Ukraine, the effectiveness of unmanned ground vehicles demonstrates the potential of UGCVs in reconnaissance and direct combat roles. Similarly, Israel's multi - dimensional unit in Gaza showcases the integration of high-tech equipment with conventional forces. These examples illustrate the importance of TTPs emphasizing human-machine collaboration, autonomous decision-making, and adaptive mission planning.[34]

Effective mission command is vital for successful human-robot teaming. Indo-Pacific Command's insights into leveraging mission command for soldier-robot teams emphasize the need for clear communication and decentralized decision-making. The increasing autonomy of UGCVs can alleviate bandwidth concerns and improve operational efficiency. However, the Army must ensure that soldiers retain control over critical decisions essential in dynamic combat situations.[35]

An operational assessment would validate the implications of fielding RCVs across DOTMLPF-P. Before RCVs arrive in battalion motor pools, the Maneuver Center of Excellence at Fort Moore, Georgia, must update technical manuals, crew gunnery standards, and – in consultation with the Combined Arms Center at Fort Leavenworth, Kansas – maneuver and maneuver support doctrine. Future Army doctrine documents should also be nested with the future Joint Warfighting Concept 4.0 to ensure interoperability across the Joint Force.[36] Soldiers in the units receiving RCVs must receive New Equipment Training from a uniformed or contract cadre on how to operate and maintain the unfamiliar system.

Based on the specifications of the new RCVs, the Installation Management Command must determine the necessity of new military construction to address the unique range requirements, digital training facilities for soldiers, and update maintenance facilities to accommodate the new RCVs on garrisons. Fielding such large quantities may require a different approach, since some systems will go directly to units while others may be stored in Army Prepositioned Stock (APS) or depots that may currently lack storage space. Funding for each of these efforts may not align with current funding priorities, so the sooner the Army completes the operational assessment, the sooner it can reprogram spending requirements to support a fielding.

RCV Considerations for Replicator

Beyond attritable, autonomous, and affordable, several ground-specific capabilities must be considered before the RCV could become a viable candidate for the Replicator initiative. Machine Learning and Artificial Intelligence (ML/AI) will be pivotal for enhancing RCV capabilities, but the technology required to manage these tasks autonomously needs further development to handle the conditions of battlefield environments reliably and remain durable throughout combat operations. These technologies will enable RCVs to perform complex tasks autonomously, such as navigating difficult terrains, identifying threats, making tactical decisions, and learning from past experiences to improve future performance. Modern ML models, particularly deep learning, have shown significant successes in processing and making sense of large datasets. More mature AI technology should provide decision-making support that allows RCVs to select the best course of action based on real-time data analysis and predefined operational strategies.

As autonomous decision-making matures for land platforms, the Army needs to be poised to capitalize on technological breakthroughs to gain advantages in mobility, lethality, power management, communications, and spectrum management. These tactical requirements must be balanced with protection considerations for the platform, its hardware and software.

Mobility. The mobility of UGCVs is paramount. The ability for the AI decision making software to allow the UGCV to self-navigate until a human driven decision is needed is as critical as any advanced capability the Army is pursuing. The speed of robotic mobility on the battlefield carrying lethal payloads can be an overwhelming advantage. Limiting human involvement in that effort should be maximized by the Army. The cost of advanced materials and technologies must be balanced with the need for affordable, mass-producible vehicles.

Lethality. The lethality of an RCV must be balanced with the Replicator's focus on attritability, incorporating weapon systems that are effective yet inexpensive enough to be considered attritable. RCV lethal capabilities must possess the ability to accurately engage targets. To maximize tactical advantages from RCVs, integration of advanced targeting systems with real-time data inputs that seamlessly integrate into the broader tactical network are critical, especially as the platforms become more autonomous and have less human interaction.

Power Management. As autonomy advances beyond teleoperation, UGCV system integration must ensure platforms can provide power for operational duration and efficiency. Platforms focused on singular or minimal mission roles, such as "first contact" UGCVs would emphasize AI enhanced mobility, lethality, and secure communications while other platforms conduct reconnaissance missions. Singularly aligned mission roles for UGCVs will limit power management concerns and emphasize operational duration and efficiency.

Communications. Secure, reliable communication systems are critical for the operational autonomy of RCVs. Effective communications ensure that RCVs can receive timely commands, coordinate with other units, and transmit valuable battlefield data back to command centers. This capability is particularly critical under Replicator, fielding autonomous systems capable of performing complex missions in contested environments. Advances in encrypted communication links that can resist jamming and interception are crucial. Ensuring that new communication technologies integrate seamlessly with existing military networks without requiring extensive human interaction or modifications presents ongoing challenges to not only service specific communications but the joint and allied communications enterprise.

Spectrum Management. Reliable, real-time data transmission poses a significant challenge in a combat environment where electronic warfare measures might be in place. RCVs must employ state-of-the-art encryption methods to protect data integrity and confidentiality preventing adversaries from intercepting or tampering with critical operational data and must resist jamming and other electronic warfare tactics that could disrupt command and control. As the electromagnetic environment becomes increasingly congested, managing the spectrum efficiently while ensuring reliable communications for autonomous RCVs becomes more complex. Options are needed for when platforms are cut-off from networks.

Protection. In comparison to manned platforms, protection may be the least prioritized capability for UGCVs. Emphasis on physical armored protection of an attritable system is counterproductive to mobility and function and seems counter to Replicator itself. Protection should be sufficient for the attritable platform to complete its mission. Integrating protective and passive detection technologies in a way that maintains the low signature profile of UGCVs is difficult and should not be pursued by the Army until more advanced technologies are available.

Anti-Tamper (AT) Technology. Attritable systems are expected to be lost and obtained by enemy combatants; therefore, RCV data storage should be offboard or have AT features to prevent its compromise. However, offboard data may cause latency slowing RCV capabilities, so data security must be balanced with survivability.

Platform Operation Software. RCV network integration allowing for coordinated attacks and interoperability support from manned and unmanned systems will be increasingly more important as unmanned and autonomous technologies are integrated into RCVs. Common Ground Autonomy and Robotic Control Software, developed by the U.S. Army Ground Vehicle Systems Center, will allow the military to maximize resources efficiently, only buying a capability once and reusing it across multiple applications, sharing upgrades across systems, creating a common transition path, and increasing competition across the platform's lifecycle.

Payload/Mission Operation Software. Advanced automation in the handling and deployment of payloads is essential, minimizing the need for human intervention on mundane and labor-intensive tasks. The software architecture of RCVs must support rapid updates and modularity. The software backbone of RCVs is pivotal to their operational efficacy, encompassing everything from mission planning and execution to real-time data processing and future capability integration of autonomous navigation. As RCVs continue to evolve, the sophistication and reliability of their software systems become critical.

Competition, Contracting, and Costs

Through industry competition the Army will determine the best product to meet the RCV's operational requirements. Competition must continue as a pillar of the RCV program across the entire lifecycle to optimize use of taxpayer dollars and ensure Army demands are consistently met. One-time competition for platform and vendor selection (vendor-lock) is not sufficient to ensure that the Army's peace and wartime productions capacity needs will be met, innovative upgrades and enhancements will continue, or that costs will be optimized.

Robust competition across all aspects of the RCV program – design, software, production, enhancements, and sustainment – will allow for shifts in focus of the program based on evolving national security needs. Low cost may be the focus in peacetime, but in a time of war, the need to surge capacity to maximize production may be paramount. Recognizing that firms have varying core competencies, the Army will benefit from maintaining competitive conditions which may drive down costs. The RCV program follows two acquisition pathways: the MTA pathway to develop the next iteration of hardware and the SWP to develop the software.[37] There are unique production factors that should be considered for both hardware and software if this capability is to be included in Replicator.

A Replicator variant of the RCV that takes the factors of autonomy, affordability, attritability, and large quantities into account creates unique design considerations. The current RCV may not fully take advantage of these factors and may need to be redesigned to address them. Adoption of modular open systems approach (MOSA) will improve the viability of the RCV program as a Replicator candidate. MOSA enables the integration of subsystems and components from various vendors, facilitating easier upgrades and maintenance, which is particularly vital in the rapidly evolving field of military robotics. MOSA will be crucial for enhancing RCV versatility, longevity, and interoperability within military operations and promises to make RCVs more adaptable, sustainable, and cost-effective.

The RCV will have a remote control. Ensuring the remote control is universal to the RCV and any other unmanned ground vehicles would be beneficial. The Replicator design can be less robust and in theory use fewer durable materials since the system is not expected to survive for 30 plus years in the fleet; this will also contribute to the overall affordability of the system. Communications and operating systems should be robust to maximize durability, but do not have to be so robust to meet long-term survivability. With large quantities procured rapidly, simplicity of design using readily available materials will be beneficial to avoid long-lead items.

Use of batteries to enable silent overwatch and passive capabilities will necessitate the use of strategic materials such as lithium in the near-term; therefore, adequate planning for large quantities should start early.

Hardware production concerns for Replicator variants largely center on manufacturing capability. Large quantities produced rapidly are expected to lead to additional facilities and tooling to accommodate multiple production lines. Other options to get large quantities are contract awards to multiple vendors. This could be two (or more) different solutions meeting the desired requirements or a single solution using government-owned technical data. Government furnished equipment, such as communications, sensors, or weapons, needs to be managed closely to increase quantities and align delivery and integration timelines. Investments in manufacturing technology will improve the production of components as well as help turn long-lead components into easier to produce items.

Software is managed differently than hardware and would remain that way as a Replicator candidate. The SWP uses agile software development methodologies that iterate software builds early and often.[38] There is a close relationship with the user, and software requirements are managed through Capability Needs Statements rather than traditional Capability Development Documents, which provides flexibility to adjust software content quickly. Software updates will be required annually but may be done more often.[39] The use of a planned System Integration Lab will facilitate software development, integration with the platform, and testing prior to deployment.[40]

Sustainment and Supply Chains

Sustainment considerations must factor into becoming a Replicator candidate, especially if the Army fields different RCV variants. This includes maintenance, repair parts, software upgrades, storage facilities, spares, and obsolescence planning. Contractor logistics may be more practical for systems in storage, while organizational maintenance should be used for systems integrated into formations. Although attritable, it remains preferrable for RCVs to return from missions for future use which require forecasting shelf-stock of repair parts. Obsolescence planning and modernization presents unique challenges given the quantities of RCV variants likely to emerge through Replicator.

Supply chain vulnerabilities must be assessed for both RCV development and lifecycle sustainment. The compressed Replicator production timeline may add additional stress on a struggling DIB, leading to initially higher costs for the DoD. Strategic materials, including high-strength lightweight alloys and advanced composites, as well as technical skillsets like software development are in high demand for many defense and commercial products across the globe.

High-strength Lightweight Alloys. Aluminum, titanium, and magnesium provide unique and specific characteristics to the RCV makeup. Aluminum alloys offer excellent strength-to-weight ratios, making them ideal for reducing the overall weight of the RCV while maintaining structural integrity. Titanium alloys offer high strength, corrosion resistance, and temperature resistance properties. They are used in critical components of the RCV, such as armor plating, propulsion systems, and engine components, to enhance durability and performance. Magnesium alloys are lightweight and exhibit good mechanical properties, including strength and stiffness, and are essential in components where weight reduction is critical, such as body panels, brackets, and interior structures.[41]

Advanced Composites. Carbon fiber-reinforced polymers, aramid fiber composites, and glass fiber-reinforced polymers share a similar disposition as the alloys. Like aluminum alloy, carbon fiver polymers have exceptional strength-to-weight ratios, making them ideal for lightweight components in RCVs. They are also used in critical defense materiel like body panels, armor, and chassis reinforcement. The Aramid fiber composites, such as Kevlar, provide high tensile strength and impact resistance properties, aiding in ballistic protection and blast mitigation to improve crew safety and vehicle survivability. Glass fiber reinforced polymers offer good strength, stiffness, and impact resistance at a much lower cost compared to carbon fiber composites but does not deliver the same level of durability or survivability.[42] In addition to the aerospace and automotive industries, these advanced composites are also in high demand in the marine industry, renewable energy sector, medical devices, and sports equipment.

Software Development. Software management becomes a supply chain concern as well because DoD-specific cybersecurity requirements may deter small firms with exquisite talent from suppling software upgrades for a relatively niche RCV market compared to the commercial market's higher demand and willingness to pay competitive prices for software requiring considerably less cybersecurity. Yet as technology advances, so do the challenges of integrating and protecting those technologies. The interconnected nature of modern supply chains exposes RCV programs to cybersecurity risks, including cyberattacks, data breaches, and intellectual property theft. Protecting sensitive information, proprietary technologies, and critical infrastructure from cyber threats requires robust cybersecurity measures, information-sharing mechanisms, and risk management strategies across the supply chain ecosystem.

The complexity of RCV systems, which involves a multitude of components, subsystems, and technologies sourced from various suppliers, increases the supply chain's vulnerability to disruptions, such as single-source dependencies, geopolitical risks, and limited domestic production capacity. A robust and resilient supply chain requires industry partners and government agencies to prioritize supply chain resiliency by implementing proactive measures to mitigate risks and enhance agility within the system. This could be achieved by diversifying sourcing strategies and reducing dependencies on single-source suppliers. By identifying alternative suppliers and fostering partnerships with multiple vendors for critical components and materials, stakeholders can mitigate the impact of supply chain disruptions and minimize production delays.

Proposed Revisions to Defense Policy

Anticipating the fielding of RCVs, defense and military service leaders should begin revising department policies now to ensure that prescriptive language does not obstruct the development or employment of future robotic ground systems. Policy revisions typically require six months to a year to complete: drafting new language, multiple staffing rounds from the action officer to general/flag officer level, legal review, formal approval, and publication. The hierarchy of policy requires updates to Department of Defense Instructions (DODI) and Directives (DODD) and Chairman of the Joint Chiefs of Staff Instructions (CJCSI) before the military services can update their own publications; however, all components could synchronize similar revisions to accelerate the process. Circulation of updated policies increases awareness of changes that will inform decisions made by program managers and acquisition officers involved in RCV procurement, as well as doctrine writers responsible for explaining how to integrate autonomous systems into units for tactical operations.

The first policies to review should relate to the use of an unmanned ambulance on the battlefield. A remote RCV may be programmed to carry a patient between a platoon's position on the frontline and an ambulance exchange point or triage center farther back in the security area. DODI 6000.11, "Patient Movement (PM)," requires the military services to collaborate in developing policies to "facilitate interoperability throughout the continuum of en route care."[43]

This includes providing medically qualified personnel to accompany a wounded service member during an evacuation from the point of injury to treatment facility.

Medical planning policy must not only change to authorize the unaccompanied transport of a patient, but it must specify the acceptable distance or duration of time for the patient to be left unattended on the RCV. Perhaps line-of-sight transport is within tolerable risk levels, but if the distance exceeds that then the policy must outline the maximum range or minutes for travel. Perhaps it would be more appropriate for the policy to authorize the medic on scene to determine whether the injury requires an attendant for the duration of the evacuation based on criteria specific to each patient: severity and location of the wound, need for a ventilator, consciousness, and willingness to travel without an attendant. Regardless of the decision, the policy discussion must include the Office of the Undersecretary of Defense for Personnel and Readiness, Defense Health Agency, and surgeons general for the military services.

The second group of policies concerns the use of autonomous weapons. A machine gun, grenade launcher, or laser mounted onto a RCV could provide additional firepower for a light infantry platoon. In January 2023, the department updated DoDD 3000.09, "Autonomy in Weapon Systems" for reasons championed by Deputy Secretary Kathleen Hicks: "DoD is committed to developing and employing all weapon systems, including those with autonomous features and functions, in a responsible and lawful manner."[44] Revisions require the use of autonomous weapons to be consistent with DoD AI Ethical Principles, establish a department-level Autonomous Weapon Systems Working Group, and provides a flowchart to determine whether a senior defense official must review and approve new applications for autonomous weapons.[45]

DODD 3000.09 directs the military services to "design and develop autonomous and semi-autonomous weapon systems that allow commanders and operators to exercise appropriate levels of human judgment over the use of force."[46] Service-level acquisition policies should mirror the requirements within the DODD to ensure that concepts and prototypes are not rejected by the Autonomous Weapon Systems Working Group for lacking rigor in developmental testing, anti-tampering and cybersecurity mechanisms, or a legal review of AI integration.

A final area for policy revisions relates to intellectual property (IP). Over the next decade, the military services will likely field multiple variants of RCVs as technologies improve navigation, maneuverability, autonomy, and new ancillary capabilities like weapons and ground sensors. MOSA will be critical for installing and integrating new hardware and software. Akin to the transfer of the Joint Light Tactical Vehicle production contract from Oshkosh Defense to AM General, the basic RCV platform may transfer from the original firm contracted to manufacture the initial set. It may be optimal for the government to own the IP of the RCV platform to allow defense labs to continuously modify the design based on operational lessons learned from fielding the RCV in different environments. As one official from Director, Operational Test and Evaluation explained, a system's performance during a controlled developmental test does not always guarantee success in desert, arctic, or urban terrain.[47]

DODI 5010.44, "Intellectual Property (IP) Acquisition and Licensing," acknowledges that weapons and information systems will become increasingly dependent on technology, and the acquisition and licensing of IP necessitates a continuous dialogue with industry.[48] Military services must integrate IP planning into their acquisition strategies early and throughout a program's life cycle, especially if RCV autonomy will continue to expand. The government must understand how the software determines decisions for system employment, especially involving target engagement with autonomous weapons. This becomes more complex when programmers write thousands or millions of lines of code that require updates to improve human-machine interface. Requirement developers, acquisition officers, and program managers must review their service-level IP policies to ensure that they provide sufficient flexibility to acquire and license IP expressly related to autonomous systems. Policy revisions should address ownership of AI-generated IP, clarifying whether it rests with the AI software developer or the defense contractor relying on the software.

Recommendations for Stakeholders

If RCVs could perform the "dull, dirty, and dangerous" jobs of demining, securing enemy grounds, patrolling, surveying, transporting materiel and people to and from the battlefield; if they could fall in formation with soldiers, detect, shoot, and destroy the enemy, then RCVs will certainly save lives, reduce risk, and provide technological battlefield advantages to those that have them.[49] To ensure the U.S. Army's RCV program becomes a viable Replicator candidate, the DoD, Congress, and industrial partners should adopt the policy and resourcing recommendations listed below.

For the Defense Department:

1. **Headquarters, Department of the Army**
    a. Develop a resourcing strategy and identify billpayers.
    b. Develop Congressional engagement strategy to discuss Replicator.
    c. Fund and initiate a Replicator RCV variant program.
2. **Next-generation Combat Vehicle Cross-functional Team**: Assume greater risk in RCV technology to accelerate the development and fielding of the platform.

3. **Maneuver Capability Development Integration Directorate**: Accelerate DOTMLPF-P integration for RCVs before arrival of the platform.
4. **Ground Combat Systems Program Executive Office**: Execute an affordable and attritable prototyping effort with industry.

For Industry:

1. **Current RCV industry partners**
   a. Provide transparent assessments of feasible technological development, supply chain vulnerabilities, and production schedules.
   b. Support using MOSA; adhere to and support development of standards.
   c. Invest in extra production capacity and R&D.
2. **Potential RCV industry partners**
   a. Dialogue with DoD to learn about opportunities.
   b. Compete for contracts, big and small.
   c. Invest in R&D.

For Congress:

1. **Authorization committees:** Underwrite risk in Replicator.
2. **Appropriation committees:** Fund the Replicator RCV variant program.

Conclusion: Improving Lethality and Saving Lives

After decades of dominance in the land domain, the United States faces new robotic and AI threats, evident from the realities of the Russo-Ukrainian war, the latest Israeli-Palestine conflict, and the PLA's modernization. Indeed, the appearance of UGCVs on the modern battlefield has begun to change the nature of war and how commanders understand, visualize, describe, and direct actions to achieve military objectives. Determining the appropriate balance between man and machine will continue to evolve with emerging technologies, and the sooner RCVs can be integrated into units across the U.S. Army, the faster an understanding of and trust in their capabilities will be realized.

In its pursuit to make an RCV variant a viable candidate for the DoD Replicator initiative, the U.S. Army must develop a strategy distinct from how it previously acquired manned ground vehicles. To secure Congressional support, the strategy must demonstrate its comparative advantage in the land domain to the continued reliance on legacy manned systems. Accelerating the DOTMLPF-P integration to begin the operational assessment concurrently with the development of RCVs will avoid delays and surprises later in the program and match the pace of the Replicator initiative. Assuming more risk in the Replicator variant prototyping effort and fielding RCV to soldiers earlier will aid in understanding the maturity of the technology sooner to hone the focus of iterative efforts.

The Government needs to signal what our focus areas are and specify which requirements need solutions but this also requires support from industry. Industry support should come in the form of providing transparent assessments of feasible technological development, calling out supply chain vulnerabilities, and providing realistic production schedules. Industry must also adhere to and support using MOSA and continue with strong investments in R&D and production capacity.

Congress must support the Replicator RCV variant, acknowledging the program's benefits by underwriting the risk in the authorizations, and providing adequate funding in the appropriations.

It will take time to fully realize the benefits of integrating RCVs into military formations to enhance all six warfighting functions: command and control, intelligence, fires, maneuver, protection, and sustainment. Yet a clear signal from the DoD and Congress to industry that the U.S. Government remains committed to a flexible production pathway will accelerate efforts to make RCVs affordable and attritable. The Replicator initiative should reward companies – large and small – wishing to compete for contracts that will shape the future of land combat.

APPENDIX: Full Political, Economic, Social, and Technological (PEST) Analysis

Political: ***Geopolitical Tensions Driving Industrial Policy Priorities and Actions***

Today's tense geopolitical environment is a strong driver for the development of RCVs. Dangerous hotspots dominate the news and reflect increasing global complexity and uncertainty. From the war in Ukraine risking escalation through the involvement of NATO members, to the Gaza conflict threatening regional contagion, to rising tensions in the Indo-Pacific, the geopolitical environment is dangerously destabilized. U.S. adversaries have significantly strengthened their industrial and military capabilities and are challenging America's technological dominance. The United States is in a period of intense security competition with the PRC, and to a lesser extent with Russia, marked by fast-evolving technologies such as AI, quantum computing, biotechnology, automation, and robotics, which are already shaping modern warfare and promise to give technologically greater influence on the battlefield.

In August of 2023, Deputy Secretary of Defense Kathleen Hicks announced the launch of the Replicator initiative to improve U.S. capabilities to counter the PLA's mass by fielding attritable autonomous systems in multiple thousands across multiple domains. These systems are meant to be less expensive, put fewer people in the line of fire, and be continuously improved and upgraded. They are to be produced and fielded at speed and scale to enhance the warfighter's capabilities and act as a deterrent by technological supremacy.

To incentivize and strengthen the national innovation and defense industrial base, in January 2024, DoD released its inaugural National Defense Industrial Strategy (NDIS). This road map prioritizes modernization of the national industrial base, placing special emphasis on advanced manufacturing automation, robotics, machine-learning, and other cutting-edge technologies. Publication is a timely and necessary response to foreign industrial policies encouraging the rapid development of automation and robotics, and it reflects a global trend that is garnering more policy attention, research support, and public resourcing. Governments all over the world are taking policy actions in the form of trade restrictions, subsidies, tax-credits, and research and development (R&D) spending to boost their domestic industries.

For its part, the Biden administration championed the CHIPS and Science Act, which passed with bipartisan support in August of 2022 and directs $280 billion toward scientific R&D and semiconductor production in an effort to attract advanced technology manufacturers to the U.S. and away from the PRC, Iran, North Korea, and Russia.[50] Another milestone policy action of the Biden administration was implementing export controls restricting the PRC's ability to obtain or manufacture advanced computing chips that could be used in Chinese-made weapons systems.

Driven by the military-technological arms race with the PRC, rising global tensions, and fast technological developments, both DoD and Congress appear to be sending clear signals to industry that there is a growing awareness, interest, and support for the development of RCVs. The NDIS provides a road map to help guide the private-public relationship toward a more effective and efficient collaboration, inclusive of advanced manufacturing automation and robotics. Defense policy catalysts such as the Replicator initiative and annual Project Convergence testing of human-machine integrated formations lend credence to the RCV concept. Supported by public and private R&D, dedicated budgeting, strategic acquisition programs, and aggressive prototyping, testing, and fielding timelines, RCVs are expected to enter human-machine formations by 2028. The U.S. objective is to achieve deterrence by technological superiority and boost the warfighter's capabilities while minimizing the loss of life. If robots could do the "dull, dirty, and dangerous" jobs of demining, securing enemy grounds, patrolling, surveying, transporting materiel and people to and from the battlefield; if they could fall in formation with solders, detect, shoot, and take out the enemy, then robots would save lives, derisk situations, and provide technological battlefield advantages to those possessing them.[51]

Economic: ***Steady U.S. and Global Economic Recovery and Disinflation***

In its April 2024 Global Economic Outlook, the International Monetary Fund (IMF) projected economic growth of 3.2% for 2024 and 2025 with median inflation declining from 2.8% to 2.4%, respectively. Growth in advanced economies is expected to accelerate slightly and be offset by a modest slowdown in emerging markets. Despite the ominous economic predictions in the post-COVID recovery period of intense inflationary pressures, the world avoided a recession. Restrictive monetary policies, such as quantitative tightening and higher-for-longer core interest rates, are moving the U.S. and the global economy toward an anticipated soft landing.[52]

Absent an unforeseen exogenous shock to the U.S. and global economy, all fundamental macro indicators – Gross Domestic Product growth, inflation, interest rates, exchange rates, commodity prices, labor markets, and consumer demand – appear favorable for ongoing and new industry investments in advanced technologies, including the development of RCVs. The U.S. economy has already surged past its pre-pandemic level and is on a path for steady growth and disinflation. Although, core inflation remains sticky and price-wage pressures persist, U.S. growth in 2024 is projected to increase to 2.7% before slowing down modestly in 2025 as gradual fiscal tightening is expected to reduce aggregate demand. Commodity prices – energy, base metals, and food – are all expected to decline in 2024 causing less inflationary pressures in the economy and the Federal Reserve's policy rate is also expected to decline later in the year. Overall, the U.S. economy has been healthier and more resilient than most, which has increased the global demand for dollar-denominated assets and strengthened the U.S. currency. A stronger dollar benefits American companies (and consumers) seeking to purchase foreign goods and services. The post-COVID normalization of international travel and business operations is abating problems with global supply chains, and transportation costs have declined with increased fuel supplies.

Social: ***Public Acceptance of "Killer Robots"***

The anticipated role and utility of RCVs as valuable assets in modern warfare is not without controversy. Fundamentally, it is a question of trust. At the microenvironment of human-machine integrated formations, the issue is user adoption: Are solders comfortable that the technology would do what it is supposed to and not get out of hand? One recent example of the risks autonomous systems pose comes from the U.S. Air Force where an AI-enabled drone attacked and killed its own operator who was testing how the system would abort a pre-programmed mission.[53] Would the solder trust the AI in the RCV? What if an adversary hacks into an RCV and takes over its functions? These are important considerations that RDT&S programs and combat experimentation will need to wrestle with to secure the warfighter's trust in the technology.

At the macroenvironment of public policies and social perceptions, the issue of lethal autonomous systems looms larger. Human Rights Watch (HRW) has repeatedly urged governments to sign a treaty and commit themselves to setting standards for responsible operations of lethal autonomous weapons. Since 2013, at least 100 nations have expressed opinions on autonomous weapons with over 31 countries calling for their ban. Advanced military nations, including Russia and the United States, argue that international governance of autonomous systems is premature. However, HRW asserts that using AI algorithms and machines in causing human deaths will "dehumanize warfare and erode human dignity."[54]

Given the growing use of autonomous weapons systems and the inherent risks associated with it, in January 2023, DoD updated its 2012 "Autonomy in Weapons Systems" directive, which sets the rules on how to handle the technology and requires the military to minimize the "probability of consequences of failure." The directive further requires that autonomous weapons systems allow operators to exercise the appropriate level of human judgement and control; that the system incorporating AI capabilities is consistent with DoD's ethical principles; and that operators adhere to the laws of war and all applicable rules of engagement. According to a statement by Deputy Secretary of Defense Kathleen Hicks, the DoD directive will help ensure that the U.S. remains the global leader not only in "developing and deploying new systems, but also safety."[55]

As technology matures and its use in combat increases, public perceptions and government regulation will no-doubt evolve as well. U.S. firms interested in RCV development should pay close attention to both the regulatory environment, as well as the public perceptions and attitudes as those could influence Congressional support.

Civilian authorities will need to comprehend the implications of employing RCVs for military purposes before choosing to approve requirements and provide resources. As momentum for using autonomous and unmanned weapons increases, so too does momentum toward establishing an international treaty restricting their use.[56] On November 1, 2023, the United Nations (UN) General Assembly began deliberations on a resolution highlighting the dangers of allowing an algorithm to ultimately control decisions involving killing. In April 2024, the UN Secretary General asked stakeholders, including industry and private firms, for input on their position about restricting said weapon systems.[57] Since the United States often sets the pace for international defense production and R&D, the sooner the U.S. government articulates UGCV policy the easier it will be to speak persuasively in forms like the UN.

Technological: ***Commitment to Rapid Experimentation***

Great and smaller powers alike are in competition for technological advantages on the battlefield, and RCVs of different sizes and capabilities are being fast-developed and employed. Two years into the war in Ukraine, the Ukrainian government is ambitiously calling for the production and fielding of an "army of robots."[58] RCVs fulfill an array of tasks on the battlefield for the Ukrainian Armed Forces: logistical RCV's carry supplies; evacuation RCVs move injured people; "kamikaze" RCV's disarm enemy trenches and minefields. Most of these are remote-controlled by people and operate within a few kilometers range. Similarly, the IDF uses RCVs to carry heavy loads, perform difficult maneuvers, and fire weapons systems.[59]

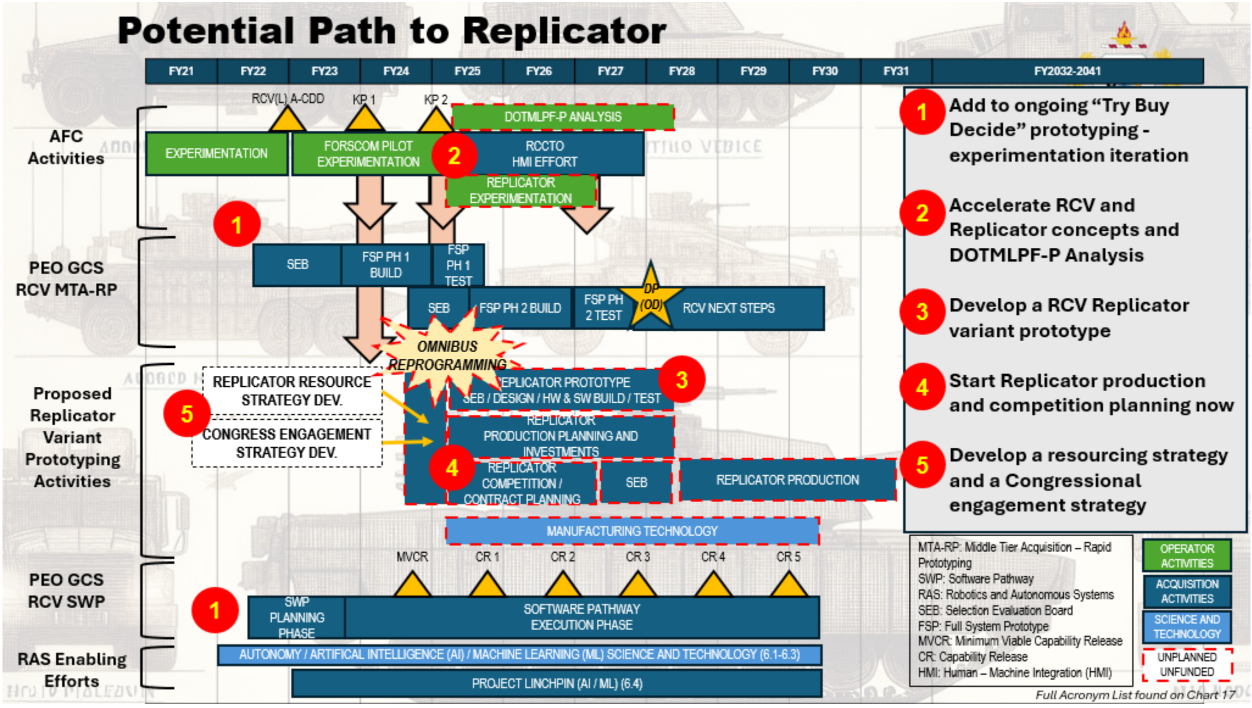
Chips, sensors, and robots will likely determine who wins the next war, and the United States must prevail technologically to either deter or win. The U.S. Army requested $92.5 million for RCV Research, Development, Test, and Evaluation (RDT&E) funding for FY 2025.[60] Examples and lessons from RCV use in Ukraine and Gaza will no-doubt inform and be factored into the Army's future RCV development objectives. In August 2023, as part of the U.S. Army's Next Generation Combat Vehicle (NGCV) program, senior Army leaders prioritized the RCV-L variant over medium and heavy concepts. In September 2023, the Army awarded four U.S. companies – McQ, Inc. (Fredericksburg, VA); Textron Systems Corporation (Hunt Valley, MD); General Dynamics Land Systems (Sterling Heights, MI); and Oshkosh Defense, LLC (Oshkosh, WI) – with agreements for the design and manufacturing of RCV-L prototypes in Phase I of a multiphase program of record competition. Each company is expected to build and deliver two prototypes for developmental testing by August 2024. The award is part of an RCV-L middle-tier acquisition of rapid prototyping that could be transitioned to production and fielding by 2030.

RCV systems are expected to deliver lethality and tactical options to the warfighter and support multi-domain operations. In Phase II, the Army will compete among the four contractors and down select in 2025. The Army will work with the winning contractor to finalize the design requirements and expect the contractor to build and deliver nine full system prototypes by 2026, leading to user reliability and performance testing to support a production decision in 2027. Fielding to the first units would begin in 2028.[61]

PEST Assessment: ***Generally Conducive Macroenvironment, but . . .***

The PEST analysis suggests that the macroenvironment generally supports UGCV development. Industry would expect stronger signals from the government in the form of dedicated budgeting, RDT&S, strategic acquisition programs, and realistic prototyping, testing, and fielding timelines. Such government decisions and actions will help catalyze broader private sector interest, generate greater competition, and accelerate the development of UGCVs. Industry expects the government to lead, offset the “valley of death” risk, and incentivize private sector engagement in this space. If the U.S. objective is to achieve deterrence by technological superiority, boost the warfighter’s capabilities, and minimize the loss of life, then now would be the time to develop the necessary programs, expand UGCV experimentation, adopt the lessons from Ukraine and Gaza, and deny China the technological advantage.

Appendix B: Potential Path to Replicator



The chart above lays out a potential plan for RCV to become a Replicator candidate. It assumes urgency to get to production and that Replicator remains a top DoD priority.

The current RCV schedule captured in the President's Budget Request for fiscal year 2025 is the baseline for this approach. Swim lanes of activity are laid out going down the left of the chart. Unplanned and unfunded activities have dashed lines. The top lane has the AFC-led activities in green. The current Middle Tier Acquisition Rapid Prototyping effort is the next layer. The proposed activities for Replicator are the next layer down. The Software Pathway effort is below that with the planned capability releases. The bottom layer depicts enabling autonomy and ML/AI. The color and key acronyms are in the lower right corner.

The potential path to Replicator is broken down into five broad activities:

Activity One (red circle with yellow 1) is the existing RCV experimentation, prototyping, and software development effort. These activities are a good example of the Army's "Try-Buy-

Decide" philosophy with the iterations of prototype development and experimentation. The intent is to not disrupt the current plan. The recommendations are additive.

Activity Two (red circle with yellow 2) is to accelerate DOTMLPF-P analysis planned for fiscal year 2027 and add more experimentation focused on Replicator. Formations with dozens, hundreds, or thousands of platforms likely will drive different considerations for DOTMLPF-P. This may be something that can leverage or be combined with the United States Army Rapid Capability and Critical Technology Office's Human Machine Integration effort.

Activity Three (red circle with yellow 3) is the recommendation to execute an additional Replicator prototype development effort in parallel with the ongoing Middle Tier Acquisition prototyping effort. The assumption is that some design changes would be needed to meet the Replicator factors of small, cheap, and many. There have been a couple of iterations of RCV prototypes so far, so there is a body of knowledge to create another iteration that takes attrition and cost reduction into account as well as some of the Replicator-specific capability considerations addressed in other portions of this study.

Activity Four (red circle with yellow 4) is to start production and competition planning. Replicator's emphasis on high quantities quickly is a significant challenge. It will take years to prepare for a significant production surge. It has to start right away with a "fund what you know and plan what you don't" approach. Key things to address are facilities, tooling, materials, and labor. Manufacturing technology to improve the efficiency of production also should be funded. Notifying and mobilizing the DIB as soon as possible is essential to setting the conditions for producing large quantities. Both the government and industry need to plan. Contract and competition planning are also important. Given the large quantities for Replicator, an approach of awarding more than one technically acceptable solution may be a means to get at quantities more quickly. Another consideration may be purchasing the technical data package or the IP rights that allow the government to award a single solution to more than one vendor.

Activity Five (red circle with yellow 5) is to develop the resourcing strategy and the Congressional engagement strategy. All of the recommended activities in this chart are new and unfunded. A resource strategy needs to be developed quickly for the end-of-year omnibus reprogramming, the first opportunity for funding. Fiscal year 2025 funding will likely be tied up in a Continuing Resolution and will not be able to be moved until there is an appropriation. Fencing the funding for the existing enablers in Science and Technology and Project Linchpin should be part of the resourcing strategy. The Congressional engagement strategy is just as critical. To move funding for a high-risk concurrent approach for the relatively new DoD Replicator initiative will need opportunities to discuss the strategy with the defense committees and work through their concerns before a reprogramming action will be favorably received.

The recommendations have risk given the number of activities being done in parallel. It requires funding commitments early before the first Replicator prototype is even designed. Congressional support for Replicator may need to be built or strengthened. The production ramp for such large quantities is extremely disruptive to the entire DIB and global supply chain, especially if there is no plan to mitigate the production cliff that happens when such robust production goes to zero in just a few years.

Endnotes

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[2] Throughout this paper we use unmanned ground combat vehicle (UGCV) to refer to a capability and Robotic Combat Vehicle (RCV) to refer to a specific Army program of record.

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