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The Rise of Robots and Autonomous Systems:
Unraveling the Challenges in U.S. Commercial and Defense RAS Industries

ROBOTICS AND AUTONOMOUS SYSTEMS

INDUSTRY STUDY

SEMINAR #5

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Executive Summary

General Douglas MacArthur is famously credited with saying, “Military failure can almost always be summarized in just two words: Too late.” Recently, the Secretary of the Air Force, Frank Kendall, resurrected this phrase to warn slow technological movement would place the United States at a strategic military disadvantage, with potentially devastating effects. As the U.S. faces a pacing challenge with China, with implications for the global world order, U.S. Robotics and Autonomous Systems (RAS) advancement will play a critical role. The 2022 National Defense Strategy emphasizes autonomous technology as an asymmetric approach to deter aggression, change kinetic conflict, and complicate escalation dynamics. The Department of Defense (DoD) seeks to mature autonomous technology through strategic investments in the domestic ecosystem and with U.S. allies and partners. The rapid advancement of commercial RAS drives the need for DoD to be a fast follower, rapidly incorporating commercial capabilities into military-relevant capabilities. Unlike many industries, the greatest obstacles to full RAS incorporation, commercially and militarily, will be cultural, ethical, and social. Accordingly, for the DoD to achieve superiority across the RAS industry, the United States must deftly navigate not only the technological challenges, but also the “soft” challenges: safety, social acceptance, trust, and human-machine integration.

During a four-month dedicated review, the 2022-2023 RAS industry study at The Eisenhower School of National Security and Resource Strategy considered relevant literature and policies, engaged with some of the foremost RAS experts and leaders, and conducted domestic and international field studies across the commercial and military RAS industries. This dedicated review provided important insights regarding RAS, the maritime, land, and air domains, and the strategic environment.

Robotics and Autonomous Systems: RAS refers to robotic systems both with and without autonomous capabilities, and non-robotic autonomous systems. Autonomy can be understood across a spectrum, with various levels of human involvement and risk. Autonomy is introduced to a machine through software, fed by data-informed algorithms. The DoD foresees a future in which humans and RAS will function as collaborative teams, reducing a warfighter's cognitive load and acting as a force multiplier. The evolution of RAS in the United States is challenged by human capital shortages, cultural acceptance issues, ethical concerns, legal restrictions, and the strategic environment.

Strategic Environment: The RAS strategic environment is shaped by internal and external factors including resources, infrastructure, human capital, laws, competitor capabilities, market trends, geopolitical factors, and ethics. With a rapidly growing market, major U.S. defense companies propelled North America to lead RAS manufacturing. As such, U.S. government procurement policies play an important role in shaping the industry. Commercially, RAS has the potential to be incorporated broadly into everyday life, which offers space for continued market growth and increased U.S. competitiveness vis-a-vis China, Russia, and other competitors. Cultural acceptance will play a major role in shaping the U.S. market.

Maritime: The United States and its allies aim to achieve a peaceful and prosperous maritime commerce network using RAS as a tool for maritime domain awareness. However, this requires addressing maintenance, operational challenges, and ethical concerns; and potentially redefining the maritime domain. The sea presents unique challenges for RAS due to its size, diverse conditions, and capacity to host contested areas. The United States and its allies must work through these challenges, as assured sea lines of communication are vital during any armed conflict. RAS can potentially transform naval operations by addressing challenges in autonomy, production, maintenance, and endurance. Ensuring the ethical and responsible use of these systems will enable the U.S. Navy to overcome strategic challenges in the coming years. Commercially, maritime labor unions have stymied RAS growth, based mainly on their concern that it could displace a vital maritime workforce. While ripe with commercial and military potential, RAS in the maritime domain faces a host of challenges ranging from shifting military paradigms to human capital considerations.

Land: To prevail in Large Scale Combat Operations (LSCO), the DoD must incorporate RAS to manage the complexity of multi-domain operations and to perform other dirty, dangerous, and dull tasks. Based on the complexity of the operating environment, the technology to operate completely autonomous Uncrewed Ground Vehicles (UGVs) is not yet mature. Current DoD guidelines limit RAS UGVs to systems constrained by appropriate human judgment, international law, and ethics. Finally, there is a significant disparity between RAS budgeting for the air and maritime domains versus the ground domain, impacting the Army's capacity to innovate and mature its technology. Conversely, the commercial market has made significant progress over the past decade with the introduction of self-driving technology. Commercial trucking also holds great promise, with several firms working to deliver autonomous trucks. The commercial industry faces a complex regulatory environment, which can quell investment and delay growth. This is important, as this technology has the potential to fulfill important military and commercial logistical roles, preserving human capital. With the potential to fulfill several dirty, dangerous, and dull tasks, RAS in the ground domain must overcome technological and budgetary limitations to reach its full potential.

Air: The U.S. defense and commercial Uncrewed Aerial System (UAS) industries stand on a precipice. The DoD is poised for dramatic technological upgrades for defense use, while the

U.S. commercial industry languishes beneath its perceived potential as international competitors strengthen their footholds. As the DoD develops Collaborative Combat Aircraft and other human-machine teaming capabilities, success will be determined by trust and understanding between human operators and their autonomous teammates. Restrictive U.S. arms sales regulations have benefitted China and Turkey, allowing their industries to grow. Commercially, the United States UAS market lags behind China, Japan, and Europe. Relatedly, the Federal Aviation Administration's (FAA) complex certification and regulation standards prove challenging for U.S. businesses. Simplifying regulatory and legislative concerns could propel RAS in the air domain, both commercially and militarily.

Introduction

The 2022 National Defense Strategy emphasizes autonomous technology as a mid- to long-term asymmetric approach to deter aggression but also has the potential to change kinetic conflict and complicate escalation dynamics.[1] The Department of Defense (DoD) seeks to mature autonomous technology through the right investments in the innovation ecosystem domestically and with U.S. allies and partners.[2] With the rapid advancement of Robotics and Autonomous Systems (RAS) in areas beyond defense, the Department acknowledges the need to "be a fast-follower where market forces are driving commercialization of militarily-relevant capabilities."[3] Though the language provides direction, the DoD does not address government leadership requirements beyond fiscal and technological support. During a four-month dedicated review, the 2022-2023 RAS industry study at The Eisenhower School of National Security and Resource Strategy found that to advance RAS-enabling industries, the U.S. must strengthen policymaking initiatives. The greatest obstacle to fully unleashing the potential of RAS, commercially and militarily, is not technology but cultural acceptance and societal decisions on human-machine boundaries. Overcoming these challenges will require successful incorporation and standardization of norms and regulations within the U.S., with U.S. allies and partners, and to an extent, with the broader international community and strategic competitors on the appropriate uses of RAS in war and peace. For the DoD to achieve technological superiority across the RAS industry, the U.S. must expedite regulatory certification, safety, and security measures for both military and commercial applications.

Part I – Strategic Environment

In The Global Competition for RAS Superiority, It'll Take More Than Money and Size To Win

RAS technologies have the potential to revolutionize both the defense and commercial sectors, enhancing U.S. national security and economic competitiveness. However, the development and use of RAS must be viewed through the lens of the strategic environment to ensure that the benefits of this technology are maximized, and any potential risks or threats are mitigated. The strategic environment encompasses a range of factors that can impact RAS development and use, including U.S. capabilities, resources, and infrastructure; workforce issues; regulations and policies; as well as external factors such as competitor capabilities, market trends, geopolitical factors, and ethical considerations. Understanding and navigating this complex strategic environment is critical for the U.S. to stay ahead in the global RAS race and maintain its national security posture in the face of potential adversaries like China and Russia. Paul Scharre explains:

> The robotics revolution isn't American-made. It isn't even American-led. Countries around the world are pushing the envelope in autonomy, many further and faster than the United States. Conversations in U.S. research labs and the Pentagon's E-ring are only one factor influencing the future of autonomous weapons. Other nations get a vote too. What they do will influence how the technology develops, proliferates, and how other nations––including the United States—react.[4]

Several internal factors within the RAS industry and more specifically within its local environment shape how RAS technology is developed and deployed. Engineering capabilities, resources, and infrastructure are essential for creating a favorable environment for innovation, advancement, and growth. RAS technology requires a highly skilled workforce due to the complex technology involved and its deployment in critical fields such as defense, healthcare, agriculture, and logistics. Furthermore, regulations, policies, and ethical considerations can also facilitate or hinder innovation and development of RAS technology.

For example, the Artificial Intelligence (AI) Bill of Rights released by the White House in October 2022 establishes safety and certification standards for U.S. RAS technologies.[5] The guidelines were not binding but were created to protect U.S. consumers and provide a path for the safe development and deployment of evolving technology. As regulations such as these may unintentionally hinder innovation, regulators must carefully consider implications for the broader industry and strategic environment before further implementation. While poorly conceived regulations will stymie industry progress, U.S. competitors will march onward outpacing the U.S. in the fast-evolving field. Accordingly, to pace our threats, a careful balance must be struck between prudent regulatory safety concerns and maximum freedom for competitive innovation.

The U.S.'s commitment to the international laws of armed conflict strengthens our global credibility and softens cultural resistance to RAS. Yet concerns abound. Particularly in the development of lethal autonomous weapon systems (LAWS).[6] Concerns regarding the loss of human control, target discrimination, accountability, the potential for an arms race, lack of empathy, and psychological and societal impacts must be considered. Finally, investment in research and development is a key factor in shaping RAS technology growth.[7] Research and development drive innovation, improves productivity, reduces costs, provides societal benefits, and facilitates a competitive advantage.

External factors shaping the use and development of RAS in the U.S. defense and commercial sectors include industry dynamics, market trends, technological advancements, legal and regulatory environment, geopolitical landscape, and socio-economic trends. Industry dynamics such as competition and market saturation impact the development and adoption of new technologies. Market trends, such as consumer demand and price fluctuations, affect the economic viability of RAS technologies. Global technological advancements, such as machine learning and sensor technology, enable new capabilities and applications. Differing legal and regulatory frameworks, such as export controls and intellectual property laws, shape the development and export of these technologies.

China looms over any discussion of the U.S. strategic environment. The 2022 National Security Strategy establishes that China intends and increasingly has the power to disrupt the international order using all four instruments of national power (diplomatic, information, military, and economic) and technology: "The PRC is the only competitor with both the intent to reshape the international order and, increasingly, the economic, diplomatic, military, and technological power to do it."[8] Directly related thereto, China is following government-backed policies such as "Made in China 2025," the "Action Outline for Promoting the Development of Big Data," and the "Next Generation Artificial Intelligence Development Plan."[9] These policies plan for China's development of manufacturing capabilities through integration of advanced technology, leverage the power of big data to promote economic growth and development and outline a blueprint for becoming a world leader in AI by 2030. The stakes for the global RAS industry competition are high.

Perhaps nowhere has the potential impact of RAS on the future of warfare been made more evident than in the Russian-Ukraine conflict. Lessons learned from Russia's invasion of Ukraine are also shaping RAS development domestically and internationally.[10] Russia has shifted its technological deployment strategy from a future capability to the reality of an ongoing war. At the same time, Ukrainian forces have demonstrated the potentially revolutionary asymmetric effects of well-employed RAS against a larger and supposedly more capable military foe. Understanding and navigating these new realities will be critical for the future of the RAS defense industry.

The RAS market landscape is highly competitive and will continue to grow on a global scale. The global military RAS market is expected to reach $19.7 billion in 2033 from $17.5 billion at present.[11] The market is dominated by the U.S., China, and Russia. Major companies such as Boeing, Lockheed Martin, Northrop Grumman, General Dynamics, and General Atomics have propelled U.S. leadership in the manufacturing of RAS technology.[12] There is a growing international focus on the development of advanced AI technologies, such as machine learning and natural language processing, to enhance the decision-making capabilities of RAS systems. Additionally, industry and military actors are focusing on the development of unmanned systems that can operate in increasingly complex environments, such as urban areas or difficult terrain.

Government procurement policies and practices related to RAS also impact the competitive landscape, as government contracts can support financial stability. In January 2023, the U.S. updated its directive on autonomy in weapons systems to reflect advances in RAS technologies and to ensure the U.S. remained a global leader.[13] Potential threats and opportunities for the U.S. RAS industry in the global market must be carefully considered to maintain a competitive advantage over potential adversaries such as China and Russia. Additionally, emerging technologies and new players in the RAS market could impact the competitive landscape in the future, and U.S. companies must be prepared to adapt to these changes to remain successful.

The dependency on materials and supplies to develop and deploy RAS technologies highlights how current events in the geopolitical arena such as the global supply chain can also shape the development of RAS technology. Countries such as Taiwan and South Korea with a competitive advantage in chip manufacturing capability can influence RAS development and deployment. Their geographic location, access to critical components, strong innovation ecosystems, and strategic partnerships contribute to their ability to maintain a steady supply chain for the development of RAS technology. Taiwan is a major supplier of critical components such as semiconductors, sensors, and microcontrollers, which are essential for the development of advanced robotics and autonomous systems and are often in short supply. Similarly, South Korea has strong government support and a robust manufacturing sector. South Korea's proximity to major markets in Asia, particularly China and Japan, facilitates free trade agreements with many countries, creating opportunities for export and collaboration.

In short, RAS technology is advancing at an ever-increasing pace that will impact everyday life amid a complex strategic environment defined by competition. Both internal factors, such as capabilities, resources, infrastructure, and investment in R&D, as well as external factors—notably China setting its own rules and seeking to outcompete the U.S.—are at play. In addition, the alluring world-wide RAS market offers space for continuing growth, especially among the three main competitors (China, Russia, and the U.S.). This strategic environment must be carefully considered as it overlays the land, air, and maritime domains of RAS.

Part II: RAS and Overview

Actually, Robots & Autonomy Are Still All About Human Interaction

In the 2016 Joint Concept for Robotics and Autonomous Systems (JCRAS), the U.S. Joint Staff deliberately transitioned from the term "unmanned" to "robotics and autonomous systems."[14] The shift represented the DoD's realization that emerging autonomy and artificial intelligence technologies have the potential to change the character of warfare. In addition, the term "unmanned" fails to recognize human involvement; most robots today are remotely operated with a human providing intelligent decision-making.[15] The DoD recognizes that RAS cannot replicate human judgment, morality, or understanding of military operations;

consequently, humans will retain overall responsibility for mission completion.[16] The DoD foresees a future where humans and RAS will create new types of collaborative teams. "The true value of these systems is to extend and complement human capability by providing potentially unlimited persistent capabilities, reducing human exposure to life-threatening tasks, and with proper design, reducing the high cognitive load currently placed on operators/supervisors."[17] To achieve that vision, the U.S. will need to better understand the complexities of the rapidly advancing RAS field and address cultural, social, and ethical concerns inhibiting greater incorporation today.

Defining Robotic and Autonomous Systems

RAS encompasses robotic systems with and without autonomous capabilities, and non-robotic autonomous systems. JCRAS defines a robot as "a powered machine capable of executing a set of actions by direct human control, computer control, or a combination of both. A robot is comprised minimally of a platform, software, and a power source."[18] Robots do not require autonomy, and many are remotely controlled by a human operator or run on basic automation software. In these scenarios, the robot itself cannot accommodate ambiguity without assistance from a human.[19] Autonomy is the convergence of automation and artificial intelligence (AI). Dr. Stephen Fino's chart below (Figure 1) highlights the relationship between automation, artificial intelligence, machine learning (ML), and autonomy.

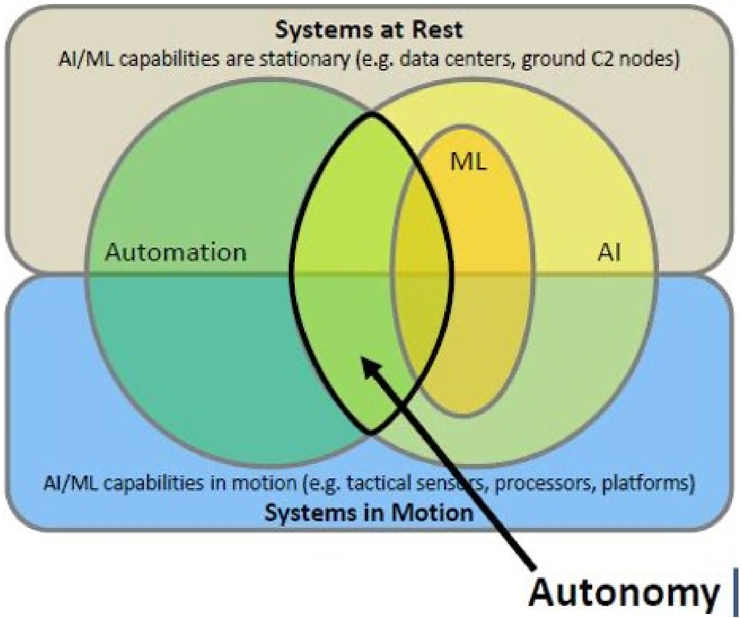


Figure 1: Autonomy Venn Diagram[20]

Artificial intelligence introduces the learning algorithms required for an autonomous system to accomplish goals in complex and unpredictable environments.[21] Just as the term "unmanned" fails to capture human involvement during operations, autonomy and AI in machines does not equal full autonomy from human intervention or control. Simon's Law of Bounded Rationality states that "the actions of a program or robot are bounded by the information it has, and the amount of time available for computation and the limitations of its algorithms."[22] Regardless of a system's level of autonomy, the human designer plays a critical role in determining its level of independence. JCRAS summarizes autonomy as a decision-making spectrum determined by the mission, level of risk, and degree of human-machine teaming.[23]

In *Army of None*, an analysis of autonomous weapons and the future of war, Paul Scharre asserts that the DoD's use of "levels" and "spectrums" to classify autonomy is over-simplistic.[24] Scharre recommends three dimensions that can independently determine a machine's autonomy: "(1) the type of task the machine is performing, (2) the relationship of the human to the machine when performing that task, and (3) the sophistication of the machine's decision-making when performing the task."[25] In this situation, a spectrum represents a position on a scale between non-autonomous and autonomous. The three-dimensional model captures the exponential number of permutations, better depicting the complexity of determining an autonomous system's level of autonomy. For instance, an aircraft may be programmed to allow adjustments to each lever of autonomy independently to fine-tune throughout an actively evolving environmental situation. The ease of adjusting each level of autonomy will depend on the human dimension of employing autonomous capabilities.

Human Capital in the Age of Robotics and Autonomy

Robotics and autonomous systems can strengthen the global economy by increasing efficiency through predictable outcomes and decreasing human errors in routine and labor-intensive tasks. In February 2017 an employee at Amazon Web Services entered an incorrect command code that took the company offline for four hours resulting in a $150 million loss.[26] RAS would have prevented this human error. An industry that includes RAS provides increased productivity resulting in lower product costs and creates new markets, transitioning workers to data-literacy jobs, and spurring wage growth.[27] Similarly, RAS can contribute to the defense industry by reducing the need for labor-intensive platforms.[28] RAS platforms in the U.S. Armed Services can extend the battlefield through long-range sensors for increased duration in isolated environments.[29] Technology is capable, industry is willing, but are people ready for everyday RAS?

Cultural Acceptance of RAS

Without social acceptance, RAS cannot achieve its full potential. Many commentators are concerned by a future filled with autonomous robots fearing it will result in mass job layoffs, while others assert that labor markets will adjust as new jobs are created.[30] Lower-income workers will be displaced by robots at twice the rate of those with higher incomes.[31] This uneven displacement of workers will increase inequality. Although increased robotization will displace workers into other labor markets through greater efficiencies, it will have a net positive impact on global economic growth.[32] These political and social challenges impact RAS acceptance.

In addition to inequality, globalization contributes to cultural values that impact attitudes toward RAS. For instance, many Asian governments and societies accept RAS with little hesitation.[33] The Japanese government often promotes positive RAS images of kindness and patience, like the popular anime cyborg cartoons.[34] These cultural backgrounds and experiences impact emotions and perceptions of robots and their ability to cohabitate with humans.[35] Some experts believe that these cultural differences are rooted in religion. Buddhism and Shinto believe that all things have a soul and spirits live in everything, even non-human objects.[36] Unlike its eastern counterparts, western countries often portray autonomous systems as violent in movies like "Terminator."[37] With their desire for independence and control, Americans have been reluctant to embrace autonomous systems without humans in the loop.[38] When robots perform according to the user's cultural norms, trust and acceptance increase. Once the U.S. public is more accepting of RAS, these systems are more likely to be deployed for commercial and defense purposes.

Ethical and Regulatory Considerations

Alongside the cultural hesitations to more fully adopting RAS, certain ethical commitments are also constraining. Cultural, social, and ethical concerns are reflected in regulations, statutes, and guidelines. The balance of these forces can encourage or slow RAS implementation. Although autonomy is not a new concept, the combination of engineering complexity and lack of social acceptance drives ethical and regulatory challenges. Ethically, the United States is committed to complying with international laws and the principle that war "remain a human endeavor with humans retaining responsibility and accountability for military actions."[39] Not all government and non-government entities subscribe to these ethical boundaries." Regulatory challenges like Federal Aviation Administration certification and approvals, and cyber security and data protections are often lengthy and arduous. RAS technologies will revolutionize the commercial and defense sectors, enhancing U.S. national security and economic competitiveness.

RAS technology is advancing at a fast pace that impacts the workforce, the defense industry, and society. RAS can deliver a predictable workforce to minimize human errors, improve US competitiveness, and strengthen the U.S. Armed Forces. Cultural acceptance is critical to the success of the RAS industry. The U.S. must overcome political and social challenges to accept RAS as a cultural norm. Accordingly, the U.S. Government must continue to modernize procurement policies related to RAS to maintain U.S. industrial competitiveness.

Part III: Maritime RAS

So Much Potential Yet So Many Challenges—Can Robots Really Sail

RAS in Maritime Defense

The United States and its allies aim to achieve a peaceful and prosperous maritime domain using autonomous vessels to augment traditional manned security and defense ships. Plans include unmanned underwater vessels (UUVs) and unmanned surface vessels (USVs) for mine countermeasures, domain awareness, and logistics. These systems present an increased operational range, reduced risk to human life, and the ability to perform missions at a lower cost. The future of weaponizing autonomous platforms offers great promise while also posing serious threats. Before these are realized, integration of today's RAS into naval operations requires addressing manufacturing, maintenance, operational, and ethical concerns.

A viable manufacturing industry is critical for USVs and UUVs to achieve their full potential in the maritime domain.[40] Even small vessels and systems take months to produce as there are only a handful of domestic Navy shipbuilders.[41] A major crisis could boost production by creating incentives to enhance the industrial base, employ flexible manufacturing techniques, and license rapidly expanded production. But growing the maritime defense RAS industry during peacetime has been a challenge because of the industry's direct tie to a struggling domestic shipbuilding industrial base. Major shipyards are venturing into autonomy, but largely in a way to sustain their existing production lines. The small shipyards that build most of today's RAS vessels require financial stability to remain competitive.[42] A shifting demand signal from the U.S. government has created a market where these firms are consolidating to remain relevant. Many shipbuilders pitch similar conceptual USV and UUV solutions, but no vessels are in large-scale production. The U.S. Navy is poised to award its first large USV program-of-record in 2025, which will represent a major indicator of the health of the industry.[43] However, until programs are established, the manufacturing capacity remains untested and unknown.

The sea presents unique challenges due to its size and environmental conditions. While autonomous vessels can provide logistical solutions on a grand scale, they also require significant support systems of their own. Regional hubs, component stockpiles, and regular maintenance would reduce downtime and improve the resiliency of production lines. But maintaining a dispersed autonomous fleet is very different than a manned strike group. The lack of an expert crew means that at-sea component failures and accidents could leave important assets nonfunctional and vulnerable to capture. Reliable self-diagnostics and efficient logistical supply chains would be crucial for deploying and maintaining UUVs and USVs. Rapid response teams may be needed for the most critical assets. Upstream component stockpiles and logistics must be strategically positioned in case of blocked or disrupted sea lines. Bases themselves may need to be autonomous to accommodate the scale of traffic. Friendly nations with USVs and UUVs all over the world would need to cooperate and deconflict to sustain operations. Stockpiling components and parts, implementing regular maintenance schedules, and establishing small tenders and shipyards in critical locations can help minimize mission downtime and maintain optimal RAS performance in forward-deployed environments.[44]

Improvements in UUV and USV software, communication, and energy generation are expected. The Navy's proactive development of these systems using common standards like Unmanned Maritime Autonomy Architecture prevents vendor lock-in and promotes a robust, organic design.[45] In the future, if weapons systems are integrated into USV and UUV platforms, their combination of endurance and autonomy present a tremendous asset. With manufacturing and logistical support in place, assets that can autonomously loiter for months would shift the paradigms of coastal defense, blockades, and offensive engagements throughout the globe. Addressing ethical concerns regarding the deployment of these types of weapons, ensuring communication security, and integrating unmanned systems into more operations will require new considerations and international agreements. With rapidly evolving technology, the concept is not far from reality. The next step is thinking through the many potential use cases, including how to respond to the deployment of weaponized maritime autonomy by adversaries.

UUVs and USVs can open the door to the transformation of naval operations. Despite several unknowns, the associated defense industry is still growing, and the U.S. Navy seems eager to lead in maritime RAS technologies so long as they are carefully balanced with manned vessels. Addressing challenges in production, maintenance, and ensuring responsible use of these systems will enable the U.S. and our allies to better face maritime strategic challenges in the coming years.

RAS in the Commercial Maritime Industry

The sea offers a wide range of commercial uses such as transportation, entertainment, resource extraction, and scientific research. With domain-specific advantages, RAS could change the fundamental structure, conduct, and performance of these industries.[46] However, commercial maritime RAS has been slow to grow, and as such, is not yet a viable industry on its own.

The future of commercial maritime RAS remains unclear. Some analysts assert that RAS for commercial ships is unfeasible. [47] They argue that fully autonomous vessels are unrealistic because of technology limitations, security issues, inaccurate savings estimates, and the indispensability of the mariner.[48] However, another camp sees an autonomous maritime revolution as inevitable, as firms adjust their investments to new technologies. A 2015 study concluded that, based on existing technology, fully autonomous navigation was viable and would soon be safe in Europe.[49] The COVID-19 outbreak further illustrated the fragile dependence of multiple markets on the maritime workforce, incentivizing industry leaders to examine their operations in relation to autonomy.[50]

Autonomy's greatest potential at sea may be in transportation.[51] The ocean covers 70% of the globe and carries 80% of the world's traded goods.[52] Compared to ground and air, open ocean track lines are linear with fewer impediments and lower traffic density. Ships are slow with a large payload capacity. Seafarers, even at international rates, are costly to pay and sustain for months. RAS could cut labor costs by up to 50%.[53] As "90% of vessel collisions involve some form of human error,"[54] fewer people in the loop could also increase savings through improved safety. With these advantages, commercial maritime transportation seems well suited for autonomy, but efforts to establish a market have been limited.

Firms in Northern Europe and Asia are leading in the exploration of maritime RAS. In 2015, Rolls Royce and Kongsberg announced autonomous projects for the commercial transportation industry in European waters.[55] Kongsberg's Yara Bierkland, a fully autonomous-capable fertilizer transport ship built for the short-but-rough transit of the Baltic Sea, began operating in Norwegian waters in 2020 with increasing levels of autonomy.[56] Other demonstrations, such as the Zhi Fei in China and the passenger ferry Soleil in Japan, have reportedly made transits with autonomous navigation.[57]

While some U.S. companies have conducted demonstrations and fielded limited offerings for the commercial sector, they lag behind the international community in demonstrating autonomy for maritime transportation. Available autonomous systems are generally small-scale. Self-powered data-gathering platforms such as Saildrone, Ocean Aero, and Wave Glider are marketed for information gathering and could have applications for commercial shipping but are finding greater defense-related opportunities.[58] SpaceX's drone landing ships present a case of limited commercial success of maritime RAS, in part because they were built to support a budding industry.[59]

While the concept of full autonomy is new, automation is ingrained in the maritime domain. Consistently improving shipboard autopilot systems have been in use for the last century.[60] Just in the last decade, heavily automated "mega-ships" have tripled in cargo capacity while maintaining the same number of crew numbers as older ships half their size. A minimal ship's company remains on board to comply with laws and mitigate unforeseen issues, but they can't fix everything.[61] Full autonomy would constitute an incremental increase in known risks that commercial management has shown a willingness to take.

However, rich in history and powerful in influence, maritime labor unions generally perceive that "autonomous vessels will adversely disrupt the labor force in the shipping industry." Like other industry workforces that face displacement, seafarers are struggling to recruit and retain while fighting to maintain jobs. In the near term, this resistance is the major impediment to greater use of RAS at sea.

Maritime Domain Recommendations

1. Prioritize a dispersed U.S. Navy fleet that leverages autonomy, and defends against it, by building smaller autonomous and manned vessels in place of the next big-deck landing helicopter assault ship (LHA). Concentrated, crewed, vessels are more vulnerable to autonomous weapons, such as smart sea mines, and other area denial capabilities. While the U.S. Navy acknowledges this risk in its unmanned and autonomous strategies, the service's budget requests still prioritize large, crewed platforms. As an initial step, funds from the construction of one large platform, such as a single LHA[62] should be redirected to multiple dispersed options like the Medium Landing Ship (LSM),[63] as well as USV/UUV programs and their infrastructure. Allocating 60 percent of an LHA budget could fund 10-15 LSMs to support dispersed amphibious operations and Marine Corps Force Design 2030. In line with the Chief of Naval Operations' vision of future unmanned ships in the fleet,[64] the remaining 40 percent could be directed to the production and development of dozens of USV platforms. This would enhance resilience and mitigate the risk of a single point of failure in a contested environment. Furthermore, it would make funds available to exploit teaming and offensive capabilities of autonomous vessels, including building out the necessary infrastructure. While it would likely be opposed by several powerful groups, it would be a strong signal to the autonomous systems and

shipbuilding industries that the Navy is serious about dispersal and exploiting the advantages of maritime RAS.

2. To avoid resistance, industry leaders should co-develop RAS technologies within maritime markets like space ports, wind farms, and data gathering. RAS presents enormous advantages and has the potential to redefine the structure, conduct, and performance of multiple commercial maritime industries. However, with resistance as a major impediment, the expansion of RAS for maritime transportation appears to be limited in the short term. Management could attempt to carefully address labor resistance head-on but that risks significant blow back. In the short-term, industry leaders should evaluate and employ advanced RAS within every new ocean-based industry. This is already being demonstrated by SpaceX's drone barges and various data-gathering UAVs and UUVs. While the co-development of maritime innovations with RAS requires more startup funding, it saves costs overall. Despite the potential of displacing future seafarers, there are safer jobs in RAS development and sustainment. Most importantly, this action would build trust and reduce resistance to RAS within the overall domain, which represents a major step toward a less expensive and more secure global supply chain.

Part IV – Land RAS

Dull, Dirty, and Dangerous? More Like Underfunded, Underdeveloped, and Unambiguously Promising

As the United States shifts away from decades of counter-insurgency warfare to focus on great power competition with Russia and China, the DoD must prepare to fight and prevail in Large Scale Combat Operations (LSCO). With the increasing complexity of modern warfare, ground services need Uncrewed Ground Vehicles (UGV) capable of Manned-Unmanned Teaming (MUMT) to manage the complexity of multi-domain operations and perform other dirty, dangerous, and dull tasks. While an ongoing debate seeks to determine how much autonomy the U.S. should allow Lethal Autonomous Weapon Systems (LAWS), a Joint Force that can deter multiple adversaries and defeat them in war requires developing and operationalizing RAS UGVs to augment U.S. military ground forces.

Deploying UGVs closer to the front line is a wicked problem, but the experience gained from deploying logistics UGVs in rear areas will significantly benefit the various LAWS UGVs in development. The US military has been developing UGV RAS Concepts of Operation (CONOP) for decades, but evolving policies and technology make baselining a CONOP elusive. Policy constraints, technology challenges, and cultural barriers make it unlikely that the U.S. military will soon field fully autonomous UGVs. Future UGVs will operate along the spectrum of non-autonomous, semi-autonomous, and supervised autonomy to full autonomy. Warfighters need training conducting various operations with UGVs to develop the Tactics, Techniques, and Procedures (TTP) that shape doctrine, CONOPs, and requirements. This process could begin immediately in logistics operations and grow to field UGVs to select maneuver units to develop TTPs.

UGV lag behind UAS, USV, UUVs

The U.S. Army and U.S. Marine Corps are behind the other services in incorporating larger RAS UGVs into their operations because UAS, UUVs, and USVs operate in a more permissive domain than UGVs[65]. While the DoD's UAS prowess comes from decades of experience, many of the Navy's USV and Uncrewed Undersea Vessels (UUV) benefit from emerging technologies and advances derived from autonomous commercial vessel development efforts. In the air, on or below the sea, uncrewed RASs have fewer obstacles, and though these environments remain dynamic, their medium is relatively static and anticipatable. UGVs face a different challenge, with few commercial analogs to rely on for solutions to tackle rugged terrain to keep up with ground troops and have military utility. Along the spectrum of autonomy, fully autonomous UGVs may be far from feasible. Some AI skeptics believe fully autonomous UGVs require artificial general intelligence, a form of AI currently beyond human capability.[66] Given the challenges posed by the land domain, the focus should be on developing UGVs with autonomous features with human operators firmly in control of UGVs with LAWS capabilities.

Policy, culture, and law require clear limitations on the extent of RAS autonomy. Like all military organizations, the US military is hierarchical, and its agents act within a construct bounded by laws, rules, and regulations, reinforced by training and organizational culture. In a sense, even human warfighters are not fully autonomous, so there should be no expectation that UGVs be fully autonomous. DoD Directive 3000.09, DOD guidelines on Autonomy in Weapon Systems, limits the development of RAS UGVs to systems constrained by appropriate human judgment, adherence to International Humanitarian Law (IHL), and ethical principles.[67] The expectation should be that UGVs incorporate the appropriate controls articulated in DoDD 3000.09 and be transparent, auditable, and explainable.[68] Systems not meeting these key performance parameters are of limited military utility.

While killer robots grab headlines, military UGV derivatives of commercial UGV technology performing logistics tasks will likely have the most immediate military impact. The US military has the most capable ground forces in the world, but they are resource-intensive and require extensive logistics support to perform their missions. As demonstrated by the early stages of the Ukraine invasion, the weaknesses of Russian logistics, including the inability to operate under attack, ended Moscow's attempt to capture Kyiv.[69] Autonomous systems have the potential to transform logistics operations in LSCO by improving efficiency, reducing costs, and enhancing mission safety. Further, incorporating logistics UGVs can reduce the tooth-to-tail ratio; ratio of troops in combat roles versus logistics roles; and, increase available combat power.[70]

UGV Funding Disparity

The DoD must balance research and development investments to maintain technological superiority in the future by equipping the Joint Forces to fight tonight. The President's FY 2024 Defense Budget request reflects investments to posture the Joint Force to prevail in great power competition with China across the vast Indo-Pacific theater.[71] Accordingly, a large percentage of the $842B requested for FY 2024 focuses on air and sea power platforms, long-range precision fires, and space systems that support the NDS.[72] The U.S. traditionally underfunds UGVs relative to other uncrewed platforms. In FY 2021, DoD spent $2.8B on UAS while only allocating $241M to UGVs.[73] The funding disparity is due to the lack of widespread fielded UGVs across the services, likely due to the technology's immaturity. No commercial market exists for UGVs that can keep up with dismounted warfighters traversing rugged terrain or equipped with LAWS capabilities. Therefore, the USG cannot rely on private sector innovation to mature UGV technology alone but must team with commercial firms to benefit from the innovation ecosystems and the data amassed by the commercial market. To do this, the DoD should engage more with technology firms on the leading edge of UGV technology that may not have historically participated in the DoD ecosystem for innovation.

Self-Driving Market May Help DOD

Companies in the UGV industry are engaged in an oligopolistic competition where few firms supply similar products. A Porter's Five Forces analysis of the industry indicates Competitive Rivalry is a key force affecting strategies in the UGV industry. Each firm supplying autonomous driving products for commercial or military purposes competes to be first to market, where they all plan to scale rapidly to gain market share. The threat of substitutes is another crucial factor. Established alternatives such as taxis, rideshare, truck drivers, railroads, public transit, air transport, and other players in the broader transportation industry will continue to impact how UGV firms develop their business strategies. UGV safety concerns remain a key hurdle in challenging established alternatives, as Americans are more pessimistic about the safety of autonomous vehicles than some of their foreign counterparts.[74] While it is challenging to complete an exhaustive five-forces analysis of this nascent and fragmented industry, it is clear this is a pivotal time for firms with high levels of investment and many new technologies in development.

Firms engaged in the commercial self-driving UGV market are deploying cutting-edge technology and investing significant corporate research and development resources to advance self-driving performance. Indeed, the commercial market has made dramatic progress over the past decade in self-driving technology optimized for well-paved and marked roads and characterized by six levels of autonomy. These levels are level 0, no driving automation; level 1, driver assistance; level 2, partial driving automation; level 3, conditional driving automation; level 4, high driving automation; level 5, full driving automation.[75] Large automakers such as Mercedes-Benz, Tesla, Volvo, Hyundai, and Volkswagen are all pursuing advanced driver assistance systems (ADAS), which fall within level 2 partial automation to level 3 conditional automation in their traditional passenger automobile offerings.[76] At the other end of the automation spectrum are commercial trucking firms like Aurora Innovation, Waymo, TuSimple, Kodiak Robotics, Gatik, Waabi, Plus, Locomotion, and Torq Robotics, working to deliver autonomous driving for Class 8 trucks.

Another group of firms developing technology that may help develop UGVs for DoD is the nascent autonomous last-mile delivery (ALMD) market. Companies in this space seek to take advantage of what Morgan Stanley estimates will be more than a $5.6 trillion e-commerce market by 2026.[77] Several negative externalities associated with traditional means of ALMD delivery in the United States (for instance by FedEx, United Parcel Service, and the U.S. Post Office)—such as cost, congestion, emissions, pollution, and infrastructure damage—drive innovation in this industry.

Several businesses, including industry leaders such as Amazon, Walmart, and Alibaba, are testing and implementing programs in the U.S., Africa, Europe, and Asia. Current projections expect the ALMD to grow to a $4.96 billion market size by 2030.[78] Firms in this industry are developing UASs and Ground Autonomous Delivery Devices (GADDs), optimized to operate in more dynamic environments than ADAS in passenger cars or commercial trucking self-driving systems, to make that last-mile delivery. ALMD companies have found specific use cases where GADDs have safely traveled among pedestrians. To date, GADDs firm Starship Technologies has found its most proven partnerships on college campuses, recently expanding to twenty-eight universities.[79] Starship operates the most proven system, with over four million autonomous deliveries and over six million miles traveled globally.[80]

Civilian self-driving technology, while not analogous to military applications, can form the automation foundation for MUMT logistics vehicles and is very close to being ready. For example, the NATO alliance's strategic concept calls for long deployment routes from seaports via public roads to NATO installations and military bases across Europe. The technology for autonomous UGV convoys that can navigate along highways close to the last mile exists today with companies like Aurora in the U.S. and InterRoc in Germany.[81]

U.S. government investments made by the Defense Advanced Research Projects Agency (DARPA) with its Grand Challenge competitions since 2004 helped pioneer the technologies from which last-mile delivery and self-driving industries derived their technology.[82] Today advances in AI, machine learning, advanced microprocessors, sensors, and actuators have commercially viable self-driving vehicles at a demonstration level as industry firms seek regulatory approvals for full deployment. Businesses developing self-driving or GADDs face a complex US regulatory environment with different rules and regulations at each level of government and by mode of transportation.[83] As a result, a lack of regulatory consistency has hindered investment and delayed industry growth. The USG needs many of these companies to survive through competition to preserve a vibrant UGV innovation ecosystem to benefit military UGV programs.

Land Domain Recommendations

1. Accelerate UGV experimentation at events like Project Convergence (PC) and exercises with partners and allies like NATO DEFENDER-Europe. All future DoD exercises and technology demonstrations should include planning, implementing, and controlling the flow of materiel, supplies, and services incorporating RAS UGVs and crewed systems. The U.S. Army hosts PC and PC2022, focused on linking sensors to deciders and effectors, and consists of the Joint Force, including allied troops from the United Kingdom and Australia. NATO DEFENDER is an ideal exercise to train and showcase UGV capabilities because it features more than 20 allied and partner nations and aggregates combat power across Europe using the civilian infrastructure. While the technology is imperfect, some existing UGVs can perform logistics operations to support PC and NATO DEFENDER exercises today, particularly using civilian infrastructure. NATO exercises like DEFENDER are partially resourced from NATO military

funds contributed by member states and the national funds of the participating states.[84] No fundamental change is required to this resourcing structure as exercise participants, who are responsible for their procurement processes, could arrange at the exercise planning level to integrate UGVs into DEFENDER operations.[85] This arrangement would achieve NATO's exercise objective of training, testing, and validating structures during peace to prepare for times of crisis.[86] The President's FY24 budget requested $90 million dollars for PC24.[87] While this is substantial, with $66 million dollars in RDT&E and 24 million dollars in O&M, cost growth is likely required in subsequent PC demonstrations to widen its scope. Current resource levels fund the Army's evaluation of technologies that will facilitate the service's role in Joint All Domain Command and Control.[88]

2. The National Highway Traffic Safety Administration (NHTSA), which regulates Automated Vehicles (AV), needs the authority and resources to develop a federally coordinated policy framework to clarify regulatory requirements across jurisdictions for realistic commercial self-driving testing and pilot programs.[89] The USG should provide a federally coordinated policy framework to clarify regulatory requirements across jurisdictions, to facilitate realistic commercial self-driving testing and pilot programs. The current regulatory environment is inconsistent across jurisdictions. Regulatory reforms to holistically address autonomous driving technologies will help commercial firms transition to generating revenue. Recently investor enthusiasm in this industry has declined because few firms have the resources to overcome regulatory hurdles to commercialize autonomous driving, with prominent U.S. firms such as Embark and Argo shutting down [90] NHTSA allocated $45.1 million of its FY23 budget to rulemaking and just $14.9 million for advanced driver assistance[91] At $1.329 billion , NHTSA's budget is substantial, but the agency needs authorities and resources to make rules

across jurisdictions for AV vehicle pilot efforts. Economists at the Brookings Institute have projected that mass AV adoption would lead to a 1.4 percent increase in U.S. GDP from the productivity gained from the reductions in traffic congestion [92] Fully resourcing the NHTSA is an investment in America's economic future.

Part V: Air RAS

King For So Long, Can The U.S. Make The Changes To Keep The Crown?

The U.S. defense and commercial UAS industries stand on a precipice. Our history of aviation success does not guarantee future U.S. leadership. The DoD is poised for dramatic technological upgrades for UAS in preparation for China's pacing challenge while transitioning away from older UAS technologies. At the same time, the U.S. commercial industry languishes beneath its perceived potential while international competitors strengthen their footholds. In pursuit of a successful transition, the DoD must outpace international adversaries. At the same time, the DoD must not forget the lessons learned from the rapid development and fielding of UAS platforms in the past. Finally, the DoD, in coordination with the Departments of State and Commerce, must work with our international allies and partners to maximize the safe and responsible development, use, and sales of UAS. Regarding the commercial UAS industry, the FAA, NASA, and industry must more deliberately coordinate and face the technological, safety, and regulatory challenges keeping the lid on this important sector.

Defense Air RAS – A Source of National Power

Recently, Chairman of the Joint Chiefs of Staff Army Gen. Mark A. Milley stated, "[t]he U.S. must adapt to the "changing character of war" or face "devastating consequences." [93] Air Force Chief of Staff Gen. Charles Q. Brown Jr. describes the "changing character of war," where all domains are contested, and capabilities matter more than numbers.[94] While first and second-generation UAS worked well in permissive environments and had been a strong global and domestic market, the DoD faces much more significant challenges in near-peer conflicts with advanced air defenses and aircraft.[95] To meet national security and defense strategies with autonomous systems, two critical challenges must be overcome. Firstly, the DoD must improve the pace and scale of developing, operationalizing, and adopting disruptive capabilities based on rapidly emerging technology in UASs to outpace adversaries.[96] Secondly, the government should work with Allied partners on the development, interoperability, and sales of UAS to deepen global security, diplomatic, economic, information, and military ties.

Challenges and Opportunities in Defense Air RAS

Frank Kendall, Secretary of the Air Force, revealed details on Collaborative Combat Aircraft (CCA) where two to five uncrewed CCA's would collaborate with a crewed fighter to conduct electronic warfare, suppression of enemy air defenses, air and ground protection, and communications; the process of introducing them would be iterative.[97] He also said his greatest fear was that Congress would not move fast enough, which would be "a gift to China that we cannot afford."[98] In part to meet these challenges and prepare for potential engagements with near-peer adversaries the Air Force is developing Skyborg which is conceptually a low-cost UAV with an autonomous aircraft teaming architecture that brings cutting-edge capabilities to the fight at a faster pace and lower cost.[99] The approach is to build a scalable autonomy core architecture that can be used across the DoD. However, government leaders should be cautious of lessons learned from past mistakes in deployed unmanned systems. The urgent need to deploy the UASs resulted in rushing them to the theater with poor design, inadequate support, and operational challenges caused by the lack of sufficient resources, time for refining concepts of operation, and training.[100] Users utilized the systems in ways not anticipated by requirements or the engineers who designed them.[101] These factors, combined with other findings, generated a lack of trust among operators and contributed to the DoD not fully realizing the potential benefits of autonomous systems.[102] Government leaders must no longer fixate on platform or autonomy at the expense of human interaction.

The crux to the success of UASs will be to develop systems that build trust and understanding between human operators and their autonomous system teammates, so they act as one. As hybrid human-machine cognitive teams are developed to leverage automation's speed, precision, and reliability while maintaining the robustness and flexibility of human intelligence, the importance of fostering trust between humans and machines increases.[103][x] As human-machine teaming and trust evolve, UASs will most likely be capable of adjusting levels of autonomy to meet operator and mission requirements, creating further challenges and complexity in software development and ensuring that human and machine interfaces are understood and trusted by users[104].

Secondly, as the UASs become more sophisticated and exquisite, the global demand continues to grow for less expensive UAS and loitering munitions.[105] China and Turkey are already gaining influence by selling cheaper and less sophisticated UASs. At least 95 countries operate UAS for military purposes, of whom 32 use Chinese systems and 28 use Turkish systems.[106] These firms invest their UAS sales revenues into research and development, strengthening their defense industrial base and developing more advanced UAS systems.[107] Additionally, several Middle Eastern partners (including Saudi Arabia, the UAE, Jordan, Morocco, and Iraq) turned to Chinese UAS systems after the U.S. denied exports, largely over human rights and export control concerns. These U.S. arms sales policies have inadvertently benefitted companies like China's Shenzhen DJI Technology Company. It became the largest global drone manufacturer in part because of less stringent Chinese regulations and lower production costs.[108] The growing Chinese and Turkish global market share undermines all four elements of U.S. power - diplomatic, economic, information, and military influence and leadership, including a loss of interoperability with allied partners. To continue leading in the defense UAS arena and remain the preferred global security partner, the U.S. needs to work with our allied partners on the development, use, and foreign sales of UAS.

U.S. Commercial UAS - A Sleeping Giant

While the U.S. manned commercial aviation industry and U.S. defense aviation industry dominate the world market, the U.S. commercial UAS market lags. A vibrant, robust, competitive, and fully realized U.S. UAS commercial market would provide the environment for innovation and potentially increased overall aviation industry capacity. The competitive pressure of a robust commercial market creates an environment encouraging innovation.[109] This innovative atmosphere would benefit both the commercial and defense industries. Accordingly, the U.S. has an interest in the growth and health of the UAS commercial market. Yet, before the UAS commercial market can reach its full potential two obstacles must be overcome. First, the UAS industry must solve key safety and technological challenges.[110] Second, the FAA in conjunction with major UAS industry participants must reach a consensus on the appropriate certification and regulations standards providing clarity and scalability for UAS businesses.

Those Pesky Threatening Substitutes

If these obstacles can be overcome, many experts estimate the potential UAS market will grow dramatically. Presently the commercial UAS industry creates approximately $1 billion in revenue, but some experts project potential industry revenue exceeding $40 billion.[111]

Describing the UAS commercial market as a single market masks the complexity and variety of firms providing and attempting to provide services and platforms. The commercial UAS market already includes sectors as varied as agriculture, fire protection, law enforcement, security, disaster reconnaissance, land surveying, package delivery, aerial photography, high altitude pseudo satellites, hobbyists, and urban air mobility. Each of these sectors has its own unique five-factors at play.[112] With that said, most sectors struggle under the fifth factor—the threat of substitutes. Without the ability to guarantee safe operations and to reliably navigate the complex regulatory environment, commercial UAS companies will continue to struggle to disrupt existing substitutes.

The Computers Still Go Down Sometimes

For some sectors, a few key technological obstacles prevent the commercial UAS market from taking off.[113] First, there is no universally agreed upon, cost-effective, solution to the problem of safely "sensing and avoiding." A manned aircraft—no matter how simple, or cheap—always has a pilot who can potentially see and avoid other aircraft in the air. Second, the UAS data links and ground control stations remain vulnerable to security breaches.[114] Because of the variety of aircraft and enterprises, there is no technological "silver bullet" or even agreed-upon "correct answer" to this challenge. Finally, an automated air traffic control system has yet to be developed to handle the anticipated increased air traffic in the national airspace to handle commercial UAS growth.[115] For each of these challenges, there are nominative solutions[116] with specific and limited applicability, but nothing yet promising industry-wide technological solutions.

Regulators Need To Regulate

To ensure safety and to avoid "picking favorites," the FAA has been slow to provide sufficient simple, concise, tailored regulations for UAS commercial operations.[117] Relatedly, the FAA has failed to provide a clear path to aircraft "type" certification for commercial UAS.[118] These twin problems prevent the industry from developing the scalability and predictability necessary for the capital investment required to drive costs low enough to compete or disrupt the threat of substitutes.[119] The current framework is simply not amenable to capital investment and large-scale growth of the commercial UAS industry.

Air RAS Recommendations:

1. The U.S. government should increase flexibility in arms sales regulatory policies for less exquisite platforms to support allies and partners, foster market expansion, promote the growth of American defense companies, enhance joint interoperability, and deter adversaries. The DoD will also benefit from additional output to the international market through the maintenance of an engaged domestic defense workforce. This would be particularly valuable in a near-peer conflict scenario where there might be a need to surge production swiftly. However, less stringent regulations may also result in U.S. exports to countries with inadequate arms export control laws, potentially leading to the use of these weapons systems in ways that violate human rights. Given the threats in this current strategic environment, this risk is overwhelmed by the benefits.

2. For AAS (Advanced Autonomous Systems) the DoD should adopt a new operator-centered development process prioritizing the warfighter throughout the entire process. Rather than its current disjointed process, this iterative "fast fail" process centered on the operator would foster trust between humans and machines such that capabilities can be delivered more

rapidly to the joint warfighter. First, this cannot be accomplished unless leadership eliminates the obstacles and encourages robust communication, collaboration, and trust-building with industry, academia, and international stakeholders. Second, Congress and DoD must recognize the importance of non-platform technologies capabilities for AAS. To maximize AAS capabilities and human-machine trust, focus areas include software enhancement and data sharing, improving system robustness, adaptability, and reliability. As primarily process-driven, this recommendation is relatively resource neutral; however, to the extent, there are manning and funding implications in implementation, the bill should be paid through divestment of legacy platforms no longer as relevant to the peer-on-peer conflict in our current strategic environment. Steadfast and determined leadership will be required to overcome cultural, Congressional, and industry resistance to aspects of this recommendation. The trade-offs will be worth it.

3. The FAA should incorporate industry directly in the rulemaking process. Instead of persisting with the current process and the advisory rule committees, the FAA should embrace negotiated rulemaking. Under negotiated rulemaking the agency invites key industry participants to work hand-in-hand with the FAA rule drafters through a neutral arbiter to agree upon regulations that meet the competing needs of all stakeholders.[120] Although negotiated rulemaking can potentially result in rules that favor current key industry participants over emerging ones, this is an acceptable risk given the alternative. Foreign countries are solving these problems and their commercial UAS industries continue to extend their lead over the U.S.[121] Negotiated rulemaking offers a potentially fast and agreeable solution to a regulatory challenge that has stymied the FAA for more than two decades.

Conclusion

Robotics and Autonomous Systems (RAS) fulfill an important role in the National Defense Strategy's emphasis on autonomous technology to deter aggression, influence kinetic conflict, and inflict potential costs on U.S. adversaries to change escalation dynamics. The evolution of RAS in the United States is shaped by human capital constraints, cultural acceptance, emerging ethical debates, and a shifting strategic environment. In the maritime domain, RAS challenges include the need to shift military paradigms and human capital considerations. Ground domain RAS holds the potential to fulfill numerous dirty, dangerous, and dull tasks, but is limited by technological and budgetary shortfalls. Finally, the air domain RAS is constricted by regulatory and legislative limitations that keep the industry from reaching its full potential. As the United States aims to outpace China and maintain the international rules-based order, it is important to consider the role RAS will play in that strategic competition. To achieve a globally superior RAS industry the United States must overcome some technological challenges, but more importantly, the U.S. must also circumvent the "soft" challenges: safety, social acceptance, trust, and human-machine integration.

Appendix A – Capstone

1. PRC-Taiwan: Short- and long-term implications; levers U.S. and others have to address them. In light of the People's Republic of China's (PRC) overwhelming advantage over Taiwan in active-duty personnel—not to mention the island's considerable distance from the US—Taiwan must make maximum use of RAS in planning its defense and play to its home-field advantage.[122] Given the disparity of military strength, Taiwan must invest in autonomous and distributed mobile capabilities that will impose severe costs on the PRC and preserve its limited human capital. Taiwan must be able to rapidly detect threats to its sovereignty, including cyber and missile attacks. AI systems linked to Taiwan's robotic defense assets could optimize response times, accuracy, and adaptability. Taiwan must strengthen its cybersecurity infrastructure to withstand potential Chinese cyber-attacks, which would be a precursor to a kinetic Chinese attack. Based on lessons from the use of autonomous systems in Ukraine, Taiwan should fully integrate and synchronize intelligence and battlefield awareness between its autonomous and manned early warning platforms. The United States can support Taiwan's defense by sharing advanced technology to increase the costs of PRC aggression.

In the near term, four autonomous weapon platforms offer Taiwan the greatest advantage while being immediately available within existing production lines. Loitering munitions such as AeroVironment's Switchblade or UVision's Hero series of weapons combine defensive standoff and automatic target recognition to devastating effect. These systems would augment the Chien Hsiang family of loitering munitions which the Taiwan state-owned National Chung-Shan Institute of Science and Technology (NCSIST) plans to mass produce by 2025.[123] Smart sea mines offer a passive measure to secure sea lines of communication in heavily navigated waters. Highly automated air-defense systems like Israel's Rafael-produced Iron Dome and its David's

Sling/SkyCeptor missile systems can neutralize massed attacking advanced missile threats, including China's DF-15, capable of reaching Taiwan.[124] To defend amphibious approaches, Textron's RIPSAW can remain submerged and is customizable with a modular flat deck to accommodate weapons and sensors.

Over the medium term, new aerial and maritime capabilities could serve as force multipliers. In the air, AI-piloted F-16s, already tested and developed by Shield AI, could boost Taiwan's defense capabilities.[125] While the PRC is expected to strike Taiwanese airfields, The U.S. maintains excess F-16s, currently stored in Arizona boneyards, which could be equipped with AI software and exported to Taiwan as Excess Defense Articles to augment Taiwan's air fleet. Additional F-16s divested over the Fiscal Year Defense Program (FYDP) would also serve this purpose. Localized maintenance would strengthen Taiwan's ability to resist a protracted air campaign.

At sea, Taiwan should deploy autonomous underwater and surface vehicles (AUSVs) to monitor and protect Taiwan's maritime borders. Equipped with advanced sonar systems, these AUSVs will detect and neutralize enemy submarines, ships, and underwater drones. Deploying a network of autonomous underwater vehicles (AUVs) in and around Taiwan could help detect incoming enemy naval assets and neutralize threats, including sea mines. The Navy should also develop a new family of inexpensive, uncrewed, long-range logistics vessels that Taiwan could use for resupply during a blockade.[126] Drawing on the effectiveness of illicit narcotics smuggling vessels—which have demonstrated their ability to remain undetected in transits to the United States—these low-profile, low-cost, and expendable semi-submersible platforms could provide critical supplies in the event of war.[127] Modular construction allows different-sized cargo sections to transport items such as munitions, fuel, or small vehicles. The vessels could potentially be launched thousands of miles from their targets, including from larger ships or bases like Luzon, Guam, and Yokosuka.

To further grow its UAS capabilities, Taiwan should fully leverage dual-use technologies and consider launching a Taiwanese version of "Ukraine's army of drones," the joint project of Ukraine's Armed Forces General Staff and Ministry of Digital Transformation. In coordination with the Ukrainian government's UNITED24 fundraising platform, the program raised $108 million between July 2022-May 2023 via cloud funding and other donations (boosted by celebrities), to build or acquire nearly 4,000 small consumer drones repurposed for Ukrainian military use.[128] The program also trained over 7,000 drone operators, mainly as part of the two-person navigator/spotter teams.[129] Taiwan should also relax procedures and laws for importing drone components and eliminate import duty taxes for drone parts and equipment, both lessons from Ukraine.

Taiwan should continue to harden its defense industrial base including by integrating smaller companies into its defense supply chain as called for at the U.S.-Taiwan Defense Industry Forum on May 3rd.[130] Over the long-term, Taiwan needs a viable long-term defense strategy built on asymmetric capabilities and weapons that fully integrate interoperable autonomous systems and turn Taiwan's maritime island geography into a strength.[131] In addition to munitions and logistics supplies, the U.S. should pre-position and stockpile autonomous defense systems in Taiwan, configured to rapidly activate, when necessary. We concur with the call by a Taiwanese UAS manufacturer for broadening U.S.-Taiwan cooperation in joint R&D for new sensors, training for operations and maintenance, and joint AI-based development.[132] The U.S. should also induce partners and allies such as Japan, Australia, and ideally, South Korea and NATO Allies to participate in co-production efforts.

Appendix B – Consolidated Policy Recommendations

During the four-month in-depth robotics and autonomous systems (RAS) industry study, two overarching themes emerged: the need to transition RAS technologies into current DoD operations and the imperative to expedite regulatory language that supports military and commercial RAS industries and market expansion. To advance RAS across the maritime, land, and air domains, DoD must move beyond experimentation and transition RAS capabilities into new or existing programs of record. While some autonomous systems are growing in maturity, some less-complex systems should be incorporated under a program of record now. In the short term, the U.S. military services must pinpoint precise areas where RAS can be introduced today, which does not require complex coordination. In the long term, the U.S. military services must identify areas in which to incorporate more complex RAS systems, which will require greater coordination. Further, RAS systems must be prioritized more broadly for future exercises to build interoperability among the United States joint force, multi-national partners, and allies.

The United States, its allies, and partners must prioritize RAS governance development that ensures regulatory certification, safety, and security measures, but also supports defense and commercial RAS industries and market expansion. The Federal Aviation Administration should incorporate industry directly into the lawmaking process to craft a solution that balances the latest technology, industry needs, and the safety of the public. Policymakers must carefully address maritime labor resistance to autonomy head-on. To promote commercial industries and market expansion, U.S. policymakers should consider increased flexibility in arms sales regulatory policies. Considering the potential to advance commercial and military RAS, the following table provides specific, resource-informed policy recommendations across all domains. The table is followed by more detailed information regarding the policy recommendations in each domain.

	Value Proposition	Policy Recommendation	Domain	Resources Needed	Trade-Off
1	Warfighter trust, vital to the acceptance and effective employment of Advanced Autonomous Systems (AAS), is limited.	**The DoD should adopt an operator-centered development process, prioritizing the warfighter and focused on AAS-specific enablers: human-machine trust, software architecture, data sharing, and system robustness.**	All	Process-driven; resource neutral other than administrative costs.	Could carry manning and funding implications these should be offset by future reductions in legacy platforms that AAS replaces; likely to face opposition from existing force culture, industry, & congressional stakeholders. These challenges will require steadfast leadership.
2	The potential advantages of sea-based autonomy are incredible. However, resistance from labor remains a strong impediment.	**Co-develop and employ full autonomy early in new ocean-based innovations such as energy extraction, space operations, colonization, and exploration.**	Maritime - Commercial	Upfront cost to achieve long-term savings & tremendous future benefits.	Reduce future opportunities for maritime labor, while displacement will occur some of the displacement can be mitigated by personnel transitioning into development and support.
3	Concentrated, manned, vessels are vulnerable to autonomous weapons, such as smart sea mines, and other area denial capabilities.	**Prioritize a dispersed U.S. Navy fleet that leverages autonomy, and defends against it, by building smaller autonomous and manned vessels in place of the next big-deck landing helicopter assault ship.**	Maritime - Defense	$3B towards a dispersed fleet, up to $1.8B directly for autonomy.	Defer budgeting for one LHA or other big-deck ship. Will face resistance from some congress & shipbuilders & need to balance with supporters. 10 U.S.C. 8062(b) carries legal requirements for USN to have 10 LHA/LPDs.
4	Restrictive arms sales policies limit the capabilities of the U.S. RAS industry.	**Increase flexibility in arms sales policies for less exquisite UAS platforms to support and build allies and partners, foster U.S. market expansion, and promote growth in U.S. Defense industrial capacity.**	Air - Defense	U.S. industry upfront investment that would pay off.	Increases the risk that weapons systems are used in ways that violate human rights. But policy easing would benefit on a wider scale given the advantages of RAS.
5	Regulatory quagmire is causing the U.S. RAS industry to lose ground to foreign competitors like China.	**The FAA should adopt negotiated rulemaking with industry.**	Air - Commercial	Administrative costs associated with shifting policy approach.	Can result in rules that favor current key firms over emerging ones, but provides the clearest path to advancing the overall industry.
6	Iterative Joint and partner Warfighter experience with UGVs in training exercises will normalize UGVs and provide feedback for developers to refine their capabilities. UGVs at highly visible demos showcase capabilities to senior leaders with the influence to facilitate military UGV innovation.	**Accelerate UGV experimentation at events like Project Convergence (PC) and exercises with partners and allies like NATO DEFENDER-Europe. All future DoD exercises and technology demonstrations should include planning, implementing, and controlling the flow of materiel, supplies, and services incorporating RAS UGVs and crewed systems.**	Land - Defense	PC2024 allocated $90M in FY24 PB to continue Army's JADC2, need additional resources to widen scope to UGV evaluation. No additional resources required for NATO exercises.	As JADC2 lessons are learned and tech transitions to programs, Army could potentially reallocate funding. UGV vendors may be incentivized to participate in PC demos if there is a path to transition from demo to EMD phase competition/program.
7	Reducing the barriers to piloting automated vehicle efforts nationwide will allow US self-driving companies to transition from demonstrations to deployment and revenue generation.	**The National Highway Traffic Safety Administration (NHTSA) needs the authority to develop a federally coordinated policy framework to clarify regulatory requirements across jurisdictions for realistic commercial self-driving testing and pilot programs.**	Land - Commercial	NHTSA needs authorities to make rules holistically for automated vehicles across jurisdictions. Future infrastructure spending may require resources for NHTSA oversight.	Legislation would be required to give NHTSA authorities to make rules across jurisdictions, which could be opposed by some industry and labor interest groups that benefit from the current system. Other agency coordination would be required as well.

Maritime Domain Policy Recommendations

1. Prioritize a dispersed U.S. Navy fleet that leverages autonomy, and defends against it, by building smaller autonomous and manned vessels in place of the next big-deck landing helicopter assault ship (LHA). Concentrated, crewed, vessels are more vulnerable to autonomous weapons, such as smart sea mines, and other area denial capabilities. While the U.S. Navy

acknowledges this risk in its unmanned and autonomous strategies, the service's budget requests still prioritize large, crewed platforms. As an initial step, funds from the construction of one large platform, such as a single LHA[133] should be redirected to multiple dispersed options like the Medium Landing Ship (LSM),[134] as well as USV/UUV programs and their infrastructure. Allocating 60 percent of an LHA budget could fund 10-15 LSMs to support dispersed amphibious operations and Marine Corps Force Design 2030. In line with the Chief of Naval Operations' vision of future unmanned ships in the fleet,[135] the remaining 40 percent could be directed to the production and development of dozens of USV platforms. This would enhance resilience and mitigate the risk of a single point of failure in a contested environment. Furthermore, it would make funds available to exploit teaming and offensive capabilities of autonomous vessels, including building out the necessary infrastructure. While it would likely be opposed by several powerful groups, it would be a strong signal to the autonomous systems and shipbuilding industries that the Navy is serious about dispersal and exploiting the advantages of maritime RAS.

2. To avoid resistance, industry leaders should co-develop RAS technologies within maritime markets like spaceports, wind farms, and data gathering. RAS presents enormous advantages and has the potential to redefine the structure, conduct, and performance of multiple commercial maritime industries. However, with resistance as a major impediment, the expansion of RAS for maritime transportation appears to be limited in the short term. Management could attempt to carefully address labor resistance head-on but that risks significant blowback. In the short-term, industry leaders should evaluate and employ advanced RAS within every new ocean-based industry. This is already being demonstrated by SpaceX's drone barges and various data-gathering UAVs and UUVs. While the co-development of maritime innovations with RAS

requires more startup funding, it saves costs overall. Despite the potential of displacing future seafarers, there are safer jobs to be found in RAS development and sustainment. Most importantly, this action would build trust and reduce resistance to RAS within the overall domain, which represents a major step toward a less expensive and more secure global supply chain.

Land Domain Policy Recommendations

1. Accelerate UGV experimentation at events like Project Convergence (PC) and exercises with partners and allies like NATO DEFENDER-Europe. All future DoD exercises and technology demonstrations should include planning, implementing, and controlling the flow of materiel, supplies, and services incorporating RAS UGVs and crewed systems. The U.S. Army hosts PC and PC2022, focused on linking sensors to deciders and effectors, and consists of the Joint Force, including allied troops from the United Kingdom and Australia. NATO DEFENDER is an ideal exercise to train and showcase UGV capabilities because it features more than 20 allied and partner nations and aggregates combat power across Europe using the civilian infrastructure. While the technology is imperfect, some existing UGVs can perform logistics operations to support PC and NATO DEFENDER exercises today, particularly using civilian infrastructure. NATO exercises like DEFENDER are partially resourced from NATO military funds contributed by member states and the national funds of the participating states.[136] No fundamental change is required to this resourcing structure as exercise participants, who are responsible for their procurement processes, could arrange at the exercise planning level to integrate UGVs into DEFENDER operations.[137] This arrangement would achieve NATO's exercise objective of training, testing, and validating structures during peace to prepare for times of crisis.[138] The President's FY24 budget requested $90 million dollars for PC24.[139] While this is

substantial, with $66 million dollars in RDT&E and 24 million dollars in O&M, cost growth is likely required in subsequent PC demonstrations to widen its scope. Current resource levels fund the Army's evaluation of technologies that will facilitate the service's role in Joint All Domain Command and Control.[140]

2. The National Highway Traffic Safety Administration (NHTSA) needs the authority and resources to develop a federally coordinated policy framework to clarify regulatory requirements across jurisdictions for realistic commercial self-driving testing and pilot programs.

The USG should provide a federally coordinated policy framework to clarify regulatory requirements across jurisdictions, to facilitate realistic commercial self-driving testing and pilot programs. The current regulatory environment is inconsistent across jurisdictions. Regulatory reforms to holistically address autonomous driving technologies will help commercial firms transition to generating revenue. Recently investor enthusiasm in this industry has declined because few firms have the resources to overcome regulatory hurdles to commercialize autonomous driving, with prominent U.S. firms such as Embark and Argo shutting down operations.[141] The National Highway Traffic Safety Administration (NHTSA) regulates Automated Vehicles (AV). It allocated $45.1 million of its FY23 budget to rulemaking and just $14.9 million for advanced driver assistance systems and automated driving systems research to test innovative solutions for highly and fully AV.[142] At $1.329 billion, NHTSA's budget is substantial, but the agency needs authorities and resources to make rules across jurisdictions for AV vehicle pilot efforts. Economists at the Brookings Institute have projected that mass AV adoption would lead to a 1.4% increase in U.S. GDP from the productivity gained from the reductions in traffic congestion alone.[143] Fully resourcing the NHTSA is an investment in America's economic future.

Air Domain Policy Recommendations

1. The U.S. government should increase flexibility in arms sales regulatory policies for less exquisite platforms to support allies and partners, foster market expansion, promote the growth of American Defense companies, enhance joint interoperability, and deter adversaries. The DoD will also benefit from additional output to the international market through the maintenance of an engaged domestic defense workforce. This would be particularly valuable in a near-peer conflict scenario where there might be a need to surge production swiftly. However, less stringent regulations may also result in U.S. exports to countries with inadequate arms export control laws, potentially leading to the use of these weapons systems in ways that violate human rights. Given the threats in this current strategic environment, this risk is overwhelmed by the benefits.

2. For AAS (Advanced Autonomous Systems) the DoD should adopt a new operator-centered development process prioritizing the warfighter throughout the entire process. Rather than its current disjointed process, this iterative "fast fail" process centered on the operator would foster trust between humans and machines such that capabilities can be delivered more rapidly to the joint warfighter. First, this cannot be accomplished unless leadership eliminates the obstacles and encourages robust communication, collaboration, and trust-building with industry, academia, and international stakeholders. Second, Congress and DoD must recognize the importance of non-platform technologies capabilities for AAS. To maximize AAS capabilities and human-machine trust, focus areas include software enhancement and data sharing, improving system robustness, adaptability, and reliability. As primarily process-driven, this recommendation is relatively resource neutral; however, to the extent, there are manning and funding implications in the implementation, the bill should be paid through divestment of legacy platforms no longer as relevant for a peer-on-peer conflict in our current strategic environment. Steadfast and

determined leadership will be required to overcome cultural, Congressional, and industry resistance to aspects of this recommendation. The trade-offs will be worth it.

3. The FAA should incorporate industry directly in the rulemaking process. Instead of persisting with the current process and the advisory rule committees, the FAA should embrace negotiated rulemaking. Under negotiated rulemaking, the agency invites key industry participants to work hand-in-hand with the FAA rule drafters through a neutral arbiter to agree upon regulations that meet the competing needs of all stakeholders. Although negotiated rulemaking can potentially result in rules that favor current key industry participants over emerging ones, this is an acceptable risk, given the alternative. Foreign countries are solving these problems and their commercial UAS industries continue to extend their lead over the US. Negotiated rulemaking offers a potentially fast and agreeable solution to a regulatory challenge that has stymied the FAA for more than two decades.

Appendix C – Industry Visits

Haifa

- Elbit Systems
- Rafael
- Technion-Israel Institute of Technology

Zur Igal

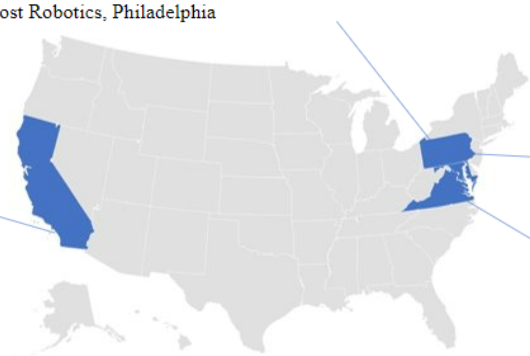
- Uvision

Pennsylvania

- Carnegie Mellon University, Pittsburg
- University of Pittsburg Human Engineering Research Lab (HERL), Pittsburg
- Army Artificial Intelligence Integration Center, Pittsburgh
- Aurora Innovation, Pittsburg
- Alpha Lab, Pittsburg
- Ghost Robotics, Philadelphia

California

- AeroVironment, Simi Valley
- General Atomics, Poway
- Shield AI, San Diego



Maryland

- Textron, Hunt Valley
- Telemedicine & Advanced Technology Research Center's (TATRC), Ft. Detrick

Virginia

- Aurora Flight Sciences, Manassas

Appendix D – Group Bios

Mrs. Samantha Brown: Samantha Brown serves as an Acquisition Program Manager with a diverse background in air and space programs. She recently served as Special Programs Division Chief at the Office of the Assistant Secretary of the Air Force for Space Acquisitions and Integration, acting as the principal Special Access Programs advisor. Holding a Bachelor's in Political Science and a Master of Public Administration from Norwich University, she joined the federal service in 2010 through the Presidential Management Fellows Program.

Mr. Michael Brown: serves as the Branch Manager for System Evaluation at the TSA's Test & Evaluation Division, boasting over 15 years of experience managing the evaluation of various DOD and DHS major acquisition programs. He kick-started his federal service at the U.S. Army Evaluation Center before transitioning to TSA T&E, where he continued to flourish as a team and organizational leader. MB is a Virginia Tech graduate with a degree in Business Information Technology, and he has completed the American University Key Executive Leadership Certificate program and is part of the 2022 cohort of the DHS Office of the Chief Procurement Officer Executive Development Program for Acquisition Leaders.

Colonel Dan Bunch: is a joint-qualified nuclear and missile operations officer with over two decades of experience in operations, staff roles, and command, including serving as a squadron commander and as a speechwriter for the Under Secretary of the Air Force. He began his career with a Bachelor's in Finance from Indiana University and served operationally in the Minuteman III weapon system. Additionally, he holds an MBA from Mississippi State University and a Masters of Operational Art and Science degree from Air University.

Mr. Martin Cota: is an Assistant Chief with the United States Border Patrol, with over 17 years of experience in field operations, supervision, and managerial roles, including national-level programs within the Strategic Planning and Analysis Directorate. Starting as a field agent in Arizona, Cota ascended through the ranks to his current position at Border Patrol Headquarters. Additionally, Cota, a

University of Phoenix graduate with a Bachelor's in Management, recently retired from the US Navy after more than 26 years of service.

Colonel Enio Barbosa Fett de Magalhaes: is a Brazilian Army infantry officer with extensive experience in airborne, jungle, and peacekeeping operations, commissioned in 1996. He has held various command and staff positions, including as Commander of an Infantry Airborne Battalion, instructor at the United States Military Academy at West Point, and as a UN military observer in Sudan. He holds a postgraduate degree in History of Foreign Affairs from Rio de Janeiro State University, a master’s in military operations from the Army Advanced School, and a Doctorate in Military Sciences from the Brazilian Army Command and Staff College.

Colonel Jens Grabowski: German Army has nearly three decades of experience as a logistics officer, including leading roles such as a combat service battalion commander and a task force commander in Mazar-i-Sharif, Afghanistan. His career, initiated as a volunteer in 1993, is marked by various assignments within the German Armed Forces and NATO, including leading a task force in the procurement and acquisition department at the German DoD. Grabowski holds a Master's degree in Economic Engineering and Management from Helmut-Schmidt-University Hamburg.

Commander George Hall: is a U.S. Coast Guard officer. He most recently served as the Special Projects Officer for the Commandant and, prior to that, Industry Liaison with USCG Congressional Affairs. CDR Hall specializes in mission support and engineering. He graduated from the U.S. Coast Guard Academy in 2005. He holds a Master’s Degree in Civil Engineering from Oregon State University and in Defense and Strategic Studies from the U.S. Naval War College. CDR Hall is a registered Professional Engineer in the State of Florida and a certified Project Management Professional.

Mr. Diego Gonzalez-Vanegas: serves as the deputy of the Cooperation Resources Group at the Colombian Ministry of Defense, leading a team of analysts and advisors to manage Foreign Military Sales (FMS) Program projects and create multiannual cooperation plans between the US Department of State and the Colombian Ministry of Defense. Prior to joining the Ministry of Defense, he worked as a public school teacher in Bogota and pursued an MBA at the University of Gloucestershire in the UK, where he also gained experience in the retail sector. In 2013, he began working as an advisor for the Planning and Budget Office in the Colombian Ministry of Defense before transitioning to his current role.

Mr. Gregory King: is a seasoned geologist with over 25 years of experience in both private and government sectors, including the NOAA, Army Corps of Engineers, and NGA. Greg is an innovator and pragmatic leader and has held various technical and leadership roles and served as the Interagency Geotechnical Assessment Team Chair from 2018-2021. He holds a Bachelor of Science in Geoscience and a minor in Business Administration from Pacific Lutheran University.

Colonel Jontae "Sherell" McGrew: is a Cyberspace Operations Officer with 21 years of service in the United States Air Force, including roles as a squadron commander at Joint Base Langley-Eustis and Vandenberg Space Force Base. Recently, she served as the Military Assistant to the Under Secretary of the Air Force. She earned her bachelor's degree in Information Systems from Auburn University in Montgomery, Alabama, and holds two graduate degrees, a Masters of Science in Management degree from Troy University, Alabama, and Masters of Operational Art and Science degree from Air University, Maxwell AFB, Alabama.

Colonel Helen Stewart: is an Air Force officer with two decades of experience, serving her entire career as a Federal Agent in the Air Force Office of Special Investigations, leading criminal, fraud, and counterintelligence operations at both detachment and squadron levels. She was commissioned through the Reserve Officer Training Corps and most recently served as the Director of Staff to the Inspector General of the Department of the Air Force. Stewart holds a bachelor's degree in French from the

University of Louisville and graduate degrees from the University of Oklahoma, Naval Postgraduate School, and Air University's Air Command and Staff College.

Mr. Brendan Sullivan: is a Senior Managing Consultant within IBM. He has over 18 years of experience working in a variety of fields including Management Consulting, International Finance, Government, and International Diplomacy. At IBM, he leads teams in the Data & Technology Transformation (D&TT) Government Practice He has Bachelor of Arts degrees in Business Economics and Modern American History from Brown University and a Master of Business Administration in Global Finance from Thunderbird School of Global Management.

Mr. Alexander Schrank: is a Foreign Service Officer with the Department of State. He most recently served as Deputy Director in the Bureau of Near Eastern Affairs and Political-Military Affairs, overseeing Foreign Military Sales to the Near East and Africa. His assignments include U.S. Embassies in Kabul, Tbilisi, Paris, Ottawa, and Tashkent, and a detail with the French Ministry of Foreign Affairs. He has also worked in the Kyrgyz Republic and Azerbaijan with the National Democratic Institute. Schrank's academic credentials include a Master's degree in Middle Eastern Regional Studies from Harvard and a Bachelor's degree from Georgetown University's School of Foreign Service.

Colonel Matt Talcott: has over 18 years of experience in JAG Corps roles, predominantly in the courtroom, having prosecuted, defended, or judged more than 110 courts-martial across the Air Force. He most recently served as the Staff Judge Advocate for the 1st Special Operations Wing at Hurlburt Field, Florida. Colonel Talcott holds a bachelor's degree in communications from St. Mary's University, a Juris Doctorate from the George Mason University School of Law, and a master's degree from the Air Command and Staff College at Maxwell Air Force Base.

Ms. Tracy Titcombe: is an Air Force Civilian Acquisition Engineer with over 24 years of experience, beginning her career as a Co-Op for the Air Force, then progressing through roles in industry as a design engineer, chief engineer, and chief program manager. After an 11-year industry stint, she returned to the Air Force as a lead engineer, technical expert, and chief engineer for the acquisition of simulation and training devices, also serving as the Air Force Principal for the Interagency/Industry Training, Simulation, and Education Conference. Titcombe holds a Bachelor's in Engineering, and an MBA, and is a certified Program Management Professional.

Colonel Havard Whiles: is an Army Acquisition Officer with a decade of experience in the Acquisition Work Force, starting his career as a logistician in Brigade Combat Teams. He has held various leadership roles, including Company Command of Bravo Company 407th Brigade Support Battalion, 2nd BCT, 82 Airborne Division, and recently served as the Product Manager for Small Caliber Ammunition, overseeing Research & Development, procurement, and lifecycle management of all DoD SCA .50 caliber and below. He holds an MBA and a Master of Science in Strategic Intelligence degree.

The instructors:

Colonel Cameron S. Pringle: serves as an assistant professor and the Chief of Staff of the Air Force's Chair at the Eisenhower School, National Defense University, where he leads U.S. Air Force students and faculty and serves as a faculty member in the National Security & Industrial Base department. Prior to this, he commanded the 319th Reconnaissance Wing, leading a premier Global Hawk wing responsible for executing a worldwide RQ-4 mission with assets valued at over $6.2 billion. A command pilot with over 2000 flight hours in various aircraft, Colonel Pringle has extensive experience in combat operations across Africa, the Balkans, Korea, and the Middle East.

CAPT Greg Freitag: is a medical doctor and graduate of the National War College, holding a Master of Science degree in National Security Strategy. He has served in various positions across operational, headquarters, and international levels, including as Flight Doctor and Chief Medical Officer at Navy

Medicine Readiness and Training Command Quantico. Currently, he serves as Military Faculty at the Dwight D. Eisenhower School, focusing on the role of health security policy in advancing U.S. national interests.

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