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SHAPING A RESPONSIBLE & SECURE FUTURE WITH ROBOTICS & AUTONOMOUS SYSTEMS

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Executive Summary

The United States' ability to promote innovation and growth in the robotics and autonomous system (RAS) industries directly impacts US national security and global stability. The character of warfare is constantly evolving. Recent events in Ukraine (and previously in Nagorno-Karabakh) revealed that RAS represents a disruptive technology at the leading edge of that evolution.[1] RAS enable smaller, dispersed forces to effectively challenge legacy sources of military strength in the air, on land, and at sea.

In a world characterized by strategic competition, the RAS industries are integral elements of national economic power. Accordingly, Russia and China are leveraging the technological revolution to secure market share in the international RAS markets. To lead the responsible integration of RAS into the commercial and defense markets, the Department of Defense (DoD) and the broader US Government must quickly address several regulatory, policy, and strategy issues.

This report presents insights gleaned from five months of dedicated RAS industry study by students at the Eisenhower School during the 2021-2022 academic year, analyzes industries that supply the air, land, and sea RAS domains and provides fully resourced policy recommendations. Coordinated with allies and partners, such policies promote innovation in the RAS industries and give much-needed support to the US commercial and defense industrial ecosystems. From a position of economic and defense strength vested in RAS, the United States can shape a safe and responsible future.

Stimulating the RAS Industry for National Defense: An Introduction

The United States' decisions to develop and integrate robotics and autonomous systems (RAS) today will shape the future national and global security landscape. In a world of strategic competition, with China as the pacing challenge, the Department of Defense's (DoD) ability in the coming years to leverage RAS to improve its capabilities, capacity, and interoperability will be critical for effective deterrence and global stability. The US Defense Industrial Base (DIB) plays a crucial role in the RAS competition as the third leg of the Iron Triangle. US firms working to advance RAS technologies must navigate complex government regulations and policies while pursuing their primary goals of profit and survival in highly competitive markets. To better compete globally, the United States must provide supportive regulations and incentivize its domestic RAS industries to produce cutting edge products and capabilities.

For the United States to emerge as a RAS leader, it must expand its cooperative efforts across the Iron Triangle, with academia, and among allies and partners. Prioritizing innovation and incentivizing research and development (R&D) will position the DIB to field practical RAS capabilities for warfighters. Dual-use technologies at the nexus of commercial and defense markets are particularly attractive areas for public and private sector cooperation and advances.

The following analysis incorporates RAS industries into the geopolitical context of strategic competition and the changing character of warfare. First, it establishes a common understanding of key RAS terms, examines the enterprise, and surveys related legal and ethical concerns. The study then delves into the air, land, and maritime domains to review the markets, industry forces, challenges, and opportunities, offering resourced policy recommendations. Finally, the study reviews how the RAS ecosystems differ in China and Russia, spotlighting the role of emerging technologies in strategic competition. This comparison illuminates the need for

the United States to generate supportive policies to enable the DIB, allies and partners, and the DoD to develop and employ RAS capabilities for a responsible and secure future.

Robotics and Autonomous Systems Enterprise

One of the challenges of defining the RAS enterprise is reaching a common grasp of the term "autonomy." Domestic and international stakeholders with various incentives, cultures, and experiences use an array of definitions with slight but significant meaningful variances. This paper adopts DoD terminology when possible.[2] DoD defines *autonomy* as:

> "the level of independence that humans grant a system to execute a given task. It is the condition or quality of being self-governing to achieve an assigned task based on the system's own situational awareness (integrated sensing, perceiving, analyzing), planning and decision-making. Autonomy refers to a spectrum of automation in which independent decision-making can be tailored for a specific mission, level of risk, and degree of human-machine teaming."[3]

Autonomy is thus a sliding scale, made even more fluid by the rapid rate of innovation. How states and industries can and should use autonomy in conjunction with robotic systems to perform tasks leads to much debate. Whether used in industry to improve margins or in combat to secure a comparative advantage, RAS represents a vast opportunity for nations to gain an advantage over their competitors. The US Interim National Security Strategic Guidance highlights the "revolution in technology" that could threaten US interests and alter the international balance of power.[4] Unfortunately, unlike many earlier technological revolutions, it is neither US-made nor US-led.[5] As technology reshapes global economic and power dynamics at an accelerating pace, it creates an opportunity and a threat to US interests. Failing to lead this technological revolution could have dire consequences for US security.

War's nature may be immutable, but the evolution of its character is accelerating in the modern era, driven faster by the pace of technological change. The most notable differences on the battlefield are embodied by the new class of smart assets capable of persistent sensing and

long-range precision strikes. Nations employing RAS in modern warfare will gain a tremendous advantage. Two contemporary conflicts illustrate the increasing role of RAS, the Azerbaijani advances in Nagorno-Karabakh and Ukraine's rebuff of Russia's armored invasion in February of 2022.[6] Presently, the United States' 2014 "Third Offset Strategy" places robots, autonomy, and human-machine teaming as its core.[7]

RAS Strategic Environment

The United States has enjoyed economic and military preeminence in recent decades. To remain well-positioned in the geopolitical landscape, the United States cannot afford to allow its competitors to lead this technological revolution. While Russia poses a minor RAS threat, China is a formidable and growing strategic competitor. To achieve US national security interests, four critical factors are necessary to support US RAS industries: a demand for robotic autonomous systems, a highly educated and skilled workforce, firms that can design and build robotic and autonomous systems, and access to cutting-edge computer chips.

Financial Challenges Hinder Industry Growth

An overarching challenge for DoD to acquire leading RAS technologies across domains is access to capital. Like many industries, the commercial sector primarily drives RAS innovation. However, the US budget process is predetermined years in advance and parceled out in disruptive continuing resolutions that prevent startups from having an entry point into the defense sector. Without funding, most startups die within two years, long before the budget cycle allows potential DoD partners to secure the contract necessary to survive the "Valley of Death." Young companies struggle to find private equity to cover the gap. Two companies recently warned that US firms and private-sector investors increasingly shun developing DoD technologies due to fiscal and social acceptability concerns.[8]

Evolving Legal, Ethical, and Strategic Considerations

States have just begun to tackle the legal and ethical implications of implementing RAS into the evolving character of warfare. International law does not prohibit states from fielding lethal RAS (LRAS), provided they comply with the law of armed conflict.[9] Given the unknowns of future technology and the divergent views of non-governmental organizations, think tanks, industry, and state governments, the international community has not yet reached a consensus on whether current international law sufficiently restricts emerging technologies.

Many developing states and non-government organizations argue that the United Nations should append a new protocol to the Convention on Prohibitions or Restrictions on the Use of Certain Conventional Weapons to specifically restrict LRAS.[10] Proponents warn that "technologies often transcend their original purpose"[11] and fear that the speed and scope of LRAS means that programming errors will cause massive civilian destruction. Finally, they fear systems that can independently select and engage targets could unravel 60 years of international humanitarian law (IHL) grounded on personal accountability.[12] Alternatively, countries with advanced LRAS programs (e.g., Russia, Israel, India, the United Kingdom, the United States) oppose bans that would prematurely inhibit the development of weapons that follow IHL. Information processing and precision-strike allow commanders to identify threats and engage targets faster than those using human-operated systems. Machines, unlike soldiers, do not make mistakes due to fatigue, nervousness, or inexperience. They also provide safe standoff distance for troops and reduce human capital requirements.[13] Accordingly, these countries argue that national weapons reviews and policy adequately control the implementation of LRAS.[14]

While autonomous weapons may lead to more accurate lethality, ethical challenges center on whether human judgment should always have a voice in the decision to take human life. As

Paul Scharre warns, weapon systems that can sense, decide, and act on their own may decrease the opportunity for human intervention.[15] The United States uses DoD policy to address ethical concerns requiring "[a]utonomous and semi-autonomous weapon systems...to allow commanders and operators to exercise appropriate levels of human judgment over the use of force."[16]

Finally, disruptive innovations like RAS can lead to strategic instability and reduced risks of human suffering, lowering the just-cause barrier to initiating war.[17] Furthermore, the sheer speed of machine decision-making means militaries risk losing fast.[18] The potential rapid loss of command and control could lead to accidental and first-strike tendencies, pre-delegation authorities, and a "tempo of war beyond the pace of human control."[19]

The United States must continue to firmly reject proposals to create new laws that restrict the development of autonomous capabilities. Instead, the United States must leverage diplomacy to ensure countries follow existing laws of war and require humans to exercise reasonable judgment over the use of lethal force when developing, fielding, and deploying RAS.[20] International law provides stability when competitors try to unravel the international liberal order. As technology revolutionizes the pace and character of war, the United States must retain its ethical principles, adequately incentivize the DIB, and prepare DoD to adapt across the domains to achieve a strategic competitive advantage in future warfare.

Air RAS -- A Source of National Power

Air RAS encompasses a variety of civilian and military opportunities to increase US national power. Commercial RAS applications, including small package delivery, air taxi services, and infrastructure and agriculture inspection, will save time and costs. Military applications include remotely piloted aircraft, loitering munitions, small drones, and massed swarms. RAS enables the military to use unmanned systems and to move at machine speed with

reduced signatures. Although implementing these advanced systems may raise concerns about increased accidents, terrorism, and privacy violations, the economic and military benefits outweigh the risks. The United States must invest in developing its air RAS industries to expand its national power and to keep this industry competitive globally.

Air RAS Global and Domestic Innovation

Commercial air RAS markets have significant economic potential. However, US firms seeking to realize this potential face stiff global competition. The United States no longer leads global R&D spending. Although US commercial R&D outlays generally exceed federal R&D in other markets, the air RAS sector currently is an outlier, with federal spending outpacing commercial. The Department of Transportation (DOT) forecasts that commercial air RAS spending will soon dominate, consistent with trends seen in other markets and R&D generally.[21]

Commercial and military air RAS products share many airframe, propulsion, computing, and networking services commonalities. Air RAS markets primarily feature dual-use technologies and include large and small producers and a wide range of prospective buyers. Among the key market elements, the different rules governing industries across global regions seriously affect innovation.[22] The United States trails the European Union and Asia in crafting the regulations needed to enable firms to introduce products to markets and create value.[23]

Air RAS Industry Structure, Conduct and Performance

The air RAS industry needs a supportive regulatory framework to reach their full potential. In one case, the urban air mobility total addressable market currently is a $3 billion market, with experts projecting it to exceed the trillion-dollar mark by 2040.[24] The associated industry is diverse, including everything from traditional primes to small startups. If supported

and well incentivized, the intensely competitive environment will push the value of commercial markets to exceed the value of defense markets.

Unmanned Aerial System (UAS) market products range from mini drones to large remotely piloted UAS that weigh several tons. Commercial applications include entertainment, surveillance, delivery, and eventually passenger transport. The defense applications include intelligence, surveillance and reconnaissance (ISR), tactical transport of material and soldiers, and kinetic strikes. Additional software and hardware payloads can further increase stealth and autonomous swarming capabilities. Both defense and commercial uses of RAS add value by providing faster service, lower cost, and safer operating distance for humans.

The global commercial UAS industry is fiercely competitive, with hundreds of firms developing electric vertical take-off and landing (eVTOLs) commercial drones.[25] Large-scale manufacturers such as Chinese drone manufacturer Dà-Jiāng Innovation (DJI) dominate portions of the market and are attempting to consolidate control through mergers and acquisitions. Like many technology industries, key component suppliers of high-quality pieces like computer chips wield strong bargaining power. Additionally, a limited STEM-talented US workforce induces competition for human capital. Finally, piloted alternatives continue to serve as reasonable substitutes as they benefit from an existing regulatory framework, public trust, and investments.

While commercial air RAS markets operate in a global competitive structure, defense markets face reduced rivalry and a monopsonist aspect that presents challenges for firms. For example, once DoD fields an asset, it focuses on sustainment rather than innovation. The manned aviation market also competes for air RAS funding as DoD requires piloted aircraft for some missions. Finally, both commercial and defense markets depend on long-term partnerships with critical suppliers and a competitive market to support the industries and spur innovation.

Air RAS Opportunities and Challenges

Innovation in the commercial air RAS market offers significant opportunities. For example, the overlap of civilian and defense UAS ensures that the nation that leads the global UAS market will provide its country with dramatic economic and military advantages. Leading commercial air RAS innovation offers increased military capabilities and capacity and spurs further commercial innovation and success in rapidly growing global markets.

While the economic and national security benefits are substantial, the United States must be prepared to face intense challenges in the commercial air RAS markets. First, air RAS firms will continue to encounter supply chain challenges, such as the ongoing computer chip shortage. Rising demand from the United States will increase the power of component suppliers and the cost of production. Second, firms are currently operating under an uncertain and undefined regulatory environment. Driven by profits, firms will hesitate to innovate in the UAS market until they have confidence the government will implement key regulations, such as those for Beyond Visual Line of Sight (BVLOS) flights. Third, the industry faces the risk of accidents that could damage its commercial market by fomenting public distrust. Finally, the proliferation of air RAS at lower price points increases the risk that these advanced capabilities become readily available to nefarious actors. The US Government must develop policies to mitigate the risks of RAS while supporting innovation and economic growth.

Air RAS Policy Recommendations

To outpace global competitors, US air RAS firms would most benefit from clarity on regulatory timelines, greater efficiency in publishing key rules, expedited waiver and exemption processes for BVLOS testing, and increased DoD and industry engagement. The following

recommendations seek to achieve two objectives: 1) unleash the potential of US commercial firms to compete globally, and 2) leverage robust domestic RAS for defense applications.

1. Reduce regulatory uncertainty.

To reduce uncertainty for investors and firms, the Federal Aviation Administration (FAA) should provide accurate timelines for developing primary UAS regulations, including timelines for intermediary steps necessary to draft and promulgate key rules. The FAA should inform both firm leaders in industry and Congress when they set and achieve milestones. This effort does not require significant resourcing, as it is already within the FAA's mission. While the agency will likely need to reprioritize internal development tasks, increasing personnel for regulatory and industry engagement should be less than $5 million per year.[26]

2. Simplify and expedite the BVLOS waiver and exception process.

While the FAA develops BVLOS regulations, the agency should improve the efficiency and scope of its waivers and exceptions process. A more liberal program to approve operations outside the limits of the current regulation will allow firms to develop and test their products. The current waiver process is costly, lengthy, and cumbersome. The FAA Reauthorization Act of 2018 called for the FAA to hasten the certification processes for specific UAS. To ensure the amendments are effective, the FAA should continue to seek recommendations from RAS firms on this issue. The resources necessary to achieve this recommendation are assessed at $5 million to temporarily increase FAA staff to amend and implement an expedited waiver process.

3. Establish "sandboxes" where industry can test air RAS in military airspace.

The DoD should leverage its unique asset of designated airspace and establish "drone zones" or designated UAV corridors in military testing ranges and installations. The US Government should also initiate a process for firms to request use of those areas for testing their

autonomous air vehicles. Such trials would supply the RAS industry with a realistic environment to test and develop products. The tests would yield data on vehicle functioning and airspace management that the FAA could use to establish BVLOS regulations. Additionally, DoD could use these partnerships with industry to survey available technologies for military applications.

4. Horizon scanning: Plan ahead for military application of commercial UAS.

DoD must continue to engage industry to quickly adapt proven products for military purposes. This engagement allows DoD to stay aware of products being developed in the commercial sector. To enable the air RAS commercial and defense markets, DoD should focus on developing common standards for cyber and communications architectures. Resourcing this effort for the US Government is minimal as it seeks to leverage its existing capacity to engage with industry. However, DoD must be aware that US industry standards must support, or at least not obstruct, firm viability in the commercial markets.

Land RAS – Losing Ground to Strategic Competitors

To realize the Third Offset Strategy, the United States must accelerate and expand its land RAS capabilities. Fortunately, US technological advancements are at higher technology readiness levels today than forecasted only a few years ago. DoD must take advantage of this opportunity to close the expanding land RAS capability gap with Russia and China.

Stakeholders of the land RAS enterprise consist of an emerging, loosely defined industry that includes private firms and defense primes such as General Dynamics, Boeing, and Textron. Land RAS R&D is following the same paradigm shift described in the air domain, with commercial firms leading the industry. For example, commercial firms are developing autonomous long-haul delivery vehicles, ride-hailing vans, and industrial robots significantly

faster than in the DoD. The United States must improve the cooperation between the government and private sectors to compete and succeed in this emerging and competitive field.

Land RAS Industry Structure, Conduct and Performance

Despite their unstructured nature, the land RAS markets for defense and commercial products are substantial within the United States. Much of the defense-relevant land RAS market consists of unmanned ground vehicles (UGV) in North America, valued at $2 billion and projected to reach $6.04 billion by 2030, registering a compounding annual growth rate of 11.4%.[27] A Porter's "Five Forces" analysis highlights the power dynamics that the government can use to develop policy solutions to spark innovation and advance land RAS capabilities.

The land RAS industry is oligopolistic and competitive, with multiple firms offering similar products and facing similar challenges. Many small firms compete to develop products quickly, seeking first-mover competitive advantages. Larger firms, mostly DIB primes, focus on developing more sophisticated products. For example, the Army's future Optionally Manned Fighting Vehicle (OMFV) which is the centerpiece of the Army's future land RAS strategy.[28]

Buyer power is the primary force in the defense land RAS market, as demonstrated by the Army's revolutionary Robotic Combat Vehicle (RCV) program. The RCV creates a family of expendable surveillance and security systems, consisting of QinetiQ's RCV-Light and Textron's M5 Ripsaw RCV-Medium.[29] Having these maneuverable and lethal RCV "disposable heroes" will change how the Army fights. However, the fleet currently consists of only eight RCV prototypes with limited testing.[30] This cautious approach lacks a dedicated funding line and presents an exceptional risk for firms driven by profit.

The DoD monopsony in the land RAS defense market is a challenge for firms striving to balance R&D spending with uncertain profits. Significant barriers keep new firms from entering

the market. Firms require a specialized technical workforce with the skills and experience to engage with the DoD as its primary customer. The threat of substitution is low in the land RAS market once DoD commits to a system. However, the potential decision to forgo UGVs in favor of sustaining legacy manned systems remains the industry's greatest threat.

Land RAS Policy Recommendations

The following recommendations intend to 1) seize opportunities in the commercial RAS sector to accelerate DoD land RAS and 2) close the land RAS gap with China and Russia.

1. Expand investment in applied R&D to make Front Line of Robots a reality.

In the emerging Multi-Domain Operations warfighting doctrine, a Forward Line of Unmanned Aerial Systems (FLUA) will enable increasingly lethal long-range fires into enemy territory to close the intelligence gap between the traditional close and deep fight. The FLUA is followed by a new middle ground between the Forward Line of Robots (FLOR) and the Forward Line of (Human) Troops (FLOT).[31] Between the FLOR and FLOT, the UGVs will flush out the enemy, stumble into meeting engagements and ambushes, make and receive the first hits, map enemy positions for artillery strikes, and reduce complex enemy obstacles for the human troops.

This is the future of land warfare in the next decade, yet today this concept has significant technological limitations, specifically: 1) current remote-control range of UGVs at 3 kilometers is within the enemy's direct fire range; 2) remote-control UGVs operators work in the open, without protection or mobility to keep pace with the RCV; and 3) RAS systems are designed for two operators, a driver and a sensor operator or gunner. DoD must expand UGVs' remote-operated range requirements to at least 29 kilometers to remove the operators from enemy artillery fire range, as remote operations will likely leave a targetable signature. Additionally, the

Army should integrate RCV operators into the Armored Multi-Purpose Vehicle so they operate as doctrinally envisioned under armor on the other side of the FLOT.

DoD should also establish requirements for increased autonomy beyond the current level of advanced remote-control operations. Increased autonomy will reduce manpower by allowing one RAS supervisor to employ many UGV and UAS with one common system. Under a "D-OOA" loop, the human will Decide the target and kill box locations, then release the autonomous system to execute the Observe, Orient, and Act cycle. If DoD strategically invests to encourage commercial RAS innovation, industry can quickly make the FLOR concept a reality.

2. Leverage commercial on-road autonomy for off-road capabilities.

Off-road driving is an indispensable requirement for expanding land domain RAS autonomy. Yet, DoD halted defense-related programs developing off-road autonomy, such as National Robotics Engineering Center's Crusher.[32] Unfortunately, the private sector has no commercial incentive to produce off-road autonomous driving technology. Thus, DoD should strategically invest in applied R&D to advance off-road autonomy. Ideally, DoD will direct a dedicated funding stream to a specified requirement in a program of record. The current OMFV program is the most likely option, which would advance off-road autonomy in a tracked vehicle.

DoD should also scale and field the Army's Leader-Follower (LF) technology for Tactical Wheeled Vehicles, which links three unmanned vehicles to a single manned vehicle during logistics convoy operations.[33] This semi-autonomous capability can drastically reduce the number of soldiers and the inherent risks of operating convoy vehicles. Simultaneously, DoD should invest in three remaining critical capabilities of LF autonomous software: 1) safe harbor features to tell platforms what to do if there is an attack or breakdown in the systems' sensors; 2) the ability to designate and transition any vehicle in the convoy as the "leader," eliminating the

requirement to man the lead vehicle; and 3) expansion of the autonomy needed for off-road operations, which would provide a program of record working to perfect off-road autonomy in wheeled vehicles. Off-road operations are significantly more complex than on-road applications and require dedicated R&D funding.

Finally, the Army should incorporate fully autonomous commercial trucks into on-road military operations. Firms such as Aurora and TuSimple are close to delivering freight on US highways without drivers.[34] DoD's commitment to autonomous logistical resupply trucks would incentivize the US commercial autonomous vehicle (AV) industry, cement leadership in this technology, and yield safe and robust sustainment in a contested logistical environment.

3. Operationalize RAS integration by establishing a unity of effort and command.

To realize the Third Offset Strategy's potential, leaders must think ahead to map a strategy for how to integrate RAS into land operations. Rigorous experimentation will enable the Army to implement RAS operational concepts across doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy.[35] This monumental task is necessary to change the way the Army fights, adapt Army culture, and incorporate cutting-edge capabilities with persistent legacy analog platforms. In the early 1990's, the Army established Force XXI to incorporate digitization.[36] It is time to do this again for RAS.

The Army should re-establish the Force XXI initiative by designating an Armored Brigade Combat Team (BCT), rebranded the "Action Force of 2040." As a critical component of Joint All-Domain Operations and Integrated Deterrence, this BCT will align unity of effort with unity of command to lead the integration of RAS. The BCT's mission will be to employ land RAS to achieve superior military overmatch against adversaries on the multi-domain battlefields of 2040. Project Convergence continues to help the Army learn how to integrate multi-domain

RAS, but its efforts are limited in size and scale. The Action Force of 2040 BCT would yield daily experimentation and accelerate DoD decision-making.

Integrating RAS into combined arms maneuver will foster wider acceptance of emerging capabilities and cultural change within DoD. If adequately resourced with funding and talent, RAS capabilities on the battlefield could result in a Revolution in Military Affairs (RMA) and provide the United States with a decisive advantage. To remain competitive, the United States must achieve the promise of the Third Offset Strategy before its competitors in the land domain.

Maritime RAS -- A Uniquely Defense Led Domain

Although water covers 71% of the planet, maritime RAS markets have developed more slowly than the markets for the air and land domains.[37] The US Navy is the largest customer in the market's defense sector and several firms, including the "primes," develop products for this market.[38] Maritime RAS applications include traditional presence and freedom of navigation missions, US Coast Guard drug interdiction, and Military Sealift Command resupply and mobile forward staging. As the US Navy will likely remain the largest near-term user of maritime RAS applications, the following analysis focuses on the Navy's surface and undersea efforts.

Maritime Defense: On the surface

Large and Medium Unmanned Surface Vehicles (L/MUSV) comprise the bulk of products in the surface maritime RAS market. LUSVs are a high endurance vessel designed to provide forward-staged weapon storage and offensive strike capability.[39] The Navy will use MUSVs integrating modular payloads for ISR.[40] Current Navy USV's are manned versions converted to operate autonomously; future variants will likely be purpose-built RAS vessels.

Maritime Defense: Undersea

The Navy has deployed undersea maritime RAS for decades, mostly small Unmanned Undersea Vehicles (UUVs) for inspection and survey purposes. The Navy's use of UUV's will broaden in the future. In 2019, the Navy ordered four Extra-Large UUVs (XLUUV) based on Boeing's Echo Voyager design. Named "Orca," these XLUUVs will be long endurance, modular vessels capable of pier- or ship-launched operations.[41] Its primary purpose will be to covertly deploy Hammerhead mines.[42] The Navy eventually will employ XLUUVs for deep and long-duration missions and smaller UUVs for deep, shallow, and dangerous undersea missions.

Maritime RAS Defense Applications

The Navy is formulating a new approach to integrate RAS into its operations. Currently, large warships such as aircraft carriers or amphibious assault ships are the focal point of battle groups. The Navy recognizes that lower-cost, higher-endurance USVs and UUVs enable a broader, more dispersed force presentation without relying on large and very expensive manned ships.[43] The Navy's new "Distributed Maritime Operations (DMO)" approach acknowledges, "Autonomous systems provide additional warfighting capability and capacity to augment our traditional combatant force, allowing the option to take on greater operational risk while maintaining a tactical and strategic advantage."[44]

Maritime RAS Industry Structure, Conduct and Performance

High barriers to entry characterize today's maritime defense RAS market. Sizeable technological hurdles and low buyer demand attract few new competitors to the market. As RAS become more common in the domain, demand will grow, technology costs will decrease, and more firms will compete. As the Navy shifts to DMO, the conduct of firms will change to keep pace with the new, albeit still limited, demand. As large-scale maritime RAS is an emerging

market, competing firms accept a high risk, high reward environment. Large firms are best suited to compete in markets with uncertain timelines and profits. Several firms with excellent reputations and brand strength have committed substantial resources to vie for maritime RAS.[45] This market competes mainly on product differentiation, not price.

The industry that supplies the maritime defense RAS market is primarily influenced by customer buying power. The Navy largely controls demand by what it buys, and when, creating a monopsony. Supplier power and the threat of substitutes are also critical forces. The global demand for high-end semiconductors and the high-capacity battery material shortage, both essential for RAS, give power to suppliers of these critical inputs. Crewed vessels as a substitute will be a persistent force in the RAS market but will decline over time as the Navy shifts to DMO and integrates USVs/UUVs into its culture. The threat of new entrants and rivalry will not soon significantly influence the market. Due to the extensive technical requirements and R&D hurdles, few firms currently compete and fewer prospects seek entry to the industry. Once DMO is fully implemented, these industrial influence factors will shift.

Maritime RAS Policy Recommendations

Recent guidance and budget allocations make it clear that DoD prioritizes researching and incorporating RAS enabled capabilities.[46] As the Navy increasingly turns to RAS to enhance capabilities and capacity, it will compete with other services for R&D funding.[47] To compete, the Navy must clearly identify how it intends to incorporate RAS into operations. A clear delineation will guide public and private R&D to equip the Navy with the RAS capabilities it needs.

1. Accelerate the drawdown of Littoral Combat Ships (LCS).

Earlier this year, Chief of Naval Operations, Admiral Michael Gilday supported the DoD budget proposal to reduce the Navy's fleet of LCS, used to pursue pirates and operate in coastal environments.[48] The savings diverted from LCS to RAS R&D will support innovations that benefit the US commercial sector and the Navy's DMO concept of employing a higher number of smaller vessels that are broadly distributed to leverage the strengths of RAS in combat.

2. Increase maritime RAS R&D spending.

Increasing federal and private investments into maritime RAS R&D will aid the Navy in fielding future unmanned surface and underwater capabilities. DoD must increase efforts to streamline communication with the commercial sector to better convey the naval applications for new and emerging technology. Expanding the Defense Innovation Unit's "Blue UAS" initiative to include a Blue USV/UUV effort would help integrate defense and commercial applications and would incorporate other dual-use technologies and innovations with USVs and UUVs.

3. Develop a strategic plan to incorporate commercial maritime RAS.

DOT's current Strategic Plan for FY2022-2026 does not include RAS. The DOT's Maritime Administration should formulate a coherent strategy to integrate maritime RAS into commercial maritime operations to spur R&D, testing, and innovation. This also will increase an understanding of the risks, threats, and opportunities associated with maritime RAS.

The United States and its Competitors

A nation's ability to harness the ongoing technological revolution to design and field RAS for comparative economic and defense advantage may determine its success—or failure—in the international strategic competition. In Europe and Asia, Russia and China are working to secure market share in the international RAS markets.

China

With firms around the globe competing in RAS industries, it is important to consider how strategic business models fit non-Western economies. In the United States, Porter's "Five Forces" analysis identifies competitive forces that shape an industry in open markets. This framework highlights major industry influences but does not capture how each fits into different national cultures. Though the framework is still useful for studying China's socialist market economy, it does not account for non-Western business philosophies prevalent in China.

Figure 1 - Modified Porters 5 Forces

Guanxi, a moral obligation toward personal relationships, directly affects how Chinese business leaders develop strategies and make decisions. Chinese firm leaders believe they are a vital component of a larger system, where each player (suppliers, buyers, new entrants) is interconnected and must operate in harmony.[49] Contrasting with free-market economies, Chinese firms navigate a unique ecosystem where the government controls how the industry functions, blurring traditional distinctions between public and private interests.[50] In China, aggressive industrial subsidies control competition, set high entry barriers, and prop up critical sectors. These factors give Chinese firms an advantage over US firms, especially in the semiconductor, communication, photovoltaics, and aerospace sectors.[51]

Over the past decade, China's robotics industry grew tremendously to become the world leader in robotics patents in 2015.[52] This growth challenges the United States' place as a technological leader and positions China to develop innovative RAS technologies for its military.

For example, China has hundreds of robotic Sharp Claw UGVs, which carry light machine guns and operate wirelessly. Unlike DoD's UGV effort, which has developed systems in small batches for testing, China has produced Sharp Claws in large quantities for deployment.[53] China has also fielded the Mule-200 robotic systems and carbon-fiber exoskeletons to augment soldier resupply capabilities and enhance soldier performance in challenging terrain.[54] China's world-leading manufacturing capacity is 28.7% of global manufacturing output, more than 10% ahead of the United States. Accordingly, China could rapidly scale these systems across their two million active-duty soldiers.[55] In contrast, the US Army has purchased eight RCVs.

Russia

President Vladimir Putin clarified Russia's commitment to RAS, stating, "whoever becomes the leader in this sphere [A.I. and RAS] will become ruler of the world."[56] To pursue Putin's vision, the Russian Military Industrial Committee approved a plan to have 30% of its combat power consist entirely of RAS platforms by 2030.[57] Critical aspects of Russia's economy will make achieving that vision difficult.

A few oligarchs of great wealth and influence play a major role in Russia's capitalist economy.[58] Their power to lobby for R&D initiatives, select preferred firms, and influence the government all affect eastern Europe's industrial framework. The large markets not controlled by oligarchs, such as natural gas and energy, are federally-owned monopolies. In both the public and private sectors, power is concentrated with the elites. From a "Five Forces" perspective, Russian oligopolies limit competition, set barriers for new entrants, and give an imbalanced advantage to specific suppliers and buyers while putting other buyers at a distinct disadvantage.[59]

While oligarchical systems are inconsistent with democratic values, they can produce economic gains, as seen in the United States during the Rockefeller, Carnegie, and Vanderbilt

era.[60] Moreover, oligopolies can leverage vast resources to build nationwide infrastructure that benefits several industries, much like governments do for nations across the globe. However, oligopolies impede fair market rates and suppress benefits tied to producing high-quality goods or to innovate new technologies for the betterment of their industry and nation. Despite these factors, Russia, has long had a penchant for developing and distributing weapons of war.

In 2016, Russia unveiled its Vikhr (Whirlwind) UGV.[61] Much more capable than China's Sharp Claw, Russia arms the Vikhr with a stabilized 30mm automatic cannon, a coaxial machine gun, and Anti-Tank Guided Munition (ATGM). Russia can also equip it with four mini-UAVs to provide ISR. Significantly, Russian forces can remotely control the Vikhr from five times farther away than the most advanced US land RAS system. Russia also developed the Uran-9, a robotic tank that operates at nearly double the range of the current US RCV-M.[62] Russia is producing land RAS weapons now, while the US OMFV will begin limited-scale production in FY2030. Russian arms sales entail 18.6% of global arms exports.[63] Therefore, even if the United States never fights Russia directly, it will likely meet Russian land RAS weapon systems in the future.

Opportunities for RAS in the United States

Firm leaders in the US market economy are incentivized by profits and ensuring their firms' long-term viability. Knowing this enables the US Government to find avenues of mutual benefit. Firm leaders are willing to invest in the R&D of innovative RAS technologies to support DoD, if reasonably assured it will prove profitable. Near-term profits are stronger incentives, particularly for smaller firms. It is incumbent on DoD to deliver a clear demand signal for the RAS capabilities it will need in the future. This feat is not easy amidst the ongoing technological revolution that is producing new defense and commercial RAS capabilities at an incredible rate.

Dual-use technologies are at the nexus of the commercial and defense RAS markets and are attractive areas for private sector funding given the potential for profits that accompanies high demand. With a clear vision and continued close engagement with industry, DoD can prioritize investments in dual-use, and defense-specific RAS technologies.

Challenges for RAS in the United States

Given firm leaders' motives, R&D to promote national security and DoD capabilities may not be their foremost priority when determining where to invest private R&D resources. US federal R&D spending doubled to $6 billion in 2021, while the top five private firms spent $80.5 billion on R&D in 2018. Private firms lead the US innovation research effort but may prioritize near-term profitability over long-term national security.[64]

Human factors, particularly bias and trust, are challenges to integrating RAS into US capabilities. Biases stem from history, experience, and culture. DoD's institutional culture of compliance can stifle free thinking and inhibit acceptance of disruptive technologies, keys to adopting RAS. Culture shifts that reduce biases require time and strong leadership from organizational leaders.[65] Service members will need training, operational experience, and understandable autonomy to develop trust in RAS. Investing in a digital workforce that is comfortable with RAS will also reduce adoption challenges.[66] To overcome RAS biases and trust issues, firms need to produce and the DoD needs to acquire high-quality, user-friendly systems. Regrettably, the US regulatory environment may inhibit progress.

The prime obstacle inhibiting US firms and DoD from developing and integrating RAS is the US regulatory environment. A supportive regulatory framework and streamlined policies that ease the testing and acquisitions process for the autonomous systems ecosystem would spur RAS innovation, production, and adoption. Teaming with other agencies, such as the DOT's FAA and

the National Highway Traffic Safety Administration, DoD should support an all-of-government approach to address restrictions and balance threats against implementation.

Finally, infrastructure and cybersecurity exacerbate the challenges of technical RAS interoperability. The federal government must strategically invest in improving infrastructure to support the additional needs of autonomous systems. Common data standards across federal agencies would improve interoperability and provide the commercial industry with predictable federal requirements. The government must carefully weigh the benefits of standardization against increasing requirements, costs, and production time for the RAS commercial sector.

Enterprise-Wide Recommendations

1. Leverage alliances and partnerships to advance US RAS.

The United States leads globally in capital investments in RAS R&D and technology employment. Still, it is neither the largest producer of commercial RAS platforms nor the largest consumer of RAS products.[67] To energize US and partner RAS industries, the United States should collaborate with allies and partners on a RAS R&D, testing, and evaluation program aimed at defense and dual-use technologies. Cooperation would increase input resources and compound the benefit to friendly nations. Australia, Japan, South Korea, and key countries in the European Union are prime candidates for this effort.

2. Promote innovation through educational pipelines.

The United States should further spur RAS innovation by realigning its educational pipelines and retaining talented foreign graduates via immigration reform. Of the three primary DoD service academies, only the Naval Academy offers a degree in Robotics. West Point offers a minor, and the Air Force Academy offers no robotics degree program. While all are top engineering schools, their curriculum should be updated to support the Third Offset Strategy and

embrace RAS. Furthermore, while US universities are renowned for their world-class science and technology (S&T) programs, enrollment and retention of foreign students with specialized expertise in RAS fields have declined since 2016 due to more friendly immigration laws abroad.[68] Reforming immigration laws to recruit and retain graduated S&T students would promote RAS growth the United States.

3. Streamline DoD RAS acquisition regulations and processes.

DoD should shift the focus of its efforts to capability portfolio-based acquisitions that incentivize firms to work with the DoD. The Federal Acquisition Regulation (FAR) is the primary guide for DoD acquisitions.[69] FAR revisions to streamline processes and incentivize firms to work with the DoD will trigger revision of supporting rules and policies to maintain alignment. The US Government should simplify the FAR to allow direct negotiations, shorten contract durations, and reduce the time to award contracts to incentivize firms to work with DoD.[70] The 2016 National Defense Authorization Act's Section 809 identified 98 changes to the FAR; to date only 15 changes related to obsolescence have been implemented.[71]

4. Align strategies to guide R&D and acquisitions funding.

Finally, DoD should refresh the 2016 Joint Concept for Robotics and Autonomous Systems to support the new Joint Warfighting Concept (JWC). The JWC's four key directives of the JWC focus on advancing Joint All Domain Command and Control, joint fires, information advantage and contested logistics.[72] An updated joint RAS concept would prioritize capability portfolios and provide a clearer vision of the future to guide public and private R&D funding. The new concept will also help steer DoD acquisitions from the traditional focus on long-term platform sustainment to a paradigm of capability portfolios enabled by rapidly evolving RAS and

software, constantly updating to maintain a comparative advantage over strategic competitors and potential adversaries.[73]

Conclusion: The Imperative for an Innovative US Government Approach to RAS

The US Government stands at an inflection point in how it will leverage the RAS industries to bolster US economic and national security. Though US firms in the land, air and sea domains stand to gain from proactive US Government policies and regulations, a one-size-fits-all Government approach to RAS would fail to directly address the unique circumstances and needs in each of the domains. Tailored approaches to the three domains are feasible and necessary.

As the character of war evolves, a thriving commercial RAS industry will bolster US economic security and empower the DIB. RAS represents the future of commercial and military markets. The future, however, will not wait. Russia is aggressively pursuing autonomous military capabilities while China persistently uses state intervention to tilt the markets in favor of its firms. RAS industry strength is a critical enabler for the United States and its allies to rapidly establish and project economic and defensive power, particularly vis-à-vis competitor nations.

To seize upon this opportunity, US policymakers must remain committed to the bedrock American institutions of ethics, rule of law, and public acceptance of cutting-edge technologies. However, policymakers must also remain flexible and address inadequate US paradigms for developing commercial regulation and incorporating RAS technologies into military capabilities. Government procedures must enable commercial firms to establish critical footholds in emerging markets and introduce RAS into military capabilities. Policy and regulatory innovation must keep pace with the technological innovation seen in RAS-related industries.

A thriving, profitable commercial RAS sector is a prerequisite to equip the military for future conflicts. US Government empowerment of the RAS industries, and DoD efforts to

integrate RAS systems will ensure the US maintains a position of strength to fight future conflicts and lead a coalition of allies and partners to a responsible and secure future.

Appendix A

Ukraine and RAS: Policy Recommendations

> Victory smiles upon those who anticipate the change in the character of war, not upon those who wait to adapt themselves after the changes occur.
>
> - Giulio Douhet, *The Command of the Air*

In the hands of Ukraine's courageous military and volunteer forces, RAS have influenced the high-intensity conflict across the ground, air, and sea domains. Ukraine's formidable defense, bolstered by international support, effectively neutralized Russia's initial offensive. Equipped with dynamic tactical RAS platforms from allies and partners, Ukraine's defenders continue to impose significant costs to Russian conventional forces. The United States has effectively balanced helping Ukraine crush President Putin's hope for a swift victory and the risk of escalating the conflict into a global war.

The US Government should continue to leverage RAS-enabled military capabilities to support Ukraine, contain Russian hostility, and deter other states from similar aggressive actions. The core US strategic interests are to help maintain a whole and sovereign Ukraine, weaken Russia as an acute military threat, protect NATO allies, and deter China from imposing its will in Asia and against Taiwan. While pursuing these strategic interests, the United States and its NATO partners must avoid international armed conflict with Russia, triggering Article V obligations under the UN Charter. RAS allows leaders to adhere to these necessary constraints

while significantly influencing the tide of war. The US Government should immediately focus on three lines of effort to build a robust portfolio of exportable RAS-enabled capabilities: (1) accelerate domestic RAS development, (2) modernize RAS export policies, and (3) create a shared industrial base. Pursuing the recommendations within these lines of effort will contribute to the security and integrated deterrence postures of the United States and its allies and partners.

1. Accelerate domestic RAS development.

To achieve its national security objectives while working within constraints, the US Government needs to formulate policy that enables defense and other instruments of national power to create effects within Ukraine from afar. RAS are particularly well suited for that mission. The US Government should seek to address rapidly evolving Ukrainian Armed Forces capabilities gaps with innovative solutions from the commercial and defense RAS markets. By serving as a rapid-response intermediary, the US Government can unleash the potential of the US DIB for the security and defense of Ukraine and similarly threatened partners.

The US Government must accelerate innovative change by mitigating RAS-restricting policies in all domains. Simultaneously, the United States must create and adopt regulations that will incentivize and enable RAS R&D investment and competitive global leadership. Several barriers inhibit the US commercial market's potential, limiting growth in the defense RAS market. DoD should support the FAA as it leads a coordinated effort with state and industry leaders to develop air RAS corridors dedicated to testing and operations. Second, the FAA should publish a UAS roadmap with clear milestones and standards for RAS operation and certification. Next, the Department of Transportation, including its Maritime Administration, should synchronize and harmonize ground and maritime efforts to provide US leadership with more capability options to assist Ukraine and future allies and partners in crisis.

2. Modernize RAS export policies.

The US Government should waive constraining Missile Technology Control Regime (MTCR) limitations. Specifically, it should share Category I UAS (*i.e.,* systems capable of delivering a payload of at least 500 kilograms to a range of at least 300 kilometers) with nations it deems particularly vulnerable and with whom the United States shares core interests.[74] While previous revisions to MTCR implementation opened the aperture for limited UAS sharing, the United States still limits the export of its Category I UAS to only a few nations. China operates with no such restraint. Sharing Category I UAS with select, vulnerable nations will increase opportunities for cooperation prior to crisis and provide options for indirect support should crisis occur.

Developing and sharing RAS-enabled combat capabilities is not without risks. For example, the United States must carefully monitor Russia's potential determination that the transfer of decisive RAS threatens force in violation of the UN Charter. The U.S. must also consider the risk of escalation and proliferation. Expanding the number of countries with which the United States shares technologically advanced capabilities requires safeguarding sensitive intellectual property. Finally, the reduced risks to friendly forces from RAS should not lower the barrier to initiating war. US leaders must mitigate these concerns, but not allow them to prevent the modernization of export policies to ensure the safety and security of vulnerable nations with which the United States shares core national interests.

3. Create a shared Defense Industrial Base.

Integrated deterrence requires interoperability, common frameworks, and maximizing the collective potential strengths among allies and partners. In the last two years, the COVID-19 pandemic, sharp increases in demand, and geo-political tensions exposed critical supply chain

risks and vulnerabilities. These challenges also induce convergent thinking within the United States and like-minded partners to consider and explore deeper synergetic partnerships such as developing a shared Defense Industrial Base internal to, and across, countries and organizations. The Office of the Under Secretary of Defense, Acquisitions and Sustainment has established enhancing global partnerships as a key pillar across armaments cooperation, safeguarding global market integrity, and supply security.[75] Meanwhile, NATO's Defence Investment Division continues to invest in autonomous platforms, intelligence, and big data, which will necessitate collaboration and interoperability.[76] [177] Furthermore, the European Union (EU) Defence Commission is actively pursuing shared DIB frameworks for defense research and joint procurement with an eye towards collaboration with the United States/NATO. [78] Finally, the Quadrilateral Security Dialogue is pursuing a defense technical alliance across numerous critical sectors with Asian partners to invest, innovate, and secure critical supply chains and technologies.[79] The United States should lead this effort while fully leveraging public-private partnerships across industry, academia, and governments to establish: 1) cooperative frameworks for convergent arms exports control practices; 2) coordinated industrial policies, and 3) synchronized trade policies.

As demonstrated in Nagorno-Karabakh and Ukraine, RAS-enabled capabilities are changing the character of warfare. To support Ukraine's defense against Russia's illegal attack on its sovereignty, the United States should focus on implementing polices to promote domestic RAS capability development, modernizing RAS export policies, and leading efforts to create a shared Defense Industrial Base with key allies and partners. These efforts will invigorate the United States' domestic RAS markets, provide US leaders with additional RAS-enabled options

during crises, and enhance the integrated deterrence postures and security of the United States and its allies and partners.

Appendix B

Consolidated Policy Recommendations

Air:

- Reduce air RAS regulatory uncertainty in the US
- Simplify and expedite the BVLOS waiver and exception process
- Establish "sandboxes" where industry can test air RAS in military airspace
- Horizon Scanning: Plan for military applications for commercial UASs

Land:

- Expand Investment in applied R&D to make the front line of robots a reality
- Leverage commercial on-road RAS and advance off-road autonomy
- Operationalize RAS integration by establishing unity of effort and command

Maritime:

- Accelerate the drawdown of Littoral Combat Ships
- Increase maritime RAS R&D spending
- Develop a strategic plan to incorporate commercial maritime RAS

US Government and DoD:

- Leverage alliances and partnerships to enable US RAS advancement
- Promote innovation through educational pipelines
- Streamline DoD RAS acquisition regulations and processes
- Align strategies to guide R&D and acquisitions funding

Appendix C

Terminology: Key RAS Terms

- Automated or Automatic: From the Center for Naval Analysis: "Automated or automatic systems function with no (or limited) human operator involvement, typically in structured and unchanging environments, and the system's performance is limited to the specific set of actions that it has been designed to accomplish ... typically these are well-defined tasks that have predetermined responses according to simple scripted or rule-based prescriptions."[80]

- Autonomous Weapon System: DoD defines as "a weapon system that, once activated, can select and engage targets without further intervention by a human operator." DoD includes human-supervised systems in this category, as defined below.[81]

- Autonomy: DoD defines autonomy as "the level of independence that humans grant a system to execute a given task. It is the condition or quality of being self-governing to achieve an assigned task based on the system's own situational awareness (integrated sensing, perceiving, analyzing), planning and decision-making. Autonomy refers to a spectrum of automation in which independent decision-making can be tailored for a specific mission, level of risk, and degree of human-machine teaming.[82]"

- Human-supervised autonomous weapon system: Here, a human is "on the loop."[83] DoD defines human-supervised as "an autonomous weapons system that is designed to provide human operators with the ability to intervene and terminate engagements, including in the event of a weapon system failure, before unacceptable levels of damage occur."

- Industry: The universe of producers that supply a market.

- Market: A group of buyers and sellers of a good or service and the institution or arrangement by which they come together to trade.

- Robot: DoD 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. It is comprised minimally of a platform, software, and a power source."[84]

- Semi-autonomous weapons system: Here, a human is "in the loop."[85] DoD defines semi-autonomous as "a weapon system that, once activated, is intended to only engage individual targets or specific target groups that have been selected by a human operator."[86]

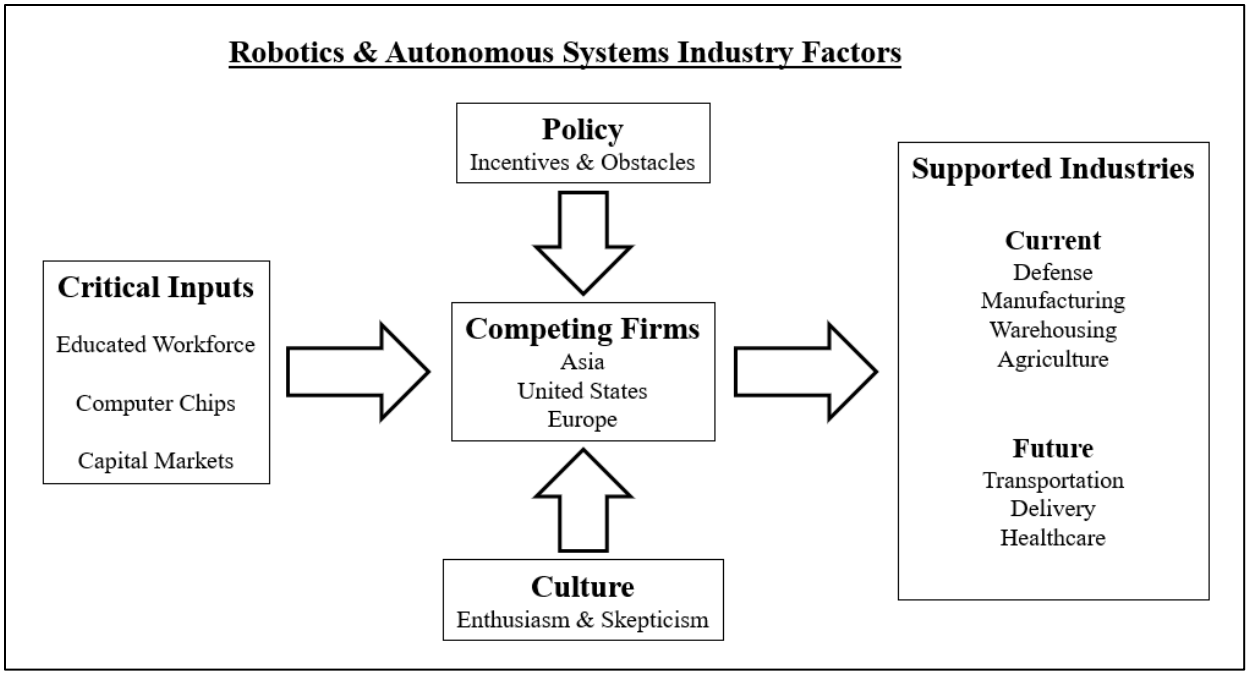
- Unmanned Platform: DoD defines as "an air, land, surface, subsurface, or space platform that does not have the human operator physically onboard the platform."[87]

Appendix D

Porter's Diamond: US RAS Enterprise

Due to the US regulatory environment that limits the commercial sector, DoD struggles to acquire and incorporate cutting-edge dual-use and RAS technologies. Vice Chairman of the Joint Chiefs of Staff Gen. Paul Selva warned in the Joint Concept for Robotic and Autonomous Systems (JCRAS), "The competitive edge will belong to those who best understand how to employ RAS, not necessarily to those with the most exquisite technology."[88]

This new geopolitical contest for technological leadership does not rest alone in the defense sector. Commercial innovation and prosperity are critical to U.S. economic growth, global influence, and military strength. For example, a thriving automotive industry that leads the world in autonomous driving and logistics provides a powerful commercial base to leverage for mobilization.[89] To grasp how to promote thriving RAS industries requires in-depth understanding of the factor conditions depicted below.



Appendix E

Risks, Assumptions, and Strategic Stability

- The United States will continue to operate in an economic free market system where U.S. firms remain profit motivated.
- The United States' access to critical minerals and rare earth elements may be reduced or denied during crisis or conflict which could substantially disrupt U.S. firms' activities in RAS.
- DOD will continue to operate in a budget constrained environment creating innovation challenges for the commercially driven RAS industry.
- The new RAS arms race is underway and will proceed with or without the United States' participation.
- Technology will continue to develop at its current rapid pace (Moore's Law will hold for foreseeable future).
- Allies and partner nations will remain or become open and transparent in RAS technology exchange and information sharing.
- Disruptive advances in military technology like RAS often lead to periods of global instability.

- Adversaries will likely not adhere to norms of human rights and international humanitarian law when employing RAS technology in combat or crisis.

- The United States, allies, and partners can self-govern their development and adoption of RAS technology to decide their own appropriate boundaries.

- The international tolerance for risk associated with increasing degrees of autonomy will rise proportionately with the threat to states' vital interests and survival.

- Autonomous weapons will likely increase the risk of first strike tendencies. States could lose fast, which presents the additional risk of expanded pre-emptive strike tendencies.

- The United States must tread carefully around the foundational paradigm of national defense under a strategically stable nuclear umbrella.

- RAS are changing the character of war. They are accelerating the speed of warfare which will decrease the possibility for human-decision making during the observe-orient-decide-act (OODA) loop.

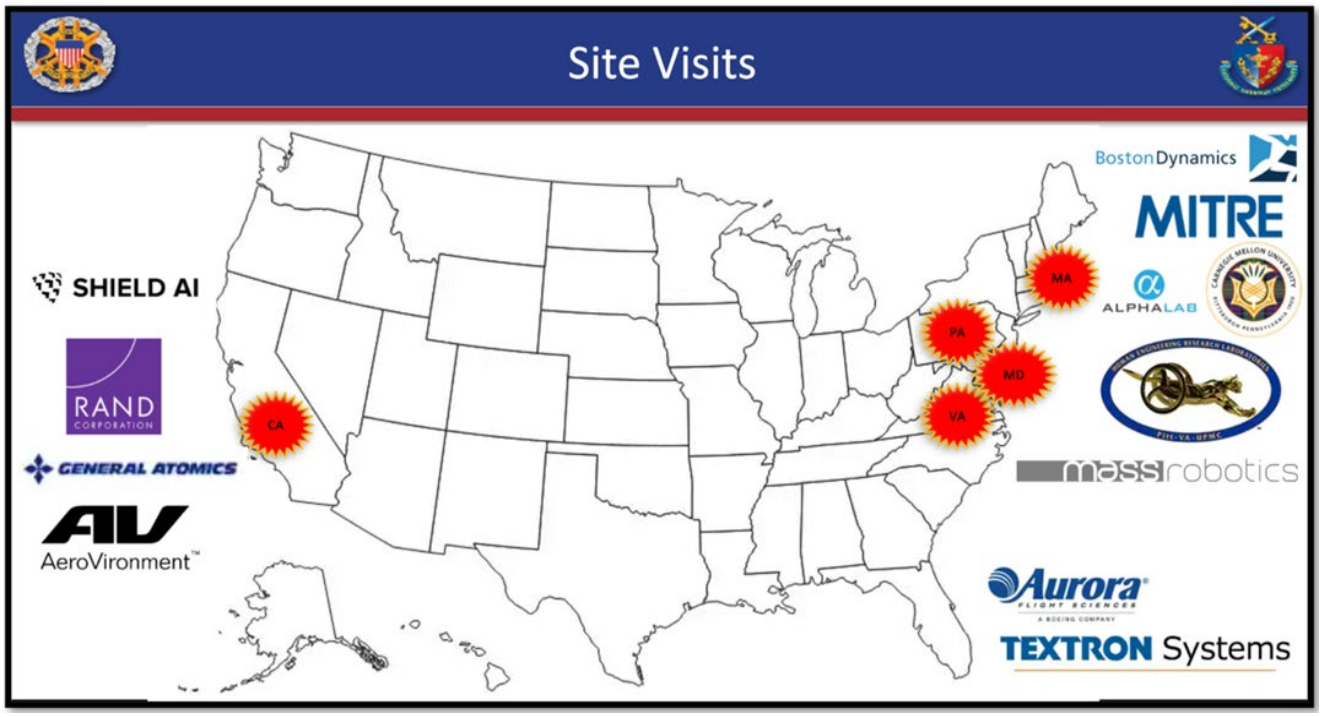
- The use of RAS in the maritime domain will steadily increase but there will not be a system shock that drives an unexpected spike in the rate of change.

- RAS in the commercial maritime domain will take a significant amount of time to turn profitable.

- The Navy will be (mostly) successful in their efforts to change strategy to Distributed Maritime Operations and not significantly impacted by other high-profile issues like the A-10 divestment.

Appendix F

Seminar Members and Firms Visited



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