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Autonomy & Robotics at the Crossroads

Policy Recommendations to Secure a Strategic Advantage

Autonomous Systems and Robotics

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The views expressed in this paper are those of the author and do not reflect the official policy or position of the National Defense University, the Department of Defense, or the U.S. Government.

FOREWORD BY COURSE DIRECTOR

The Charge to Shape the Future of Autonomous Systems

Dear National Security and Resource Strategy reader,

In March 2025, the Dwight D. Eisenhower School for National Security and Resource Strategy tasked its Autonomous Systems and Robotics Industry Study seminar with an ambitious challenge: to produce a capstone Group Report that rivals the strategic insight of an elite consulting firm. This directive emerged from a collaboration with our Distinguished Visitor Panel, comprising senior military leaders and industry experts, whose expertise in capability development, acquisition, and innovation shaped the contours of this effort. Their charge was clear: deliver bold, nuanced, and resource-informed policy recommendations to strengthen the U.S. defense industrial base and secure strategic dominance in an era of rapid technological disruption.

The United States stands at a crossroads. Emerging technologies—artificial intelligence (AI), machine learning, and advanced robotics—promise to transform both the battlefield and the industrial backbone that sustains it. Yet this promise comes with complex tensions. The Department of Defense (DoD) and defense industrial base (DIB) grapple with whether autonomy should be centralized across platforms for interoperability or specialized for individual systems to maximize performance—a debate with no clear optimum. Traditional acquisition processes risk entrenching vendor-specific solutions, slowing proliferation at the “speed of relevance” and ceding ground to adversaries like China and Russia. Meanwhile, warfare itself evolves at “machine speed,” demanding seamless man-machine teaming to distill chaos into actionable knowledge, amplify decision-making, and achieve cognitive overmatch.

This report responds to these dynamics with a singular focus: How can the U.S. harness autonomous systems and AI to revolutionize warfighting and industrial capacity in tandem? The panel's insights inspired three guiding threads:

- **Enterprise Architecture and Acquisition:** Craft a government-led framework for autonomy, AI, and machine learning that accelerates innovation, sidesteps vendor lock-in, and reimagines acquisition to match technological and operational tempo.
- **Industrial Efficiency and Policy:** Leverage AI and autonomy to optimize production of critical defense assets—ships, submarines, aircraft—balancing cost and schedule with employment impacts, and integrating tools like digital twins, simulated training environments, and IoT.
- **Human-Machine Teaming:** Forge strategies to unite warriors and machines into a cohesive force, enhancing kill chains, simplifying complexity, and designing training and organizational models for decision-making superiority.

What follows is the culmination of our students' rigorous analysis—future strategic leaders tasked with weighing strategic competition, ethical trade-offs, and resource realities. Their recommendations aim not just to answer the panel's call, but to offer a roadmap for U.S. preeminence in an age defined by the convergence of technology and warfare. This Foreword sets the stage for their work, a testament to the intellectual energy and creative resolve invested to meet the demands of a discerning client—and a nation at a pivotal moment.

With respect,
Gregory H. Freitag, MD
CAPT, U.S. Navy
Course Director, Autonomous Systems & Robotics

TABLE OF CONTENTS

FOREWORD BY COURSE DIRECTOR.....	ii
TABLE OF CONTENTS.....	iv
LIST OF TABLES.....	vi
LIST OF FIGURES.....	viii
PREFACE.....	ix
INDUSTRY STUDY PRESENTATIONS AND FIELD STUDIES.....	x
ACKNOWLEDGEMENTS.....	xi
EXECUTIVE SUMMARY.....	xiii
INTRODUCTION.....	1
STRATEGIC ENVIRONMENT.....	3
<i>Current Industry Status</i>	3
<i>Key Issues</i>	4
<i>Supply Chain Management to AS&R</i>	10
<i>Factor Conditions and Broader Issues Affecting Inputs</i>	11
<i>Strategic Competition</i>	12
STAKEHOLDER INTERESTS.....	14
<i>State of Business-Government Relations</i>	14
<i>21st Century Mobilization Preparedness</i>	21
ANALYSIS.....	27
<i>Industry Structure and Competitive Forces</i>	27
POLICY RECOMMENDATIONS.....	33
<i>Reform to Secure Robotics Supply Chains</i>	34
<i>Use DoD Contracts to Seed Domestic Robotics Suppliers</i>	34
<i>Acquisition Reforms to Strengthen Industry Participation and Private Investment</i>	35
<i>Establish DoD-Wide Standards for AS&R and Modular Open Systems</i>	40
CONCLUSION.....	45
APPENDIX A – AI IMPACTS ON AS&R.....	48
APPENDIX B – WARGAMING WITH AS&R.....	50
APPENDIX C – ADDITIONAL POLICY RECOMMENDATIONS.....	52
<i>Recommendations Requiring Statutory Changes</i>	53

<i>Best Business Practice Recommendations</i>	61
APPENDIX D: STAKEHOLDER PERSPECTIVES ON AS&R.....	80
APPENDIX E: ALLIED CONTRIBUTIONS: THE CASE FOR SOUTH KOREA.....	84
APPENDIX F: FIRM CONDUCT AND STRATEGIC BEHAVIOR.....	87
APPENDIX G: GENERATIVE ARTIFICIAL INTELLIGENCE USAGE	90
GLOSSARY OF ACRONYMS.....	177
BIBLIOGRAPHY.....	180

LIST OF TABLES

Table 1 - AS&R Faculty & Seminar Members.....	ix
Table 2 - Presentations.....	x
Table 3 - Field Studies	xi
Table 4 - Summary of Recommendations	33
Table 5 - Details to Support Recommendation to Use DoD Contracts to Seed Domestic Robotics Suppliers	34
Table 6 - Details to Support Recommendation for ITAR Modernization	35
Table 7- Details to Support Recommendation to Reform Facility Clearance Eligibility	37
Table 8 - Details to Support Recommendation to Modernize Profit Policy to Incentivize Private Sector Co-Investment.....	39
Table 9 - Details to Support Recommendation to Establish National and Military Safety, Performance, and Interoperability Standards.....	41
Table 10 - Details to Support Recommendation to Adopt MOSA as the Default for AS&R	42
Table 11 - Summary of Additional Recommendations	52
Table 12 - Details to Support Recommendation to Establish a Government-Wide AS&R Commission	53
Table 13 - Details to Support Recommendation to Implement Targeted Tax Incentives for Adoption of Robotics and Autonomy R&D	54
Table 14 - Details to Support Recommendation to Improve Federal Investment in Robotics and Autonomy Education and Workforce Development.....	55
Table 15 - Details to Support Recommendation to Fund Public-Private Robotics Innovation Initiatives.....	56

Table 16 - Details to Support Recommendation to Eliminate CSDR Reporting as a Barrier to Entry.....	58
Table 17 - Details to Support Recommendation to Modify Cost Accounting Requirements to Reduce Barriers to Entry for Small to Medium-Sized Companies.....	59
Table 18 - Details to Support Recommendation to Establish Strategic Outreach for Emerging Defense Suppliers	61
Table 19 - Details to Support Recommendation to Establish Infrastructure Sharing and Testbeds	62
Table 20 - Details to Support Recommendation to Ensure Procurement Follow-Through to Bridge the “Valley of Death”	64
Table 21 - Details to Support Recommendation to Make DoD a Leading Adopter of Robotics and Autonomy Technologies	66
Table 22 - Details to Support Recommendation to Incorporate AS&R into Acquisition Programs	67
Table 23 - Details to Support Recommendation to Institutionalize Leading Commercial Product Development Principles	68
Table 24 - Details to Support Recommendation to Reinstate and Expand Advanced Acquisition Workforce Training in Modern Development Practices.....	70
Table 25 - Details on Demand Signaling and Procurement Commitments to Attract Private Capital.....	72
Table 26 - Details to Support Recommendation to Expand Challenge-Based Acquisition	73
Table 27 - Details to Support Recommendation to Establish Milestone-Based “Prizes” and Non-Dilutive Incentives	75

Table 28 - Details to Support Recommendation to Prioritize Dual-Use Robotics for Acquisition and Partnerships	76
Table 29 - Details to Support Recommendation to Leverage the New DoD Office of Strategic Capital to Attract Private Financing	77

LIST OF FIGURES

Figure 1 - SAE J3016 Levels of Driving Automation	6
Figure 2 - Industrial Robotic Usage Comparison by Country	21
Figure 3 - Levels of Driving Autonomy	48

PREFACE

The Autonomous Systems and Robotics (AS&R) Industry Study (IS), directed by CAPT Gregory Freitag and Dr. Anita Kellogg, examined key trends, challenges, and opportunities in the rapidly evolving AS&R industry.¹ Colonel Marcus McNabb served as Student Lead for a seminar team comprising senior military officers and government civilians from the U.S. and partner countries. Drawing on expertise in operations, acquisition, logistics, diplomacy, and healthcare, the team conducted in-depth engagements with industry, government, and academic leaders to assess the strategic implications of AS&R and develop bold and actionable insights.

Table 1 - AS&R Faculty & Seminar Members

AS&R Industry Study Seminar Members (AY 24-25)		
FACULTY	Captain Gregory Freitag	U.S. Navy IS Faculty Lead
	Dr. Anita Kellogg	U.S. Department of Defense IS Faculty Deputy
STUDENTS	Colonel Marcus McNabb	U.S. Air Force, Seminar Leader
	Mrs. Erin Anderson	U.S. Navy
	Captain Ahmad Alkhazraji	United Arab Emirates Navy
	Mr. Peter Dyaico	U.S. State Department
	Lieutenant Colonel Chad Handley	U.S. Army
	Lieutenant Colonel William Harrell	U.S. Air Force
	Mr. Christopher Hattayer	U.S. State Department
	Colonel Jorge Hernandez Figueroa	Guatemala Army
	Mr. David Kuroda	U.S. Defense Acquisition University
	Lieutenant Colonel Alex Montgomery	U.S. Army
	Lieutenant Colonel Karen Perry	U.S. Marine Corps
	Colonel Roderick Richardson	U.S. Army
	Lieutenant Colonel Bradley Son	U.S. Army
	Lieutenant Colonel Shannon Waller	U.S. Marine Corps

¹ Generative Artificial Intelligence (AI) was used to assist in the writing of this report.

INDUSTRY STUDY PRESENTATIONS AND FIELD STUDIES

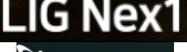
The Seminar engaged with leaders and subject matter experts from industry, academia, and the federal government. The tables below summarize key presentations and field studies.²

Table 2 - Presentations

Title	Speaker
The AI Stack and Thinking Machines	Mr. Shane Shaneman Nvidia Corporation
Concept of the "AI Stack" as a perspective on how to scaffold AI into applications such as robotics and other autonomous systems.	
Democratization of Technology	Dr. Kerry Chávez Texas Tech University
How AS&R applications impact national security and undercut the pathway of high-end expensive weapon systems.	
Great Power Implications of AS&R	Mr. Josh Wallin Center for New American Security
Great Power implications of using autonomous systems in society and when used to leverage national power.	
DoD Services' Requirements Determination	DoD Service Representatives
Current and future applications of AS&R technology and the processes the services use to define requirements and work with industry.	
OSD Critical Technologies Office	Dr. Christopher Palmer OSD R&E
Set the context for current policies and priorities in the Pentagon's lead directorate for prioritizing Human Machine Teaming in AS&R	
Airpower as a Paradigm for Human Machine Teaming	Dr. Steven A. Fino Collins Aerospace & Author of "Tiger Check"
The application of AS&R in the air domain and implications for Human-Machine Teaming.	
OT&E and the Role of Trust in AS&R	Dr. Laura Freeman Virginia Tech National Security Institute
Set the context for current policies and priorities in the Pentagon's lead directorate for prioritizing testing and evaluation in AS&R	
Innovation According to DARPA	Dr. Benjamin Bishop DARPA
Examine the roll of DARPA in spurring innovation for the DoD and the Nation.	
Keeping the Promise of AS&R in Perspective	Mr. Kent Massey HDT Global
Explore counter arguments to temper expectations about the promise of AS&R based on hard-learned experiences in the field.	
Advancement & Regulation of AS&R in the Air & Ground Domains	Dr. Nitin Sydney MITRE Corporation
A survey of current and emerging applications of Advanced Air Mobility (AAM) aircraft and autonomous ground vehicles in the commercial sector, coupled with an examination of how the U.S. regulatory environment and processes promote or hinder innovation.	
The Role of Fiction in AS&R	P.W. Singer Author of "Burn In"
Examine an acclaimed author's fictional perspective on future AS&R technology and the implications for the DoD.	
Assessment of the Private Firm	Mrs. Rael Blorian Pitchbook.com
Exposure to a proprietary subscription service that examines companies to understand private firms further, their place in the AS&R economy, and how privately held companies get funded for innovative ideas.	
Who Hacked My Robot?	Dr. Nathan VanHoudnos Carnegie Mellon University
Understand the brittleness of AS&R and develop strategies to combat potential vulnerabilities.	
Introduction to the South Korean Defense Industrial Base	Colonel Youngsun Kim Republic of Korea Defense Forces
Overview of the Korean defense industrial base with a special focus on AS&R.	

² Quotes or paraphrases obtained from Field Study/Couplet/Guest Speakers will be anonymized throughout the document to protect speaker candor, transparency, and Chatham House Rules.

Table 3 - Field Studies

	Logo	Name	Location	Date
Local Field Study		HDT Global Battle Lab and Advanced Development Engineering (BLADE)	Fredricksburg, VA	January 2025
		Aurora Flight Sciences, a Boeing Company	Manassas, VA	February 2025
		Textron Systems	Cockeysville, MD	March 2025
		AeroVironment	Centreville, VA	April 2025
Compleat Field Studies		Carnegie Mellon University Cloud Lab	Pittsburgh, PA	February 2025
		Advanced Robotics for Manufacturing Institute	Pittsburgh, PA	February 2025
		Human Engineering Research Laboratories	Pittsburgh, PA	February 2025
		Aurora Innovations	Pittsburgh, PA	February 2025
		TechForge	Pittsburgh, PA	February 2025
		The Engine	Boston, MA	March 2025
		Mass Challenge	Boston, MA	March 2025
		DIVE Technologies	Boston, MA	March 2025
		Boston Dynamics	Boston, MA	March 2025
		Apptronik, Inc	Austin, TX	April 2025
CONUS Field Study		AeroVironment	Moorpark, CA	March 2025
		Machina Labs AI	Chatsworth, CA	March 2025
		Anduril	Costa Mesa, CA	April 2025
		All American Racers	Santa Ana, CA	April 2025
		General Atomics Aeronautical Systems	Poway, CA	April 2025
		Shield AI	San Diego, CA	April 2025
		Nvidia Corporation	Santa Clara, CA	April 2025
OCONUS Field Study		Daedong Mobility	Daegu, ROK	April 2025
		HD Hyundai Heavy Industries Robotics Manufacturing	Daegu, ROK	April 2025
		Optimus System	Daegu, ROK	April 2025
		Daegu Gyeongbuk Institute of Science and Technology	Daegu, ROK	April 2025
		Korea Institute of Robotics & Technology Convergence	Pohang, ROK	April 2025
		Ajintek	Daegu, ROK	April 2025
		LIG Nex1	Daegu, ROK	April 2025
		Korea Institute for Robot Industry Advancement (KIRIA)	Daegu, ROK	April 2025
		LIG Nex1 Pangyo House	Seongnam, ROK	April 2025
		Hanwha Aerospace R&D Pangyo House	Seongnam, ROK	April 2025
		HD Hyundai Global R&D Center	Seongnam, ROK	April 2025
		Hyundai Motor Robotics Lab/Central Research Center	Uiwang, ROK	April 2025

ACKNOWLEDGEMENTS

CAPT Freitag and Dr. Kellogg crafted a robust course that challenged our assumptions and formed the foundation of the seminar's understanding of the AS&R industry. We thank the presenters, guides, and hosts who generously shared their time, hospitality, and insights, helping the seminar better understand their industry and needs. This report highlights critical AS&R industry issues and policies needed to bolster national security during this rapidly evolving and consequential era. The entire seminar contributed via conceptual development, critical analysis, and written content to produce this report. Their exemplary teamwork made this effort possible.

EXECUTIVE SUMMARY

The Autonomous Systems & Robotics (AS&R) industry is increasingly consequential to national defense and economic competition. This research examines the current structure and challenges of the AS&R sector through Porter's Five Forces, while drawing from extensive research, field studies, and comparisons with partner nations. While the U.S. continues to lead in several areas of robotics and artificial intelligence (AI) development, the U.S. Defense Industrial Base (DIB) faces numerous limitations, many of which stem from outdated policy frameworks, rigid acquisition models, and dependence on foreign suppliers. To outpace China, the DoD must secure supply chains and standardize autonomy to ensure AS&R systems are interoperable, scalable, and field-ready.

A few prime contractors dominate the AS&R market, creating a challenging environment for new and innovative companies to enter, thus enlarging the barriers to entry into the market. At the same time, many firms face long procurement timelines and concerns over intellectual property (IP) protection. The U.S. DIB's continued reliance on Chinese-dominated supply chains for key components such as rare-earth elements and semiconductors exposes significant vulnerabilities in potential conflict scenarios. The DoD must expand domestic sourcing and production investments to mitigate this strategic risk. Insights from a site visit to a large defense contractor in California revealed acquisition barriers that directly informed the recommendations to reform facility clearance eligibility for innovative firms. Additionally, the lack of standardized technical requirements and interoperability frameworks across military services slows adoption and integration. Competitor nations like China are aggressively pushing ahead with state-driven AS&R policies with far fewer restrictions, and allies like South Korea have adopted a more coordinated industrial policy.

To respond to these challenges, the report recommends four key actions. First, the DoD should use its contracting power to seed domestic robotic suppliers, which includes long-term contracts and incentives for U.S.-based production of key robotic components. Second, the DoD should reform facility clearance (FCL) eligibility policies to enable interim sponsorships of firms with validated defense relevance before contract award, given that security parameters are met. Third, the DoD must reform and modernize existing profit policies to create an incentive-based structure to reward companies that take early risks in defense-relevant technologies. Companies will hesitate to enter the defense sector without a return on investment (ROI). Lastly, the DoD should establish service-wide standards for safety, cybersecurity, and interoperability and mandate the use of Modular Open Systems Approaches (MOSA) wherever feasible. These reforms enhance DoD and industry autonomous systems architecture, industry efficiency, and human-machine teaming. Appendix C offers additional policy recommendations to strengthen the AS&R industry and enhance collaboration between private industry and the government.

If the U.S. hopes to maintain a competitive edge in developing and executing autonomous capabilities, it must fund innovation and fix structural issues that slow the adoption. Speed, scalability, and interoperability are imperative.

INTRODUCTION

The Autonomous Systems and Robotics (AS&R) industry stands at a pivotal crossroads, significantly shaping the future landscape of national security, economic competitiveness, and technological innovation. Autonomous systems, characterized by increasing sophistication in Artificial Intelligence (AI), robotics, and machine learning, transition rapidly from theoretical aspirations to critical operational assets. The AS&R industry encompasses various platforms, including uncrewed aerial, maritime, and ground vehicles, industrial robotics, and sophisticated loitering munitions, each increasingly indispensable for modern defense operations.

Emerging trends within the AS&R industry underscore the urgent imperative for robust strategic direction and enhanced collaboration between government entities, academia, and private industry. Innovations such as additive manufacturing, iterative software updates, human-machine teaming (HMT), digital twins, and reinforcement learning (RL) accelerate game-changing capability development and testing, but also highlight vulnerabilities, particularly within supply chains reliant on geopolitical adversaries. Additionally, workforce shortages in key specialties such as CNC machinists and digital twin scene generators, complex regulatory environments, and inconsistent government demand signals present barriers to rapid innovation and adoption.

The United States (U.S.) faces heightened strategic competition from near-peer adversaries, particularly China and Russia, who continually advance their autonomous warfare capabilities. These advancements pose direct challenges to U.S. technological supremacy and operational preparedness. As the global race for autonomy escalates, the U.S. must adopt integrated policies and targeted investments that foster domestic innovation, ensure secure supply chains, and solidify technological partnerships with allies. The performance and agility of

the AS&R industry will thus not only dictate economic trajectories but also profoundly influence national security outcomes.

U.S. government and industry leaders in the AS&R posed a challenge to identify key issues and develop bold, actionable policy recommendations across three strategic pillars: Enterprise Architecture and Acquisition, Industrial Efficiency and Policy, and HMT. To address this challenge, the paper begins with an overview of the strategic environment shaping the AS&R industry. This section discusses industry status, key issues, overall trends, and the state of strategic competition. A thorough discussion of various stakeholder interests follows, focusing on government-business relations and examining the industry's mobilization readiness. The paper then presents an industry analysis via Porter's Five Forces. Finally, the paper presents policy recommendations to spur the industry into action. The multiple appendices bookending this report include additional discussions on the impact of AI and warfighting, policy recommendations, and other key topics.

STRATEGIC ENVIRONMENT

The AS&R industry operates in a dynamic and complex environment. The rate of technological change, the adaptability of allies, partners, and adversaries, and an understanding of the technologically feasible, influence the industry dynamics. This section highlights the current industry status, specific innovation trends, an industry forecast, the supply chain environment, and how adversaries' industrial base currently operates.

CURRENT INDUSTRY STATUS

The U.S., its allies, and partners are investing heavily in research and development (R&D) to further AS&R technology, specifically in AI, command and control platforms, loitering munitions, humanoid robots, and uncrewed vehicles. To support this effort, the DoD's Developmental Test, Evaluation, and Assessment Division identifies challenges and shares best practices across test and evaluation organizations to inform and improve service-level requirements planning. In addition, the DoD works across interagency, industry, and academia to integrate best practices and lessons learned.³ These processes assist in developing new requirements to describe what is in the art of the possible. The U.S., in coordination with its allies, such as the United Kingdom, Australia, France, South Korea, and Japan, actively develops the technology and establishes requirements for AS&R, including the DoD's adoption of Modular Open Systems Architecture (MOSA).

³ Chief Technology Officer. "Autonomous Systems." U.S. Department of Defense. Accessed April 28, 2025. <https://www.cto.mil/dtea/autonomous/>.

KEY ISSUES

Intellectual Property Rights - DoD Instruction 5010.44, *Intellectual Property and Acquisition*, governs the policy of procuring IP rights related to DoD acquisition. The general DoD position is to work with industry to determine the rights of IP systems, balancing the needs of government and industry. DoD 5010.44 paragraph 1.2 states:

“Acquiring and licensing the appropriate IP is vital for ensuring the systems will remain functional, sustainable, upgradable, and affordable. Because balancing the interests of the U.S. Government and industry in IP can be difficult, early and effective understanding, planning, and communications between the U.S. Government and industry is critical, as is ensuring delivery, acceptance, and management of the necessary IP deliverables (e.g., technical data and computer software), with appropriate license rights. The DoD requires fair treatment of IP owners, and seeks to create conditions that encourage technologically advanced solutions to meet DoD needs.”⁴

The primary concern for IP rights is preventing vendor lock, specifically in the Operations and Sustainment cycle, while the DoD utilizes the acquired item. However, numerous field study firms confirmed other concerns: the industry’s view of IP overreach, failure to account for industry investment, and ambiguously defined contract terms.⁵

Overstated Autonomy Claims – The industry lacks consensus on whether current technology can fulfill the DoD's requirements for fully autonomous systems. Experts in the uncrewed aerial systems (UAS) and autonomy industry stated that the technology has existed for over twenty years and should be employed based on service requirements.⁶ In addition, Kent Massey argues that full autonomy is not a viable solution for military applications, despite other industries’

⁴ Lord, Ellen. Department of Defense Instruction 5010.44 Intellectual Property Acquisition and Licensing. October 16, 2019.

⁵ Allums, Vicki. Intellectual Property and Data Rights Considerations, Defense Acquisition University, November 7, 2019. <https://business.defense.gov/Portals/57/MARC%20Presentation.pdf?ver=2019-11-06-084251-993>.

⁶ Discussion with defense UAS and one-way attack firm representatives, April 2025.

claims that they will soon achieve full autonomy.⁷ Limitations include the inability of autonomous systems to identify negative obstacles and side slopes, inadequate electric motors and batteries, and the constrained reach and endurance of existing autonomous platforms. In addition, the autonomous system can account for more than 50% of the vehicle's cost.⁸

Vagueness of Industry Capability –UAS, UGV, and UUV firms consistently failed to provide specific details about how autonomous functions work within their systems.⁹ When asked to explain the implementation of autonomy, they responded vaguely. Follow-up questions did not clarify whether they withheld information due to security classification, intellectual property concerns, or both. This lack of transparency makes it difficult to assess whether the industry is overstating its capabilities or whether the technology has matured enough for the DoD to adopt autonomous systems without human intervention. In several engagements, representatives from UGV and UAS firms admitted that current technology cannot support full autonomy.¹⁰

This same lack of clarity also affects industry standardization. AS&R sectors define autonomy levels differently. SAE International (formerly the Society of Automotive Engineers) defines levels of driving automation, as shown in Figure 1.¹¹ However, this standard does not extend to the maritime or aviation industries. To address the aviation gap, Anderson et al. adapted the SAE framework to aviation with autonomy levels defined as aviate, navigate, communicate, system management, and command decisions.¹² Because no external authority has

⁷ Lambert, Fred. "Tesla Full-Service Self Driving is Stagnating After Elon Said It is Going Exponential." Electrek. March 23, 2025. <https://electrek.co/2025/03/23/tesla-full-self-driving-stagnating-after-elon-exponential/>.

⁸ Massey, Kent. "Squad Mission Essential Transport." NDIA Ground Robotics and Capability Conference. March 2, 2016.

⁹ Discussion with UAS, UGV, and UUV firms currently producing products for DoD, February – April 2025.

¹⁰ Discussions with UGV and UAS production firms, March – April 2025.

¹¹ SAE International. "SAE Levels of Driving Automation: Refined for Clarity and International Audience." May 3, 2021. <https://www.sae.org/blog/sae-j3016-update>.

¹² Anderson, Eric, Timothy Fannin, and Brent Nelson. "Levels of Aviation Autonomy." 2018 IEEE/AIAA 37th Digital Avionics Systems Conference (DASC). London, UK: 2018. doi: 10.1109/DASC.2018.8569280.

established comprehensive autonomy definitions, the DoD must take the lead and define its own, either through a single overarching definition or domain-specific ones.

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	SAE LEVEL 0™	SAE LEVEL 1™	SAE LEVEL 2™	SAE LEVEL 3™	SAE LEVEL 4™	SAE LEVEL 5™
What does the human in the driver's seat have to do?	You <u>are</u> driving whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering			You <u>are not</u> driving when these automated driving features are engaged – even if you are seated in “the driver's seat”		
	You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety			When the feature requests, you must drive	These automated driving features will not require you to take over driving	

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	These are driver support features			These are automated driving features		
What do these features do?	These features are limited to providing warnings and momentary assistance	These features provide steering OR brake/acceleration support to the driver	These features provide steering AND brake/acceleration support to the driver	These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met	This feature can drive the vehicle under all conditions	
Example Features	<ul style="list-style-type: none"> • automatic emergency braking • blind spot warning • lane departure warning 	<ul style="list-style-type: none"> • lane centering OR • adaptive cruise control 	<ul style="list-style-type: none"> • lane centering AND • adaptive cruise control at the same time 	<ul style="list-style-type: none"> • traffic jam chauffeur 	<ul style="list-style-type: none"> • local driverless taxi • pedals/steering wheel may or may not be installed 	<ul style="list-style-type: none"> • same as level 4, but feature can drive everywhere in all conditions

Figure 1 - SAE J3016 Levels of Driving Automation¹³

Current Workforce Trends – The AS&R industry utilizes geographic clusters, as described by Michael Porter, to leverage access to potential talent.¹⁴ According to the management of companies visited, numerous companies rely on nearby academic institutions to harness essential engineering expertise, enabling the development of hardware and software applications required to fulfill customer requirements. One software engineer operating in the digital twin and testbed sector described the need for artistic scene renderers as the major limiting factor, constraining the

¹³ SAE International. “SAE Levels of Driving Automation: Refined for Clarity and International Audience.” May 3, 2021. <https://www.sae.org/blog/sae-j3016-update>.

¹⁴ Porter, Michael. “Clusters and the New Economics of Competition.” Harvard Business Review. November-December 1998. <https://hbr.org/1998/11/clusters-and-the-new-economics-of-competition>.

development of virtual worlds needed to advance AI and autonomy via digital twin simulations across multiple industries.¹⁵

It is typical for employees to leave one organization and join another within the commercial sector and the defense industrial base, applying their production experience in their new role. In-demand employees will sometimes work for multiple companies within the industry, reflecting this employment trend. Notably, there are specific shortages in Computer Numerical Control (CNC) machinists, who often move between UAS and one-way attack firms within a given cluster to meet fluctuating demand, which can be a targeted sector for the improved effectiveness of federal investments.¹⁶

Industry Forecast

While progress within industry continues, further industry and government improvements are necessary to address 21st-century battlefield demands. Advancements in requirements, acquisition processes, and technological understanding continue within the AS&R domain.

Requirements – Several interviewed requirements planners admitted they lacked a solid understanding of the true capability of AS&R systems and the acquisition timelines and costs associated with these systems. Some members knew the funding outlay but did not know how each service intends to utilize or field them to specific units. Also, some planners were unaware of how some AS&R systems would be employed, while others were unaware of some technical aspects of the autonomous systems. Exposure to the systems is needed for requirements planners to work with acquisition professionals effectively.¹⁷

¹⁵ Discussion with commercial software development representatives, March 2025.

¹⁶ Discussion with defense technology firm representatives, March 2025

¹⁷ Discussion with military requirements planners, January 2025.

Acquisition Processes – Most interviewed industry experts expressed concerns about funding requirements based on annual budget needs, the length of time for contract approval, and the “valley of death” associated with innovation shortfalls. Industry leaders hold differing perspectives on the acquisition process. Defense prime contractors expressed satisfaction with the current system, while smaller firms attempting to enter the defense market struggle with the timeliness of contract awards, significantly affecting their operations.¹⁸

Innovation Trends

Becoming the “Gap Filler” – One key trend is that smaller companies are focusing on attritable systems and affordable mass platforms. Companies such as Anduril, AeroVironment, and L3Harris were recently awarded contracts under the Replicator initiative.¹⁹ Non-traditional defense contractor representatives stated that they are actively addressing the capability gaps identified by the DoD, focusing specifically on accelerating the product time to market.²⁰ In addition, these smaller companies consistently look at the acquisition strategies of other companies to meet demands. For example, Anduril’s acquisition of Dive Technologies in 2022 shows the expansion of smaller firms to meet the DoD’s innovation requirements.²¹

Use of Additive Manufacturing / 3D Printing Technology – Multiple industry partners described how they incorporate additive manufacturing into their production processes. However, as with discussions on intellectual property rights, many focused on general concepts

¹⁸ Discussion with UAS and one-way attack defense firm representatives, February - April 2025.

¹⁹ Defense Innovation Unit. “Defense Innovation Unit Announces Software Vendors to Support Replicator.” November 20, 2024. <https://www.diu.mil/latest/defense-innovation-unit-announces-software-vendors-to-support-replicator>.

²⁰ Discussion with UAS, UGV, and UUV defense firm representatives, April 2025.

²¹ Anduril Industries. “Anduril Industries Acquires Dive Technologies.” February 2, 2022. <https://www.anduril.com/article/anduril-industries-acquires-dive-technologies/>.

and did not explain how they applied additive manufacturing in early production, reduced material and part costs, or tackled supply chain issues.²²

Iterative Updates for Software Requirements on Mission-Based Platforms – There is a growing lag in software update requirements for autonomous systems due to the time it takes to upgrade a platform fully. Historically, updating a platform across the DoD based on operational requirements took months. However, one UAS platform manufacturer stated that autonomous systems may require software rollouts every two weeks to remain relevant. According to these software engineer experts, version control and acceptance testing from the manufacturer are the two biggest hindrances to rapid fleetwide software updates.²³

Human-Machine Teaming – DoD requirements consistently describe a need for HMT within platforms based on current technological limitations to achieve full autonomy. In *Our Robots, Ourselves*, Dave Mindell highlights the Air Force’s challenges with the Predator platform, particularly its struggle to define the role of the human operator versus the pilot and to balance the platform’s autonomous capabilities with the essential functions of the ground control station.²⁴ Other services, such as the Army, also developed requirements for an uncrewed ground vehicle (UGV) that requires remote driving capability.²⁵ UAS and UGV firms provided numerous examples of HMT, including tethers and remote controls, and GPS-enabled technology for military and commercial applications.²⁶

²² Discussion with commercial and defense technology firm representatives, February - April 2025.

²³ Discussion with UAS and one-way attack defense industry representatives, April 2025.

²⁴ Mindell, David A. *Our Robots Ourselves*. New York: Penguin Publishing, 2015.

²⁵ Massey, “Squad Mission Essential Transport.”

²⁶ Daedong Kioti. “Daedong-KIRO Complete Field Demonstration Required to Commercialize Autonomous Transportation Robots.” November 3, 2023. <https://daedong-kioti.com/news/daedongnews/1138>.

Reinforcement Learning – RL, defined as “a type of machine learning that lets virtual or physical agents learn through experience, often finding novel solutions to difficult problems and exceeding human performance,” is underutilized in the industry.²⁷ Multiple software engineers and business development professionals of UAS conveyed a lack of RL proliferation in the industry and the need to adopt this type of learning within their autonomy. More importantly, these same industry experts stated that RL does not occur with any specific regularity or frequency.²⁸ Future autonomous systems must learn through experience via methods such as RL to realize their potential. However, this learning requires many thousands (or more) iterations depending on the complexity of the problem and environment. Engineers use software-driven testing tools (e.g., digital twins) to refine RL algorithms within realistic time and cost constraints.

SUPPLY CHAIN MANAGEMENT TO AS&R

One of the primary concerns of UAS, UUV, and UGV manufacturers is supply chain management and the DIB’s reliance on international suppliers to meet the DoD’s requirements. In a market where thousands of vendors offer everything from commodities to specialty items, firms must forecast to meet their production timelines. Supply chain managers from AS&R firms described lead times as long as 24-36 months to meet their production schedules.²⁹

PRC Dependencies – A significant supply chain management issue is dependency on PRC companies to meet requirements. For example, Govini’s National Security Scorecard analysis consistently shows that China is still heavily involved in the supply chain of DoD’s critical

²⁷ Taylor, Matthew E., Nicholas Nissen, Yuan Wang, and Neda Navidi. 2023. “Improving Reinforcement Learning with Human Assistance: An Argument for Human Subject Studies with HIPPO Gym.” *Neural Computing & Applications* 35 (32): 23429–39. doi:10.1007/s00521-021-06375-y.

²⁸ Discussion with UAS industry representatives, April 2025.

²⁹ Discussion with defense industry representing UAS, UGV, and UUV manufacturers, April 2025.

technologies. Specifically, China has 158 suppliers within the AS&R supply chain, which Govini identified in its 2024 report.³⁰ Most supply chain professionals we interviewed reported significant progress in removing PRC companies from their supply chains to comply with U.S. policies. However, most AS&R companies we visited during our field studies also revealed that companies rarely observed supply chain visibility beyond their second tier of suppliers.³¹

Critical Earth Elements – The U.S. depends on PRC-supplied rare earth minerals and is reducing its dependency by improving domestic supply chains. Since 2020, the DoD has invested \$439M to address dependencies in seventeen critical rare earth minerals. The DoD has worked with United Kingdom, Australian, and Canadian suppliers and invoked the Defense Production Act (DPA) with domestic suppliers where applicable.³² China still controls the preponderance of rare earth refining capability worldwide. Second- and third-tier suppliers source semiconductors from China, reinforcing the dominance of those who depend on them. Taiwan manufactures more semiconductors than any other country, and China actively refines the rare earth elements needed to produce them. As the U.S. depends on Taiwan for its semiconductor supply, a conflict could drive nations to compete for the limited availability of both semiconductors and rare earth elements.

FACTOR CONDITIONS AND BROADER ISSUES AFFECTING INPUTS

Cost of AS&R Systems – Business development and leadership teams from the firms visited said the cost-benefit comparison between developing autonomous systems and relying on human

³⁰ Work, Robert and Tara Murphy Dougherty. “The 2024 National Security Scorecard.” ark.ai by Govini. 2024.

³¹ Discussion with aerospace and defense technology firm representatives, February - April 2025.

³² Vergun, David. “Securing Critical Minerals Vital to National Security, Official Says.” DoD News. January 10, 2025. <https://www.defense.gov/News/News-Stories/Article/Article/4026144/securing-critical-minerals-vital-to-national-security-official-says/>.

development of AS&R systems was a significant concern.³³ Because the DoD acquires platforms in limited quantities, most industry leaders expressed concerns about costs. Computational costs dominate economic feasibility discussions for autonomous systems. In addition to infrastructure costs, the power to compile and compute algorithms consumes enormous amounts of power, with forecasts of a possible 16-42 gigawatts in the U.S. by 2030.³⁴ As discussed with HDT, compute costs can account for over 50% of AS&R platform costs.³⁵

STRATEGIC COMPETITION

Adversaries - U.S. adversaries, such as China, Russia, Iran, and North Korea, are also developing AS&R systems:

- China – China poses the most significant threat regarding technical capability and its ability to produce large quantities at scale. They are developing various autonomous system platforms within the People’s Liberation Army (PLA), including autonomous submarines, uncrewed surface vehicles (USVs), drones, and remote sensing and targeting platforms. They also continue to modify some existing platforms, which show promise for HMT applications.³⁶
- Russia – Before the Russia-Ukraine conflict, Russia had already invested in autonomous technology.³⁷ Their AS&R development and deployment accelerated during the conflict.

³³ Massey, “Squad Mission Essential Transport.”

³⁴ Keegan, Brian. “Assessing Power Constraints for AI.” Sands Capital. 12/12/2024.
<https://www.sandscapital.com/assessing-power-constraints-for-ai/>.

³⁵ Massey, “Squad Mission Essential Transport.”

³⁶ Kania, Elsa. “AI Weapons in China’s Military Innovations.” Brookings Institute. April 2020.
https://www.brookings.edu/wp-content/uploads/2020/04/FP_20200427_ai_weapons_kania_v2.pdf.

³⁷ Tadjeh, Yasmin. “Algorithmic Warfare: Russia Expanding Fleet of AI-Enabled Weapons.” National Defense Magazine. July 20, 2021. <https://www.nationaldefensemagazine.org/articles/2021/7/20/russia-expanding-fleet-of-ai-enabled-weapons>.

Russia's uncrewed maritime, ground, and air vehicle development displays a capable industrial base, including the Uran-9 UGV, the Orion drone series, and USVs.³⁸ Notably, the conflict has assisted in developing tactics, techniques, and procedures in employing this technology on the battlefield.

- Iran – Iran continues to develop and deploy drones like the Shahed series for intelligence, surveillance, and reconnaissance (ISR) and targeted strikes. They are also investing in ground-based autonomous technologies.³⁹
- North Korea – Kim Jong-un, North Korea's leader, emphasized prioritizing autonomous systems in the country's military modernization efforts. North Korea claims to have developed AI-powered suicide drones, early warning and control aircraft, and a reconnaissance drone that resembles the U.S. RQ-4 Global Hawk.⁴⁰

Though considerable debate persists on the effectiveness of adversary platforms, the industrial bases of these countries demonstrate their technological capability and willingness to compete in the AS&R space.

In response to today's strategic environment, the AS&R industry must actively address key challenges, including resolving IP disputes, strengthening supply chains, clarifying capability details, tempering inflated autonomy claims, and restructuring workforce management. To meet the demands of modern battlefields and counter threats from China, Russia, North Korea, and Iran, industry leaders must drive these changes without delay.

³⁸ Total Military Insight. "Advancements in Russian Military Technology, A Comprehensive Analysis." July 17, 2024. https://totalmilitaryinsight.com/russian-military-technology-advancements/#Expansion_of_Robotics_and_Autonomous_Systems.

³⁹ Total Military Insight. "Advancing Defense Technologies: Military Innovations in Iran." August 26, 2024. <https://totalmilitaryinsight.com/military-innovations-in-iran/>.

⁴⁰ Seo, Ji-Eun. "North Korean Leader Kim Jong-Un Oversees AI Suicide Drone Showcase." Korea JoongAng Daily. March 27, 2025. <https://koreajoongangdaily.joins.com/news/2025-03-27/national/northKorea/Kim-Jongun-oversees-AI-suicide-drone-showcase/2271993>.

STAKEHOLDER INTERESTS

Key stakeholders in the AS&R industry include end users and consumers, private sector firms, government and regulatory bodies, technical communities, academia, and the public, each with distinct priorities, concerns, and expectations. Understanding the multifaceted interests, relationship dynamics, and readiness is critical for developing, deploying, and governing autonomous technologies in ways that create shared value while mitigating risks. Appendix D contains additional information on stakeholder interests.

STATE OF BUSINESS-GOVERNMENT RELATIONS

Collaboration and tension characterize business-government relations. Collaborative interactions drive innovation, optimize processes, and improve the deployment of AS&R across defense and commercial industries. However, several notable tensions exist between stakeholder interests, including managing the tradeoffs between innovation and safety, and transparency and IP safeguards. The sections below explore collaboration and tension between government and industry stakeholders within the AS&R sector.

Geographic and Economic Incentives

Companies developing autonomous capabilities demonstrate increasing sensitivity to local economic incentives when making facility location decisions. Anduril's strategic decision to establish manufacturing operations in Columbus, Ohio, reflects this trend by explicitly citing favorable state and local incentives as a primary motivating factor.⁴¹ This demonstrates that

⁴¹ Pabst, Stavroula. "Ohio Goes All In for Anduril." Responsible Statecraft. February 20, 2025. <https://responsiblestatecraft.org/anduril-ohio>.

regional economic development policies can serve as powerful tools for shaping the geographic distribution of the AS&R industrial base.

Similarly, Hyundai Motor Group's significant investment in AS&R in South Korea demonstrates how national industrial policies can drive corporate investment decisions. Hyundai's expansion into robotics represents a strategic pivot supported by Korean government initiatives to establish leadership in advanced manufacturing and autonomous technologies.⁴²

Public-Private Partnerships

Research collaborations establish key links between the U.S. Government, academia, and the private sector. In 2020, the Center for Marine Autonomy and Robotics at Virginia Tech (VT), Dive Technologies (before acquisition by Anduril), and the Defense Advanced Research Projects Agency (DARPA) launched a successful research collaboration. Dive Technologies partnered with VT Ocean Engineering researchers and students to develop and test an uncrewed undersea vehicle (UUV) hydrodynamic design and software for fully autonomous subsea operation.⁴³ DARPA funded Dive Technologies to develop further its dual-impact defense and commercial subsea technologies, products, and capabilities.⁴⁴ The R&D investment resulted in successfully developing and commercializing the DIVE-LD UUV, which demonstrates advanced capabilities for extended ocean missions up to 6,000 meters deep. The DIVE-LD UUV is a commercially viable product supporting defense and civilian maritime applications.⁴⁵ These partnerships are

⁴² International Trade Administration. "South Korea Robotics Industry." U.S. Department of Commerce. Accessed April 28, 2025. <https://www.trade.gov/market-intelligence/south-korea-robotics-industry>.

⁴³ Green, Jama. "Ocean Engineers Continue to Optimize Design and Performance of Autonomous Underwater Vehicle." Virginia Tech. 2021. <https://news.vt.edu/articles/2021/08/cmar-dive-partnership.html>

⁴⁴ Rees, Caroline. "DARPA Grant Accelerates AUV Commercialization." Unmanned Systems Technology. 2022. <https://www.unmannedsystemstechnology.com/2022/02/darpa-grant-accelerates-auv-commercialization/>

⁴⁵ Anduril Industries. "DIVE-LD." Accessed May 1, 2025. <https://www.anduril.com/hardware/dive-ld/>.

critical to the AS&R industry as they bring together expertise, resources, and ideas to foster groundbreaking solutions. Dive Technologies' success reflects the value of R&D investment in fostering technological breakthroughs that benefit national security and industry growth. The DoD must actively expand DARPA consortia to accelerate the transition of cutting-edge technologies into operational use.

Classification and Transparency Challenges

During our field study, an aerospace and defense technology firm emphasized that strict classification of advanced autonomy applications obstructs business operations, particularly when engaging with investors. The inability to discuss technical capabilities and development roadmaps with potential funding sources restricts access to capital and complicates strategic planning.⁴⁶ This challenge is especially acute for companies seeking to transition from commercial to defense applications or attract non-traditional investors to the defense innovation ecosystem. DoD should refine its declassification processes, allowing investors to access sufficient information while maintaining national security protections. Adjustments to the process can foster greater private sector engagement and accelerate the transition of autonomous technologies from research to operational deployment.

A Federally Funded Research and Development Center (FFRDC), operating at the intersection of government and industry, confirmed the challenges of transferring innovations between classified and unclassified domains.⁴⁷ Government investment in research expands

⁴⁶ Discussion with aerospace and defense technology firm representatives, April 2025.

⁴⁷ Discussion with FFRDC representatives, February 2025.

commercial adaptation potential and strengthens the flow of innovation into national security applications.

Contract Structures Prohibiting Innovation

Industry partners expressed concerns about misaligned incentives in defense contracts. Anduril specifically criticized government contract types and procurement methods, noting that cost-plus contracts encourage inefficiency and inhibit innovation.⁴⁸ This misalignment creates a tension between government objectives for rapid capability development and industry business models optimized for the existing acquisition system.

A firm specializing in ground robotics identified contracting timelines as a critical impediment to innovation. The company disclosed that the extended timelines for government contracting processes often conflict with the rapid development cycles characteristic of cutting-edge technology, forcing difficult decisions between pursuing government opportunities and maintaining technological competitiveness.⁴⁹

Further, a non-profit incubator and accelerator observed how defense contracting structures often fail to accommodate the financial realities of startups. The firm emphasized that early-stage companies require predictable revenue streams and reasonable payment schedules to sustain operations.⁵⁰ To expand the DIB, the DoD must reform contract structures by streamlining payment schedules to reduce cash flow constraints. Revised contractual terms will support startup viability and foster a competitive industrial base.

⁴⁸ Pepperdine University. "Palmer Luckey, Founder of Anduril Defense Industry Disruptor - President Speaker Series (2024)." YouTube. October 3, 2024. <https://www.youtube.com/watch?v=az81MHug0Nw&t=2109s>.

⁴⁹ Discussion with ground robotics firm, March 2025.

⁵⁰ Discussion with non-profit incubator and accelerator firm representatives, March 2025.

Barriers to New Entrants and Innovators

New entrants encounter significant obstacles when entering the defense ecosystem. One barrier is the inability to access classified requirements or bid on relevant contracts without an FCL. A government contracting entity or a cleared defense contractor must sponsor a facility to obtain an FCL.⁵¹ This ‘chicken and egg’ problem reduces DoD’s access to innovative capabilities and limits growth opportunities for emerging technology companies. Further, a UUV firm noted how the classification requirements for advanced autonomy work create barriers for new entrants, which often lack the facilities or certification to conduct classified operations.⁵² These barriers disproportionately affect smaller and newer firms, introduce inefficiencies in the acquisition process, and reduce the diversity and innovative capacity of the industrial base.

Aurora Innovation’s journey in the autonomous trucking sector demonstrates how regulatory uncertainties can create substantial barriers for companies developing autonomous capabilities, even in commercial markets. The firm's experience navigating evolving safety standards and operating permissions highlights how policy frameworks can accelerate or impede the advancement of autonomous technologies across sectors.⁵³

Regarding innovation inhibitors, a recurring concern across industry stakeholders is the disproportionate flow of defense dollars to established prime contractors at the expense of smaller, more agile innovators. A UAS defense firm noted that while small firms can access venture capital funding, government agencies continue to award contracts primarily to large incumbents, reinforcing the status quo. This pattern threatens to discourage entrepreneurial

⁵¹ Defense Counterintelligence and Security Agency. “Facility Clearances.” Accessed on 29 April 2025. <https://www.dcsa.mil/FCL/>.

⁵² Discussion with UUV representatives, March 2025.

⁵³ Taube, David. “Aurora expresses optimism for national AV framework.” Trucking Dive. 3 March 2025. <https://www.truckingdive.com/news/aurora-trump-administration-national-framework/741211/>.

ventures in the defense technology space, as continued failures will “zap the energy” of emerging companies seeking to enter the market.⁵⁴

Further, many innovative companies are hesitant to contract with or offer their most advanced technologies to the DoD out of fear of losing their IP. In the National Defense Industrial Association’s 2024 Vital Signs Survey, twenty-eight percent of private sector respondents said their companies decided not to include specific technologies in bids because of IP concerns. In addition, twenty-one percent of private sector respondents feared that IP requirements threaten their rights, leading them to forgo bidding on defense contracts.⁵⁵

Aurora Flight Sciences, acquired by Boeing in 2017, represents both the potential and challenges for innovative companies in the autonomous systems space. Before the acquisition, Aurora successfully navigated the transition from a small innovative firm to a significant defense contractor.⁵⁶ However, Boeing’s acquisition of Aurora sparks debate on the DIB’s ability to support independent innovation at scale.

Strategic Direction and Coordination

Stakeholder engagements consistently highlight the lack of a comprehensive U.S. strategy for AS&R. A USV defense firm with experience developing autonomous platforms for several military services advocated for more coherent requirements development across services to drive greater standardization and interoperability in the AS&R industry.⁵⁷ The absence of

⁵⁴ Discussion with UAS defense firm representatives, April 2025.

⁵⁵ Seeds, Michael. “The Balance of Protecting IP and Data Rights.” National Defense. 2024. <https://www.nationaldefensemagazine.org/articles/2024/10/4/policy-points-the-balance-of-protecting-ip-and-data-rights>.

⁵⁶ Seeds, “The Balance of Protecting IP and Data Rights.”

⁵⁷ Discussion with USV defense firm representatives, March 2025.

coordinated requirements drives inefficiencies and limits the potential for common platforms across missions. This strategic void impedes coordinated investment, creates uncertainty for industry planning, and fails to channel research toward national security priorities.

The lack of clear direction contrasts sharply with other nations, which have established more coherent strategic frameworks to guide their development efforts. The South Korean model, exemplified by the coordinated efforts of companies like Hyundai, Daedong Mobility, and nationally funded research institutions like the Korea Institute of Robotics & Technology Convergence (KIRO) Disaster Robotics Center, demonstrates the benefits of national-level strategic direction. South Korea's explicit policies supporting AS&R development through targeted investments in strategic technologies and tax incentives for AI-related investments have mobilized resources across public and private sectors, accelerating capability advancement in ways the more fragmented U.S. approach has struggled to match. Consequently, South Korea is rapidly incorporating robotics into its manufacturing sector while advancing AS&R for defense applications.⁵⁸ As depicted in Figure 2, South Korea is a global leader in industrial robotics with 1,012 robots per 10,000 employees, more than six times the global average of 151.⁵⁹

⁵⁸ Total Military Insight. "Advancements in Robotics in the South Korean Military Strategy." August 2, 2024. <https://totalmilitaryinsight.com/robotics-in-the-south-korean-military/>

⁵⁹ Zhu, Kayla. "Which Countries Have the Most Industrial Robots?" Visual Capitalist. November 20, 2024. https://www.visualcapitalist.com/which-countries-have-the-most-industrial-robots/#google_vignette

Rank	Country	Industrial robots operating per 10,000 employees
1	KR South Korea	1012
2	SG Singapore	730
3	DE Germany	415
4	JP Japan	397
5	CN China	392
6	SE Sweden	343
7	HK Hong Kong	333
8	CH Switzerland	296
9	TW Taiwan	292
10	us U.S.	285
	 World (Average)	151

Figure 2 - Industrial Robotic Usage Comparison by Country⁶⁰

21ST CENTURY MOBILIZATION PREPAREDNESS

Mobilization preparedness in the 21st century involves integrating advanced technologies into national defense strategies. Autonomous systems enhance logistics, surveillance, and combat operations capabilities, enabling rapid and efficient mobilization. However, surge capacity and skilled workforce constraints impact production scaling and the pace of innovation in autonomous capabilities. The DoD must amplify co-production with international allies and partners, invest in domestic AS&R skills, leverage dual-use manufacturing capabilities, prioritize domestic manufacturing automation, and broadly pursue digital twin testing to maintain a competitive edge against strategic rivals.

⁶⁰ Zhu, Kayla. "Which Countries."

International Co-Production

Defense firms face significant hurdles navigating the complex regulatory landscape governing international sales. Export control regulations impose strict licensing requirements, creating substantial obstacles for U.S. firms in selling defense products and systems to international allies and partners. A UAS defense firm explained that export license requests take excessive time due to reviewers' limited technical expertise and misinterpretation of terminology.⁶¹ The firm's experience highlights how current regulatory frameworks can impede the ability of U.S. firms to compete globally, particularly when facing competitors from nations with more streamlined export processes. These inefficiencies create a competitive disadvantage for U.S. companies in global markets and inhibit the scaling of production that would benefit domestic capabilities.

General Atomics Aeronautical Systems Inc.'s partnership with Hanwha Aerospace in South Korea for UASs highlights a dynamic paradigm shift within the DIB.⁶² Facing DoD funding constraints, General Atomics engaged Hanwha in a co-production arrangement for its Mojave UAS platform. This partnership will strengthen technological cooperation with an international ally and expand UAS production capabilities.⁶³

Co-production leverages country-specific expertise, improves economies of scale, and reduces the financial burden of defense production on individual countries. By collaborating on defense projects, the U.S. can build trust and interoperability, ensuring that the U.S. military and

⁶¹ Discussion with UAS firm representatives, March 2025.

⁶² Defence Industry Europe. "Hanwha Aerospace and General Atomics Announce Strategic Partnership on Unmanned Aircraft Systems." April 2, 2025. <https://defence-industry.eu/hanwha-aerospace-and-general-atomics-announce-strategic-partnership-on-unmanned-aircraft-systems/>.

⁶³ Defence Industry Europe. "Hanwha Aerospace."

allied forces can operate seamlessly. Utilizing co-production to increase military surge capacity is a strategic deterrence mechanism to promote regional and global security and stability.

While such partnerships can expand market access and distribute development costs, they also introduce potential challenges related to technology transfer, sovereign capability development, and supply chain security. The lack of a systematic U.S. approach to co-production agreements limits the strategic benefits that could be derived from these arrangements. Hyundai's acquisition of Boston Dynamics represents a significant case study in international technology transfer and its implications for national security and industrial policy. This acquisition transferred ownership of advanced robotics capabilities that the U.S. government substantially funded and developed, raising questions about strategic evaluations of such transactions to foreign allies and partners.

Human Capital Constraints

The skilled workforce required for AS&R development and production represents a significant constraint on mobilization capacity. A defense firm specializing in UAS stated that training a new technician requires approximately eighteen months, creating a substantial lead time for workforce expansion.⁶⁴ This personnel development timeline slows production growth, regardless of financial resources or material availability.

NVIDIA has addressed workforce development challenges through its Deep Learning Institute, which provides education and certification in AI and robotics to expand the available

⁶⁴ Discussion with UAS defense firm representatives, April 2025.

talent pool.⁶⁵ This proactive approach to human capital development represents a potential model for building surge capacity in critical technical skills.

Dual-Use Industries and Scalability

The experience of All American Racing demonstrates both the opportunity and limitations of leveraging dual-use manufacturing capabilities. The company successfully pivoted from being a leading developer of automotive racecars for decades to producing components for the defense and space sectors based on its composite material expertise. However, tedious manual processes constrain their production capacity, limiting surge potential.⁶⁶ This pattern repeats across the U.S. industrial base, where specialized manufacturing capabilities cannot often rapidly scale production in response to crisis demands.

Hyundai's strategic expansion into robotics through its acquisition of Boston Dynamics and significant investments in manufacturing automation illustrates how automotive manufacturing capacity could support autonomous systems production in crisis scenarios. Hyundai's established production lines, workforce, and automation systems could be repurposed to support rapid production of autonomous systems, much like how automotive factories have historically adapted during wartime to produce military equipment. However, shifting from vehicle to robotic system production would demand significant adaptation.

⁶⁵ NVIDIA. "NVIDIA Deep Learning Institute." Accessed May 5, 2025. <https://www.nvidia.com/en-us/training/>

⁶⁶ Discussion with Space and Defense Systems firm representatives, April 2025.

Manufacturing Automation

Discussions with multiple UAS defense firms highlighted important nuances regarding using automation in manufacturing processes. The firms' experiences suggest that over-automation can impede innovation during R&D phases. Allowing for rapid design changes and iterative testing before committing to casting and molding for mass production ultimately saves time and money.⁶⁷ Further, autonomous systems cannot achieve cost-efficiency because the defense market requires low quantities of equipment and systems. Low production volumes reduce cost-effectiveness, making it challenging to justify the initial investment and operational costs associated with fully autonomous manufacturing systems. Defense companies have demonstrated selective integration of automation in key areas of the production process where it yields the most significant efficiency or quality improvements, rather than a blanket adoption.⁶⁸

Daedong Mobility and HDT Global demonstrate effective hybrid approaches to manufacturing automation, balancing efficiency with flexibility. While Daedong employs modular systems that can be rapidly reconfigured for design changes or surge capacity, HDT maintains manual assembly for complex components while automating standardized production.⁶⁹ These models offer valuable insights for maintaining DIB resilience while achieving cost efficiencies in defense manufacturing.

Digital Twins and Testing Infrastructure

The testing and validation of AS&R represents a critical capability for peacetime development and wartime adaptation. NVIDIA emphasized that, in the future, engineers must

⁶⁷ Discussion with defense manufacturing firm, April 2025.

⁶⁸ Discussion with UAS defense firm representatives, March 2025.

⁶⁹ Discussion with HDT Global and Daedong representatives, January and April 2025.

rely heavily on digital twin testing to refine systems without exposing physical prototypes to adversarial observation.⁷⁰ However, the industrial base and government testing facilities have not yet developed the necessary infrastructure to support this approach.

An FFRDC identified the need for standardized testing protocols and environments for autonomous systems, particularly for validating performance in contested or degraded conditions.⁷¹ The organization's work on common test frameworks highlights how coordinated testing infrastructure could accelerate capability development while ensuring interoperability across platforms and systems.

NVIDIA has made significant investments in simulation capabilities through its Omniverse platform, which enables the creation of digital twins for testing autonomous systems across virtual environments.⁷² The company's approach demonstrates how commercial technologies could support defense requirements for secure testing and validation. However, questions remain about aligning commercial simulation priorities with military testing needs. Building upon the analysis of stakeholder interests in the AS&R industry, the following section applies Porter's Five Forces framework to examine the industry landscape's competitive dynamics.

⁷⁰ Discussion with NVIDIA representatives, April 2025.

⁷¹ Discussion with FFRDC representatives, March 2025.

⁷² Discussion with NVIDIA representatives, April 2025.

ANALYSIS

INDUSTRY STRUCTURE AND COMPETITIVE FORCES

Market structure and competitive forces heavily shape the AS&R industry.⁷³ The highly concentrated market structure is a defining feature, especially in the U.S., where post-Cold War consolidation reduced dozens of defense contractors to only a few prime firms. This consolidation, combined with the high costs and specialized expertise required to develop advanced autonomous systems, raises significant barriers to entry for new firms.⁷⁴ Moreover, the defense market's limited production quantities and complex acquisition bureaucracy discourage small startups and non-traditional tech companies from entry.⁷⁵ The industry's structure is oligopolistic, with a few dominant firms and high entry hurdles, causing implications for competition and innovation.

The role of government as the primary buyer is another critical structural factor. Defense autonomy markets often function as a monopsony with a single-customer market dominated by government procurement, shaping profitability and firm behavior.⁷⁶ With the DoD setting requirements and controlling demand, firms have limited leverage. Government buyers push for cost efficiency and standardization, which can squeeze industry margins and reduce incentives for firms to invest aggressively in innovation. The bargaining power of buyers is thus very high.

⁷³ Porter, Michael E. "The Five Competitive Forces That Shape Strategy." Harvard Business Review. January 2008. <https://hbr.org/2008/01/the-five-competitive-forces-that-shape-strategy>.

⁷⁴ Lopez, C. Todd. "DOD Report: Consolidation of Defense Industrial Base Poses Risks to National Security." U.S. Department of Defense. 2022. <https://www.defense.gov/News/News-Stories/Article/Article/2937898/dod-report-consolidation-of-defense-industrial-base-poses-risks-to-national-sec/>.

⁷⁵ Walker, Dinah. "Trends in U.S. Military Spending." Council on Foreign Relations. 2014. <https://www.cfr.org/report/trends-us-military-spending>.

⁷⁶ Valerie Insinna, Valerie. "'I Don't See It': Before Their CCA Drones Even Take to the Air, Anduril and General Atomics Trade Shots." Breaking Defense. September 26, 2024. <https://breakingdefense.com/2024/09/i-dont-see-it-before-their-cca-drones-even-take-to-the-air-anduril-and-general-atomics-trade-shots/>; Honrada, Gabriel. "Drones Alone Won't Solve U.S. Navy's China Problem." Asia Times. 2024. <https://asiatimes.com/2024/11/drones-alone-wont-solve-us-navys-china-problem/#>; Hanninamane, Aditi. "The Evolution of Underwater Drones: A Pivotal Aspect in Future Warfare." Centre For Security and Strategy Studies. 2024. <https://www.cescube.com/vp-the-evolution-of-underwater-drones-a-pivotal-aspect-in-future-warfare>.

In the U.S., the DoD's budget decisions and procurement strategies determine which projects thrive. Even in allied nations or commercial spin-offs, export controls (e.g., ITAR) further constrain market size by limiting international sales of sensitive systems.⁷⁷ Conversely, U.S. strategic competitors like China rely on state-driven demand to shape their domestic industry. China's centralized military procurement and civil-military fusion policies make the state the chief investor and customer for indigenous autonomous systems.⁷⁸ A government-led architecture would take advantage of the buyer power and lower the barriers for potential market entrants.

In contrast, the bargaining power of suppliers in AS&R is moderate but growing in importance. The industry depends on specialized components such as semiconductors, lithium-based batteries, advanced sensors, and AI processors, often sourced from a limited number of global suppliers. Many of these critical components come from or rely on supply chains in rival nations (for instance, rare earth elements and battery cells sourced mainly from China), creating strategic vulnerabilities.⁷⁹ Any disruption, whether a trade restriction or conflict, could hamper production. Additionally, the rapid growth of AI and robotics has increased demand for skilled labor (scene renderers, engineers, roboticists, and machinists) that outstrips supply.⁸⁰ This labor shortage endows specialized talent and component suppliers with greater power. Firms are attempting to mitigate these supply-side risks through vertical integration or alliances; for

⁷⁷ International Trade Administration. "U.S. Export Controls." U.S. Department of Commerce. Accessed April 28, 2025. <https://www.trade.gov/us-export-controls>.

⁷⁸ U.S. Department of State. "Military Civil Fusion and the People's Republic of China." Accessed April 28, 2025. <https://www.state.gov/wp-content/uploads/2020/05/What-is-MCF-One-Pager.pdf>

⁷⁹ Interviews with U.S.-based manufacturers, March-April, 2025; Wilson, Bradley et al. "Characterizing the Uncrewed Systems Industrial Base." RAND Corporation. April 26, 2023. https://www.rand.org/pubs/research_reports/RRA1474-1.html.

⁸⁰ Council of Economic Advisors. "AI Talent Report." Washington, DC: White House, January 14, 2025. <https://bidenwhitehouse.archives.gov/cea/written-materials/2025/01/14/ai-talent-report/>.

example, U.S. company Anduril partnered with South Korea's Hanwha to secure battery and drivetrain technology for ground robots.⁸¹ While suppliers do not dictate terms to the same degree as the buyers, supply chain constraints and talent scarcity moderate the industry's growth and raise costs. Automation and robotics can certainly help alleviate some of these challenges. However, one robotics manufacturer we spoke with emphasized that the approach takes a significant amount of time and money, and their company takes a deliberate approach in deciding on implementing automated and robotic manufacturing capabilities.⁸²

The intensity of competitive rivalry in the AS&R industry is a paradox: at one level, rivalry is limited by market structure, but at another, it escalates globally. In the U.S. market, a small number of incumbents (legacy defense primes and a few well-funded new entrants) compete for large military programs, which can result in fierce winner-takes-all contract competitions but relatively few players. Once the government "down-selects" a prime contractor for a major system, rivalry temporarily decreases as the winner dominates production. For example, the U.S. Navy recently chose a single firm (Boeing) for its next-generation UAS program.⁸³ Such down-selections, aimed at efficiency, can reduce longer-term innovation and industrial resilience. Globally, however, rivalry is intensifying: China and Russia's rapid advancements in uncrewed systems development have spurred a technology race. China's defense industry, buoyed by massive state investment and a vast manufacturing base, fields an

⁸¹ Mehta, Aaron. "Anduril, Hanwha Team for Army's S-MET Robot Transport Competition." *Breaking Defense*. February 29, 2024. <https://breakingdefense.com/2024/02/anduril-hanwha-team-for-armys-s-met-robot-transport-competition/>.

⁸² Discussion with multi-domain robotics firm, April 2025.

⁸³ Anduril Industries. "Anduril Selected for U.S. Air Force Collaborative Combat Aircraft Program." April 24, 2024. <https://www.anduril.com/anduril-air-force-collaborative-combat-aircraft-CCA/>; Hill, John. "USAF Selects Anduril and General Atomics as CCA Vendors." *Airforce Technology*. April 25, 2024. <https://www.airforce-technology.com/news/usaf-selects-anduril-and-general-atomics-as-cca-vendors/>; Mordor Intelligence. "Unmanned Aerial Vehicles Market Size," Accessed April 20, 2025. <https://www.mordorintelligence.com/industry-reports/uav-market>.

expanding array of drones and robotic vehicles, directly challenging U.S. technological dominance.⁸⁴ Despite economic constraints, Russia has deployed armed robotic vehicles (like the Uran-9 and Marker UGVs) in conflict zones to demonstrate and refine its capabilities.⁸⁵ Furthermore, several U.S. allies and smaller states contribute to competitive rivalry by developing niche autonomous platforms (for instance, Estonia's Milrem THeMIS UGV and Israel's armed border robots) that sometimes outpace U.S. development.⁸⁶ This broader competitive landscape creates a high level of rivalry in strategic terms, even if the government carefully manages competition for contracts at the firm level. Each country views autonomous systems as critical to the future of military power, fueling a race to innovate and deploy these technologies.

The threat of new entrants in the AS&R industry remains relatively low, yet not negligible. High upfront R&D costs, lengthy development timelines, and the need to navigate military procurement processes create substantial barriers to entry for startups.⁸⁷ Incumbent firms

⁸⁴ Blanchette, Jude, Briana Bolandq, and Lily McElwee. "What Is Beijing's Timeline for 'Reunification' with Taiwan?" Center for Strategic & International Studies. Interpret: China, May 26, 2023. <https://interpret.csis.org/what-is-beijings-timeline-for-reunification-with-taiwan/>; Barrie, Douglas. "It's Not Your Father's PLAAF: China's Push to Develop Domestic Air-to-Air Missiles." War on the Rocks. February 21, 2018. <https://warontherocks.com/2018/02/not-fathers-plaaf-chinas-push-develop-domestic-air-air-missiles/>; Saballa, Joe. "China Develops Own 'Loyal Wingman' to Rival US." The Defense Post. December 16, 2024. <https://thedefensepost.com/2024/12/16/china-loyal-wingman-us/>; Sato, Daisuke. "China Works on Urban Combat Robot." Defence Blog. January 13, 2024. <https://defence-blog.com/china-works-on-urban-combat-robot/>; Staff Writer With AFP. "China Shows off Robot 'Dogs of War' in Cambodia Drills." The Defense Post. May 16, 2024. <https://thedefensepost.com/2024/05/16/china-robot-dogs-of-war/>.

⁸⁵ Bendett, Samuel. "Strength in Numbers: Russia and the Future of Drone Swarms." Modern War Institute at West Point. April 20, 2021. <https://mwi.westpoint.edu/strength-in-numbers-russia-and-the-future-of-drone-swarms/>; Bendett, Samuel. "Russia's Artificial Intelligence Boom May Not Survive the War." Defense One. April 15, 2022. <https://www.defenseone.com/ideas/2022/04/russias-artificial-intelligence-boom-may-not-survive-war/365743/>; Kallenborn, Zachary and Marcel Plichta. "Release the Robot Hounds: Providing Unmanned Ground Vehicles to Ukraine." Center for Strategic and International Studies. April 3, 2023. <https://www.csis.org/analysis/release-robot-hounds-providing-unmanned-ground-vehicles-ukraine>.

⁸⁶ Santos, Tamiris. "Milrem Robotics Reveals Armed UGV to Be Supplied to Ukraine and Teases Launch of 8x8 RCV." Janes. January 27, 2025. <https://www.janes.com/osint-insights/defence-news/land/milrem-robotics-reveals-armed-ugv-to-be-supplied-to-ukraine-and-teases-launch-of-88-rcv>.

⁸⁷ Mordor Intelligence, "Unmanned Aerial Vehicles Market Size."

maintain advantages in manufacturing capacity, regulatory expertise, and existing relationships.⁸⁸ Nevertheless, the emerging dual-use nature of robotics and AI opened doors for non-traditional entrants through partnerships and acquisitions. In recent years, venture-backed firms like Shield AI and Anduril entered the defense market with innovative AI software and uncrewed platforms, often teaming with established defense contractors or foreign partners to bolster their credibility and production capabilities.⁸⁹ U.S. allies also serve as entry points: collaborations such as General Atomics teaming with South Korea's Hanwha to co-produce aerial drones exemplify how international partnerships can build new industrial capacity.⁹⁰ Still, given the dominance of a few players and tight government oversight, new entrants face an uphill battle unless they bring a unique capability, benefit from direct government sponsorship, or receive significant funding support from revenue streams such as venture capital.

Finally, the threat of substitutes for advanced AS&R is generally low in the defense context. No close substitute exists that can replicate the force-multiplying effects of autonomous platforms without incurring significant disadvantages. Traditional crewed military platforms or human labor can fill some roles at greater risk and often at higher long-term costs. For example,

⁸⁸ Pettyjohn, Stacie, Hannah Dennis, and Molly Campbell. "Swarms over the Strait: Drone Warfare in a Future Fight to Defend Taiwan." Center for New American Security. June 20, 2024; Defense Innovation Unit. "Replicator." Defense Innovation Unit. Accessed February 12, 2025. <https://www.diu.mil/replicator>; Oliver, Matt. "How the 'Elon Musk of missiles' is plotting to blow up the defence industry." The Telegraph. October 5, 2024; U.S. Department of Defense. National Defense Industrial Strategy. 2023; Allen, Greg and Isaac Goldston. "The Department of Defense's Collaborative Combat Aircraft Program: Good News, Bad News, and Unanswered Questions." Center for Strategic and International Studies. August 6, 2024. <https://www.csis.org/analysis/departments-defenses-collaborative-combat-aircraft-program-good-news-bad-news-and>.

⁸⁹ Anduril Industries. "HD Hyundai and Anduril Industries Announce Strategic Partnership on Maritime Systems, Autonomy and Mass Manufacturing." April 13, 2024. <https://www.anduril.com/article/hd-hyundai-and-anduril-industries-announce-strategic-partnership-on-maritime-systems-autonomy/>; Biesecker, Cal. "Booz Allen, Shield AI Partner On Autonomous Solutions For U.S. Military." Defense Daily. March 18, 2025. <https://www.defensedaily.com/booz-allen-shield-ai-partner-on-autonomous-solutions-for-u-s-military/business-financial/>.

⁹⁰ General Atomics. "GA-ASI Inks Collaboration Deal With South Korea's Hanwha." Accessed April 17, 2025. <https://www.ga.com/ga-asi-inks-collaboration-deal-with-south-korea-hanwha>.

legacy crewed and uncrewed systems cannot survive against modern air defenses or cover the vast distances required in a potential Indo-Pacific conflict, making them poor substitutes for next-generation autonomous drones.⁹¹ Similarly, using soldiers for tasks that robots could do (like explosive ordnance disposal or high-risk reconnaissance) exposes personnel to danger, an increasingly unacceptable risk when uncrewed alternatives exist.⁹² While space-based assets or cyber operations might accomplish some missions (instead of physical drones), these have limitations and often complement rather than replace autonomous vehicles.⁹³ In sum, the industry's products occupy a unique and growing role in military operations, meaning the incentive to develop true substitutes is low; the focus is on improving autonomous systems.

These forces shape an industry environment where profitability and innovation are tightly coupled to government decisions and great-power competition. Notably, across uncrewed aerial, ground, and maritime domains, the two strongest forces are the power of the government buyer and the degree of competitive rivalry.⁹⁴ The government buyer's significant influence over the market determines product pricing and can potentially limit profit margins artificially. Concurrently, the existential need to stay ahead of rival nations drives firms (and governments) to invest in new capabilities despite limited short-term profits. This dynamic significantly affects how firms behave and how well the industry supports national security goals.

⁹¹ Seligman, Lara. "With an Eye Toward China, Pentagon Weighs Slashing Global Hawk Drone." *Foreign Policy*. November 18, 2019. <https://foreignpolicy.com/2019/11/18/china-pentagon-global-hawk-drone/>.

⁹² Mordor Intelligence, "Unmanned Aerial Vehicles Market Size."

⁹³ Magnuson, Stew. "Army Envisions Legions of Autonomous Logistics Robots to Deliver Supplies." *National Defense Magazine*. February 27, 2024.

⁹⁴ Seligman, "With an Eye Toward China, Pentagon Weighs Slashing Global Hawk Drone."

POLICY RECOMMENDATIONS

To harness the full potential of AI, autonomy, and robotics, the U.S. government must improve how it buys, not just what it buys. The DoD must act as a smarter customer that rewards innovation, reduces friction, and sends clear, predictable market signals. Rather than trying to control outcomes, DoD should create the conditions for private industry to succeed within a free market economy. This section answers the central task: accelerating the fielding of AS&R while rebuilding an industrial base that can outpace China.

These recommendations propose targeted, actionable reforms maximizing existing authorities. They focus on four strategic priorities: seeding domestic suppliers, removing acquisition barriers that block private investment, enforcing technical standards that drive interoperability and trust, and mandating modular open systems to promote interoperability, flexibility, and competition. These actions enable DoD to shape demand, reduce investment risk, and strengthen the national security innovation base. Appendix C offers additional recommendations addressing workforce constraints, test infrastructure, and scaling challenges.⁹⁵

Table 4 - Summary of Recommendations

Recommendation	Responsible Office(s)
Use DoD Contracts to Seed Domestic Robotics Suppliers	SECDEF; OUSD(A&S)
Modernize ITAR for Allied Co-Production	DoS (DDTC); USD (A&S); BIS
Reform Facility Clearance Eligibility	DCSA; OUSD(A&S)
Modernize Profit Policy	OUSD(A&S) Principal Director, Defense Pricing and Contracting (DPC)
Establish National and Military AS&R Standards	NIST; Joint Staff (J6/J7/J8); USD(R&E); DoD CIO; CDAO Supporting: ANSI, Industry Partners, Allied Nations
Adopt MOSA as the Default for AS&R	USD(A&S); USD(R&E); CDAO; SAEs

⁹⁵ Association for Advancing Automation. "A3 Policy Recommendations and Advocacy Principles for the U.S." 2023. <https://www.automate.org/a3/advocacy-principles>.

REFORM TO SECURE ROBOTICS SUPPLY CHAINS

Use DoD Contracts to Seed Domestic Robotics Suppliers

Table 5 - Details to Support Recommendation to Use DoD Contracts to Seed Domestic Robotics Suppliers

Action	Leverage DoD’s procurement power to seed and secure U.S. and allied critical robotics components and systems suppliers.
Responsible Office(s) or Individual(s)	<ul style="list-style-type: none"> • SECDEF • OUSD(A&S)

Rationale - As detailed in the industry analysis, persistent reliance on foreign suppliers for rare earth components and semiconductors poses a critical vulnerability.⁹⁶ Building on successful models like Blue UAS and magnet re-shoring, cut lead times by 80% and enabled \$100 million in secure drone buys.⁹⁷

DoD should insert domestic sourcing requirements or incentives in AS&R contracts (e.g., “Buy American” provisions) and use multiyear procurement to justify supplier capital investment. It should also expand the use of DPA Title III and reprioritize IBAS funds for sensors, actuators, and advanced batteries.⁹⁸ DoD can run competitions, fund winners, and follow through with volume purchases.⁹⁹ Applying this approach to emerging AS&R will give suppliers the confidence to manufacture in America. Using its procurement power strategically, the DoD

⁹⁶ Tadjdeh, Yasmin. “Viewpoint: China Solidifies Dominance in Rare Earth Processing.” National Defense Magazine. March 21, 2019.

⁹⁷ Defense Innovation Unit. “Blue UAS Cleared List – FAQ.” U.S. Department of Defense. Updated April 2025. <https://www.diu.mil/blue-uas-cleared-list>; Biesecker, Calvin. “Limited Resources Limit DIU’s Ability To Clear Commercial Drones For DoD, Industry Official Says” Avionics International. April 3, 2025.

<https://www.aviationtoday.com/2025/04/03/limited-resources-limit-dius-ability-to-clear-commercial-drones-for>.
⁹⁷ Office of Industrial Policy. “Fiscal Year 2022 Industrial Capabilities Report to Congress.” U.S. Department of Defense. July 12, 2022. <https://media.defense.gov/2022/Jul/12/2003039820/-1/-1/1/FY22-INDUSTRIAL-CAPABILITIES-REPORT.PDF>.

⁹⁸ Office of the Under Secretary of Defense for Acquisition and Sustainment. “Industrial Base Analysis and Sustainment (IBAS) Program Overview.” U.S. Department of Defense. Accessed April 28, 2025. <https://www.businessdefense.gov/ibr/ibas.html>.

⁹⁹ Defense Innovation Unit. “Blue UAS Framework 2.0. U.S. Department of Defense. Accessed May 5, 2025. <https://www.diu.mil/blue-uas>.

can close supply chain gaps and reinforce a more self-sufficient and resilient DIB.¹⁰⁰

Resources Required - Reallocate DPAAIII and IBAS resources to prioritize AS&R manufacturing. Designate critical components for investment through guidance from the Secretary or USD(A&S). Manage AS&R projects with current funding, DIB initiatives, and the Defense Innovation Unit (DIU) using competitions, agreements, and supplier development. Integrate procurement incentives into programs via service acquisition executives (SAE) directives. Enhance AS&R supply chain resilience using existing DoD authorities and budgets.

ACQUISITION REFORMS TO STRENGTHEN INDUSTRY PARTICIPATION AND PRIVATE INVESTMENT

To maintain a competitive edge in AS&R, the DoD must address longstanding acquisition barriers that deter private-sector participation and limit industrial mobilization. This section presents three interdependent reform initiatives: streamlining export licensing under ITAR, revising FCL eligibility to enable earlier industry engagement, and modernizing profit policy to incentivize private-sector investment in defense-relevant technologies. These actions strengthen the DIB, improve access to innovative capabilities, and ensure the Department can respond to urgent needs quickly.

Modernize ITAR to Accelerate Allied Co-Production and Export Licensing

Table 6 - Details to Support Recommendation for ITAR Modernization

Action	Reform ITAR to streamline export licensing for allied co-production.
Responsible Office(s) or Individual(s)	<ul style="list-style-type: none"> • Department of State (DDTC) • USD(A&S), Office of Industrial Policy) • Department of Commerce (BIS)

¹⁰⁰ Association for Advancing Automation, "A3 Policy Recommendations and Advocacy Principles for the U.S."

Rationale - The Department of State's (DoS) Directorate of Defense Trade Controls (DDTC) administers ITAR under the authority of the Arms Export Control Act (AECA), which governs the export of defense articles and technical data to safeguard national security and foreign policy interests.¹⁰¹ However, the current regulatory framework creates delays and uncertainty that inhibit the DoD's ability to scale production in coordination with allies. Government-imposed licensing requirements restrict the timely exchange of controlled technologies, even with close partners, which undermines co-production agreements and weakens allied interoperability.

Additionally, overlapping export control jurisdiction with the Department of Commerce through the Export Administration Regulations (EAR), which govern dual-use technologies, adds another layer of complexity to the industrial mobilization process.¹⁰² These regulatory challenges create the most significant obstacles during time-sensitive situations, such as surge production or contingency operations. Reforming ITAR to enable clearer, faster licensing pathways, including pre-approved lists for key allies, would strengthen collective security and support the objectives in the National Defense Strategy and Executive Order 14017 on America's Supply Chains.¹⁰³ Congress codified this approach in the FY2023 NDAA by

¹⁰¹ U.S. Department of State. *22 CFR Parts 120–130: International Traffic in Arms Regulations (ITAR)*, under the authority of the Arms Export Control Act (AECA), 22 U.S.C. § 2751 et seq., <https://www.ecfr.gov/current/title-22/chapter-I/subchapter-M>.

U.S. Congress. *Arms Export Control Act*, Pub. L. No. 90-629, 82 Stat. 1320 (1968), codified as amended at 22 U.S.C. § 2751 et seq., <https://www.govinfo.gov/content/pkg/USCODE-2022-title22/html/USCODE-2022-title22-chap39.htm>.

¹⁰² Bureau of Industry and Security. *Export Administration Regulations (EAR)*, 15 CFR Parts 730–774. U.S. Department of Commerce. <https://www.ecfr.gov/current/title-15/subtitle-B/chapter-VII/subchapter-C>.

¹⁰³ Biden, Joseph R, Jr. “Executive Order 14017 of February 24, 2021: America's Supply Chains.” Code of Federal Regulations, title 3 (2021): 11849–11854. <https://www.federalregister.gov/documents/2021/03/01/2021-04280/americas-supply-chains>.

authorizing ITAR exemptions for Australia and the United Kingdom under AUKUS, laying the groundwork for faster technology transfer with trusted partners.¹⁰⁴

Effective ITAR reform requires coordinated action across agencies. The DoS should create fast-track licensing pathways and pre-approved export lists, while the DoD should identify priority technologies for export. BIS should harmonize dual-use export policies, and the National Security Council (NSC) should oversee interagency coordination.

The responsible agencies should develop an integrated digital platform for license tracking and secure data exchange. Training managers must ensure that acquisition and security cooperation professionals learn updated export processes and technology-sharing mechanisms. Interagency working groups can support implementation without significant new appropriations. Congressional liaison offices should prepare for necessary statutory clarifications or international agreement updates.

In coordination with the DoD and NSC, the DoS should reform ITAR for predictable licensing for allied co-production and data sharing, including creating pre-approved technology lists and integrating reforms into industrial mobilization planning.

Reform Facility Clearance Eligibility

Table 7- Details to Support Recommendation to Reform Facility Clearance Eligibility

Action	Revise FCL eligibility policies to enable interim sponsorship of firms with validated defense relevance before contract award.
Responsible Office(s) or Individual(s)	<ul style="list-style-type: none"> • DCSA • OUSD(A&S)

¹⁰⁴ McPherson, James E. “Implementation of ITAR Exemptions Under AUKUS.” Testimony before the House Foreign Affairs Committee, Subcommittee on Oversight and Accountability. March 2024. <https://foreignaffairs.house.gov/>.

Rationale - The DoD should revise FCL eligibility policies to enable interim sponsorship of firms with validated defense relevance before contract award. To ensure strategic alignment with DoD priorities, DoD should begin eligibility with firms participating in established innovation initiatives, such as the SBIR program and Tech Bridges.¹⁰⁵ Afterward, the DoD should expand eligibility to firms that are developing priority technologies through department-level critical technology lists and modernization roadmaps.

Required Resources: Modifying FCL eligibility requirements will require additional personnel at the Defense Counterintelligence and Security Agency (DCSA) to process FCL requests.

OUSD(A&S) must set formal criteria and controls to ensure defense relevance before contract awards. DoD must update the Defense Information System for Security (DISS), policy guidance, and training materials to enforce the new pathway. Program offices can integrate some adjustments into existing cycles but will need dedicated funding to manage the increased workload, system changes, and stakeholder engagement during the transition.

Service component acquisition activities can use Cooperative Research and Development Agreements (CRADAs) under 32 C.F.R. § 117 as an interim solution. CRADAs let firms show their technical skill on real projects that can lead to an FCL if the commercial entity meets all requirements and has facility clearance sponsorship from a Contract Security Administration, such as the DoD. The DoD can work with firms on unclassified or controlled unclassified information (CUI) projects, then determine their need for clearance without funding an R&D contract, allowing firms to showcase capabilities without accessing classified information.

¹⁰⁵ U.S. Small Business Administration. "Small Business Innovation Research (SBIR) Program." Accessed April 29, 2025. <https://www.sbir.gov/about>.
NavalX. "Tech Bridges Overview." U.S. Department of the Navy. Accessed April 29, 2025. <https://www.secnav.navy.mil/agility/Pages/techbridges.aspx>.

Modernize Profit Policy to Incentivize Private Sector Co-Investment

Table 8 - Details to Support Recommendation to Modernize Profit Policy to Incentivize Private Sector Co-Investment

Action	Revise the weighted guidelines profit policy (DFARS 215.404-71) ¹⁰⁶ to authorize higher profit objectives when contractors invest significant private capital in early-stage R&D or prototype defense-relevant technologies.
Responsible Office(s) or Individual(s)	<ul style="list-style-type: none"> • OUSD(A&S) Principal Director, Defense Pricing and Contracting (DPC)

Rationale - As discussed in the Industry Analysis section, structural barriers and low defense margins limit new market entrants. To address this, the DoD should revise DFARS 215.404-71¹⁰⁷ to authorize higher profit objectives when firms use private capital for early-stage defense-relevant development. Aligning profit policy with commercial expectations can attract co-investment, reduce reliance on traditional primes, and boost innovation. DIU's 2022 report noted that the DoD's restrictive profit policy hindered venture-funded firms seeking returns over 12%, which exceeded DoD limits. Updating profit policy to incentivize private investment in early-stage R&D could align industry goals with national security, supporting DoD's resilient defense industrial base.¹⁰⁸

Resources Required - OUSD(A&S), through its DPC office, must assign policy staff to revise DFARS 215.404-71 and develop guidance that formally recognizes higher profit objectives tied to private investment in early-stage R&D and prototyping. DPC must coordinate with SAEs to update internal pricing templates and evaluation criteria, ensuring consistent application across contracting commands. The Defense Contract Audit Agency (DCAA) may require updated audit

¹⁰⁶ U.S. Department of Defense. "Defense Federal Acquisition Regulation Supplement (DFARS), Procedures, Guidance, and Information 215.404-71—Weighted Guidelines Method." Accessed April 29, 2025. <https://www.acquisition.gov/dfars/part-215-contracting-pricing#DFARS-215.404-71>.

¹⁰⁷ U.S. Department of Defense, "Defense Federal Acquisition Regulation Supplement (DFARS), Weighted Guidelines Method."

¹⁰⁸ Defense Innovation Unit. "Annual Report FY2022." U.S. Department of Defense. 2023. <https://www.diu.mil/library/annual-reports>.

procedures and training to assess private capital contributions under the new policy. Acquisition training organizations, including the Defense Acquisition University (DAU), must incorporate the revised profit guidance into mandatory training programs for contracting officers and pricing analysts. While much of this work can align with existing update cycles, DoD will need to dedicate additional staff time and targeted training resources to ensure a smooth transition and prevent implementation delays. With these resources in place, DoD can proceed with the steps needed to implement the revised policy.

To implement this reform, OUSD(A&S) DPC should draft updated policy language, revise DFARS 215.404-71, and issue clear guidance on evaluating private capital contributions. DPC must also update internal pricing tools and coordinate with the services to ensure consistent application across contracting activities. Contracting commands should train personnel on the revised criteria and apply sound judgment when setting profit objectives tied to investment risk. Acquisition leadership must ensure the revised policy is used as intended—to strengthen the industrial base, encourage innovation, and accelerate the delivery of critical defense capabilities.

ESTABLISH DOD-WIDE STANDARDS FOR AS&R AND MODULAR OPEN SYSTEMS

The DoD must act decisively to establish unified safety, cybersecurity, and interoperability standards for AS&R. Without clear technical thresholds and consistent acquisition practices, the Department will fragment capabilities, delay fielding, and weaken industrial competitiveness. The following recommendations propose the development of national and military-specific standards, coupled with mandatory adoption of MOSA, to ensure rapid, secure, and interoperable integration of autonomous technologies into the future force.

Establish National and Military Safety, Performance, and Interoperability Standards

Table 9 - Details to Support Recommendation to Establish National and Military Safety, Performance, and Interoperability Standards

Action	Establish National and Military Safety, Performance, and Interoperability Standards
Responsible Office(s) or Individual(s)	<ul style="list-style-type: none"> • National Institute of Standards and Technology (NIST) • Joint Staff (J6/J7/J8) • Office of the Under Secretary of Defense for Research and Engineering (USD(R&E)) • DoD Chief Information Officer (CIO) • CDAO
Supporting Office(s)	<ul style="list-style-type: none"> • American National Standards Institute (ANSI) • Industry partners • Allied nations

Rationale - As the Strategic Environment section outlines, fragmented technical standards and vague interoperability requirements hinder integration across the AS&R ecosystem. To address this, Congress should direct NIST and DoD to accelerate the creation of enforceable national and military-specific standards. These standards should cover safety, cybersecurity, HMT, and data interfaces, with acquisition offices embedding them into program requirements and certification protocols.

Congress should use the NDAA to direct NIST and DoD to establish national and military standards for AS&R, focusing on safety, cybersecurity, data exchange, and performance thresholds. USD(R&E), the Joint Staff (J7/J8), and CDAO should define military-specific reference architectures and interface requirements. Acquisition offices should incorporate these standards into solicitations and enforce them using MOSA-aligned interface control documents and verification protocols. NIST and ANSI should coordinate with industry to align standards with commercial practices, while DoD works with NATO and Five Eyes partners to promote

allied interoperability. These steps fulfill DoD’s obligation under 10 U.S.C. § 4401 to define enforceable interface standards for MOSA-compliant systems.¹⁰⁹

Adopt MOSA as the Default for AS&R

Table 10 - Details to Support Recommendation to Adopt MOSA as the Default for AS&R

Action	Mandate MOSA as the default acquisition and design strategy for all AS&R
Responsible Office(s) or Individual(s)	<ul style="list-style-type: none"> • USD(A&S) • USD(R&E) • CDAO • SAEs

Rationale - As discussed in the industry analysis section, fragmented architectures and closed vendor ecosystems limit competition and delay capability integration. MOSA addresses these issues by enabling programs to adopt open interface standards, promote cross-vendor interoperability, and accelerate upgrades without requiring complete system redesigns. Programs like the OMFV, aimed at replacing the M2 Bradley Infantry Fighting Vehicle, and the Navy’s USV are adopting MOSA mandates.¹¹⁰ However, GAO reports show inconsistent enforcement. Applying MOSA as a standardized framework enforced through interface testing and certification could reduce lock-in and speed up modular upgrades. These priorities align with Executive Order 13806, which promotes modular systems and rapid innovation adoption.¹¹¹

¹⁰⁹ U.S. Code. Title 10, § 4401 – Modular Open System Approach in Development of Weapon Systems. <https://www.law.cornell.edu/uscode/text/10/4401>.

¹¹⁰ U.S. Department of the Army. “Army Announces Contract Awards for Optionally Manned Fighting Vehicle.” June 26, 2023. https://www.army.mil/article/267920/army_announces_contract_awards_for_omfv.
U.S. Department of the Navy. “U.S. Navy Completes Final Testing Milestone for Unmanned Surface Vessel Program.” January 10, 2025. <https://www.navy.mil/Press-Office/News-Stories/Article/4011047/us-navy-completes-final-testing-milestone-for-unmanned-surface-vessel-program/>.

¹¹¹ Trump, Donal J. “Executive Order No. 13806: Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States.” 82 Fed. Reg. 34,779. July 26, 2017.

The DoD can accelerate capability delivery and cut costs by establishing clear technical standards and co-developing civil-military guidelines. The MOSA approach supports these objectives by enabling rapid integration and upgrades while preserving contractor intellectual property. To implement MOSA effectively, DoD must set realistic policy mandates, hold itself accountable for integration, and focus on standardized interfaces. Program offices must avoid forcing modularity when it undermines performance or drives excessive costs.

Clarifying MOSA's Role: DoD should treat MOSA as a strategic acquisition framework, not a rigid architecture. Instead of dictating system design, DoD must evaluate contractors based on their ability to deliver modular, interoperable subsystems that meet open interface standards. DoD must define and verify those interfaces while allowing internal innovation within modules. This balance fosters flexibility and preserves interoperability.

Acquisition officials must prioritize interface control documentation, compatibility testing, and cross-vendor verification, not rely on compliance checklists. MOSA drives competition and adaptability only when DoD enforces meaningful interoperability requirements, not arbitrary modularity metrics. Last, DoD must also protect contractor IP to sustain innovation.

Resources Required - DoD must allocate dedicated resources to implement these reforms. Congress and the Department should fund NIST to lead standards development and coordinate with industry. The Joint Staff (J7/J8) and USD(A&S) must assign additional personnel to manage standard-setting, procurement integration, and certification design. DoD should invest in expanding testing infrastructure and establishing formal certification programs.

The DoD can leverage current resources and interagency groups without new funding. NIST can reassign staff for AI and cybersecurity standards. The DoD should integrate standards development into acquisition reviews and test interoperability at current facilities. Acquisition

leaders must include MOSA training in DAWIA certification courses for proper policy application.¹¹²

¹¹² U.S. Government Accountability Office. "Weapon Systems Annual Assessment: Programs Are Not Consistently Implementing Practices That Can Help Accelerate Acquisitions." GAO-23-106059. June 2023. <https://www.gao.gov/products/gao-23-106059>.

CONCLUSION

The implications of achieving and maintaining a strategic advantage in the AS&R industry are profound. The U.S. is at a crossroads in leveraging the power of the AS&R industry to maintain its competitive and strategic advantage. The U.S. must adopt policies that empower industry success and compel government stakeholders to embrace innovative solutions across three critical areas: enterprise architecture and acquisition, industrial efficiency and policy, and HMT. To drive progress, this paper recommends action in four key areas: (1) reform investment strategies to strengthen the domestic robotics supply chain; (2) streamline acquisition processes and remove classification barriers to increase industry participation and attract private investment; (3) establish DoD-wide standards for AS&R and MOSA; and (4) modernize DoD standards and certifications to embrace software-heavy development efforts such as digital twins as a risk-informed replacement testing methodology rather than an additional requirement.¹¹³

AS&R represents a cornerstone of future military power and an area where technological leadership translates into battlefield superiority. This is a shift of the competition from human manpower to machine intelligence and quantity.¹¹⁴ The country (or coalition) that best harnesses AS&R will attain significant military advantages, such as reduced risk to military personnel, faster decision cycles, and the ability to project power with swarms of expendable systems. For the U.S. and its allies, maintaining an edge will require addressing the weaknesses in their industries' performance, such as improving surge manufacturing capacity, sustaining more competitors to stimulate innovation, and smoothing the path for new technologies from lab to

¹¹³ Cenciotti, David. "Skunk Works' X-56A Poised To Become World's First Digitally-Certified Aircraft" The Aviationist. August 30, 2024. <https://theaviationist.com/2024/08/30/x-56a-digitally-certified/>.

¹¹⁴ Bendett, Samuel. "Strength in Numbers: Russia and the Future of Drone Swarms." Modern War Institute at West Point. April 20, 2021. <https://mwi.westpoint.edu/strength-in-numbers-russia-and-the-future-of-drone-swarms/>; Bendett, Samuel. "Russia's Artificial Intelligence Boom May Not Survive the War." Defense One. April 15, 2022. <https://www.defenseone.com/ideas/2022/04/russias-artificial-intelligence-boom-may-not-survive-war/365743/>.

battlefield.¹¹⁵ Allies like South Korea, Japan, and NATO partners are crucial in this effort; integrating allied production and R&D could help democracies collectively surpass the scale that adversaries such as China can achieve alone.¹¹⁶

Conversely, the PRC's strategic aim to become a "world-class military by 2049" with leading AS&R capabilities means the U.S.-China contest in this industry will likely define the next generation of warfare.¹¹⁷ Beijing's civil-military fusion model seeks to erode America's qualitative lead by unifying academic, commercial, and military resources towards common goals. Therefore, the U.S. must evaluate both how individual firms in this industry perform and how the broader innovation ecosystem functions, especially in comparison to authoritarian competitors. The U.S. holds an edge in many AS&R-related technologies but risks falling behind in speed of deployment and volume. The next five years will be critical as the U.S. Air Force, Navy, and Army actively field CCAs, USVs, and UGVs. These deployments mark key

¹¹⁵ Commission on Planning, Programming, Budgeting, and Execution Reform. "Final Report March 2024." March 2024. https://ppbereform.senate.gov/wp-content/uploads/2024/03/Commission-on-PPBE-Reform_Full-Report_6-March-2024_FINAL.pdf; Stein, Aaron. "You Go to War With the Industrial Base You Have, Not the Industrial Base You Want." War on the Rocks. August 16, 2023. <https://warontherocks.com/2023/08/you-go-to-war-with-the-industrial-base-you-have-not-the-industrial-base-you-want/>; Hanninamane, Aditi. "The Evolution of Underwater Drones: A Pivotal Aspect in Future Warfare." Centre For Security and Strategy Studies. 2024. <https://www.cescube.com/vp-the-evolution-of-underwater-drones-a-pivotal-aspect-in-future-warfare>.

¹¹⁶ Walker, Dinah. "Trends in U.S. Military Spending." Council on Foreign Relations. 2014. <https://www.cfr.org/report/trends-us-military-spending>; U.S. Department of Defense. "National Defense Science and Technology Strategy 2023." 2023. <https://media.defense.gov/2023/May/09/2003218877/-1/-1/0/NDSTS-FINAL-WEB-VERSION.PDF>; Markets and Markets. "Unmanned Underwater Vehicles Market Size, Share, Trends & Growth." 2024. <https://www.marketsandmarkets.com/Market-Reports/unmanned-underwater-vehicles-market-140710720.html>

¹¹⁷ U.S. Department of State, "Military Civil Fusion and the People's Republic of China.," Garamone, Jim. "DOD Report Details Chinese Efforts to Build Military Power." U.S. Department of Defense. 2023. <https://www.defense.gov/News/News-Stories/Article/Article/3562442/dod-report-details-chinese-efforts-to-build-military-power/>; Jiang, Ben. "China's own Tesla Optimus? Beijing's ambitions in humanoid robots in full display at expo." South China Morning Post. August 23, 2024. <https://www.scmp.com/tech/tech-trends/article/3275609/chinas-own-tesla-optimus-beijings-ambitions-humanoid-robots-full-display-expo>; Stokes, Jacob. "Military Artificial Intelligence, the People's Liberation Army, and U.S.-China Strategic Competition." Center for a New American Security. February 1, 2024. <https://www.cnas.org/publications/congressional-testimony/military-artificial-intelligence-the-peoples-liberation-army-and-u-s-china-strategic-competition>.

milestones to test whether the Western AS&R industry can overcome structural constraints and deliver autonomy at scale.¹¹⁸

¹¹⁸ Du, Jacqueline et al. “Global Automation: Humanoid Robots – The AI Accelerant.” Goldman Sachs. January 2024. <https://www.goldmansachs.com/pdfs/insights/pages/gs-research/global-automation-humanoid-robot-the-ai-accelerant/report.pdf>; Li, Qiaoyi and Kevin Krolicki. “China’s Robot Makers Chase Tesla to Deliver Humanoid Workers.” Reuters. August 23, 2024. <https://www.reuters.com/technology/chinas-robot-makers-chase-tesla-deliver-humanoid-workers-2024-08-23/>; Atkinson, Robert D. “How Innovative Is China in the Robotics Industry?” Information Technology and Innovation Foundation. March 2024. <https://www2.itif.org/2024-chinese-robotics-innovation.pdf>; Huld, Arence. “Investing in the Future: Opportunities in China’s Humanoid Robotics and Embodied AI Industry.” China Briefing. April 2025. <https://www.china-briefing.com/news/chinese-humanoid-robot-market-opportunities/>; U.S. Department of Defense. “Military and Security Developments Involving the PRC.”. 2024. <https://media.defense.gov/2024/Dec/18/2003615520/-1/-1/0/MILITARY-AND-SECURITY-DEVELOPMENTS-INVOLVING-THE-PEOPLES-REPUBLIC-OF-CHINA-2024.PDF>; Black, James et al. “Strategic competition in the age of AI: Emerging risks and opportunities from military use of artificial intelligence.” RAND Corporation. September 6, 2024. https://www.rand.org/pubs/research_reports/RRA3295-1.html; Dew, Nicholas and Ira Lewis. “U.S. Defense Innovation and Industrial Policy: An Assessment of Where Things Currently Stand.” Naval Postgraduate School. August 1, 2024. <https://nps.edu/web/ddm/-/defense-innovation>; Fieckert, Andrew. “The Army’s Robotic Combat Vehicle (RCV) Program.” Congressional Research Service. January 16, 2025. <https://www.congress.gov/crs-product/IF11876>; Hearing Before the Committee on Armed Services. “Emerging Technologies and Their Impact on National Security.” United States Senate One Hundred Seventeenth Congress, First Session, S. HRG. 117–148, February 23, 2021.

APPENDIX A – AI IMPACTS ON AS&R

Artificial intelligence (AI) is critical to the AS&R industry, allowing these systems to perceive, reason, plan, and act independently or semi-independently. AI impacts the AS&R industry based on system tasks and functions in five primary modalities: (1) perception and sensing; (2) decision-making and planning; (3) control and actuation; (4) communication and collaboration; and (5) maintenance and predictive diagnostics.¹¹⁹

Autonomy does not present a binary condition but varies based on the degree of automation desired and the complexity of the task and environment. The automotive industry has the most mature model, where the SAE J3016 standard delineates six levels of driving automation, ranging from Level 0 (no automation) to Level 5 (full automation) (see Figure 3).¹²⁰ The industry widely adopts this taxonomy to classify the extent of vehicle automation. The intrusiveness of AI increases with the levels of automation.¹²¹ Conversely, the need for human intervention decreases as the levels of automation increase. The AS&R industry widely operates

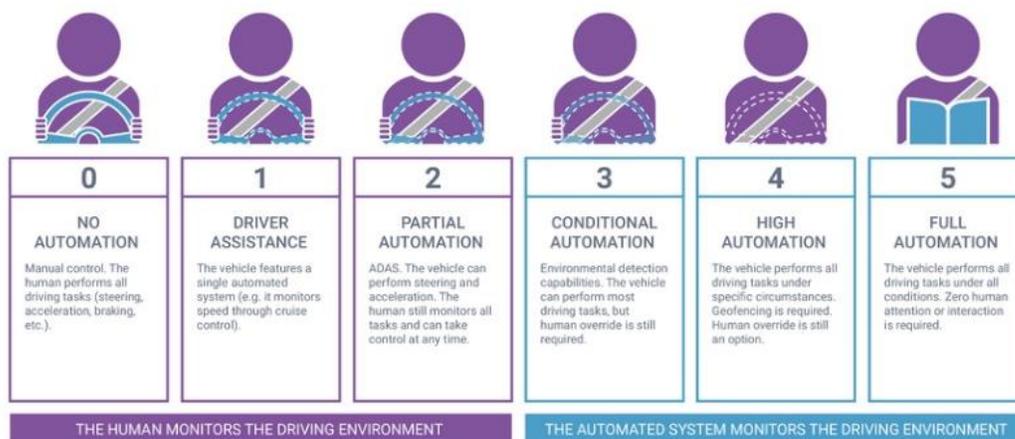


Figure 3 - Levels of Driving Automation

¹¹⁹ ElevatEd. "Role of AI in Autonomous Vehicles." 98th Percentile. October 16, 2024. <https://www.98thpercentile.com/blog/role-of-ai-in-autonomous-vehicles>.

¹²⁰ Synopsys Editorial Staff. "The 6 Levels of Vehicle Automation Explained." Synopsys. February 15, 2025. <https://www.synopsys.com/blogs/chip-design/autonomous-driving-levels.html>.

¹²¹ Malik, S. et al. "How Do Autonomous Vehicles Decide?" Sensors (Basel). 2022;23(1):317. Published 2022 Dec 28. <https://pmc.ncbi.nlm.nih.gov/articles/PMC9823427/>.

at Levels 0-2, with limited applications at Level 3-4. No industry participant that we studied has achieved Level 5 autonomy.

RL has the potential to accelerate and transform the AS&R industry rapidly. RL is a subset of AI that learns through iterative interaction with its environment by reinforcing behaviors and actions that produce positive results. On its own, RL offers a transformative capability for AS&R by allowing algorithms to autonomously improve performance without explicit human direction on how to do so. However, continuous monitoring, validation, and verification processes after deployment are still necessary to ensure the RL-enabled capability meets mission performance standards.¹²²

However, a truly transformative next step for the AS&R industry is utilizing RL in the digital space, particularly with digital twins, a technique we did not observe during our field study visits. This coupling of RL and digital twins could enable rapid advancements during development by enabling thousands (or more, limited only by compute, time, and energy consumption) of digital iterations on RL algorithms without relying on physical hardware. This approach saves significant time and resources during development and testing because software iterations are significantly cheaper and faster than hardware iterations. However, this approach will require rethinking certain DoD standards and certification processes. For example, airworthiness testing is an extensive, laborious, and expensive process that does not support rapid iteration and fielding of small, low-cost autonomous aerial systems.¹²³ This process would require a significant revamp to support this approach.

¹²² Chief Digital and Artificial Intelligence Officer. "Pathway to AI Readiness." U.S. Department of Defense. May 7, 2025. <https://www.ai.mil/About/Resources/Pathway-to-AI-Readiness/Testing-and-Evaluation/>.

¹²³ Thomas, Dustin, Jordan Atkins, and Peter Dyrud. "Print, Crash, and Reprint: How the Air Force Should Rethink Small Drones" War on the Rocks. May 6, 2025. <https://warontherocks.com/2025/05/print-crash-and-reprint-how-the-air-force-should-rethink-small-drones/>.

APPENDIX B – WARGAMING WITH AS&R

Wargames impact AS&R profoundly. Wargame results have driven much of the recent emphasis on military robots. For example, the Center for Strategic & International Studies conducted a well-known wargame in 2023 that revealed devastating losses when the U.S., Taiwan, and Japan repelled a simulated Chinese invasion of Taiwan.¹²⁴ That wargame produced multiple recommendations, including a need for more reliance on automated systems to aid in defense and reduce the loss of life. Additionally, other wargames ascertained the impacts of autonomous systems on crisis escalation and the likelihood of retaliation.¹²⁵ The AS&R-wargaming relationship may soon expand to include additional applications.

Organizations often shroud modern AS&R military programs in secrecy to maintain a military advantage. These layers of secrecy can force much of the development of autonomous systems into the virtual world, where developers build and utilize “digital twins” for much of the development and testing.¹²⁶ Digital twins allow the development of AS&R to proceed much faster than a typical hardware-based approach permits, due to the ability to replicate environments realistically and execute many simulated tests in a condensed amount of time.¹²⁷ As computing power expands, models will become more realistic and accelerate testing to build statistical models predicting a system's performance in a realistic environment. If those digital tests include adversarial actors, analysts can determine probabilities of death at levels of fidelity

¹²⁴ Cancian, Mark F., Matthew Cancian, and Eric Heginbotham. “The First Battle of the Next War: Wargaming a Chinese Invasion of Taiwan.” Center for Strategic & International Studies, National Defense University. January 2023. https://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/230109_Cancian_FirstBattle_NextWar.pdf?VersionId=WdEUwJYWlySMPIr3ivhFolxC_gZQuSQQ.

¹²⁵ Lin-Greenberg, Erik. “Wargame of Drones: Remotely Piloted Aircraft and Crisis Escalation.” *Journal of Conflict Resolution* 66, no. 10, November 2022. <https://doi.org/10.1177/00220027221106960>.

¹²⁶ Discussion with autonomous software firm, April 2025.

¹²⁷ Martin, Scott. “What Is a Digital Twin?” NVIDIA Blog (blog). December 14, 2021. <https://blogs.nvidia.com/blog/what-is-a-digital-twin/>.

and speed once unimaginable. The results of digital twin testing will enhance the realism of wargames more effectively than the archaic methods wargame designers currently use. There is publicly available evidence that digital twins are beginning to influence wargames, though the potential implications are much more profound than what publicly available sources discuss.¹²⁸

The implications for national security are substantial. With more realistic inputs, wargames will be more realistic and valuable, providing better insights into the outcomes of future conflicts. Analysts should feed the outcomes into the current or future AS&R development process to improve their performance and effectiveness.

¹²⁸ Feldscher, Jacqueline. "Space Force Buys a Digital Twin of Orbital Space." *Defense One*. March 31, 2022. <https://www.defenseone.com/business/2022/03/space-force-buys-digital-twin-orbital-space/363858/>; Cantrell et al., "Digital Twins for Sustainment-Oriented Wargaming," in *AIAA SCITECH 2025 Forum*, AIAA SciTech Forum (American Institute of Aeronautics and Astronautics, 2025), <https://doi.org/10.2514/6.2025-0706>.

APPENDIX C – ADDITIONAL POLICY RECOMMENDATIONS

Table 11 - Summary of Additional Recommendations

Action	Responsible Office(s)
Establish a Government-Wide AS&R Commission	OSTP; National AI Initiative Office; OSD
Implement Targeted Tax Incentives for Robotics and Autonomy R&D	U.S. Congress; President; Treasury; IRS
Improve Federal Investment in Robotics and Autonomy Education	USD(R&E); OASD(R); DoD STEM Office
Fund Public-Private Robotics Innovation Initiatives	U.S. Congress; DoD; NSF
Eliminate CSDR Reporting as a Barrier	CAPE; USD(A&S); DPC
Modify Cost Accounting Requirements for Small Companies	CASB; OFPP; CAPE; DPC
Strategic Outreach for Emerging Defense Suppliers	USD(A&S); SAEs; PEOs
Establish Infrastructure Sharing and Testbeds	USD(R&E); Service Labs; NAMC
Ensure Procurement Follow-Through for Prototypes	USD(A&S); USD(Comptroller); DPC; Service Comptrollers
Make DoD a Leading Adopter of Robotics	JROC; Service Component Requirements Oversight
Incorporate AS&R into Acquisition Programs	USD(A&S); USD(R&E); SAEs; PEOs
Institutionalize Leading Commercial Development Principles	USD(A&S); USD(R&E); SAEs; PEOs
Reinstate Advanced Acquisition Workforce Training	USD(A&S); HCI; DAU; Service DACMs
Use Demand Signaling to Attract Private Capital	USD(A&S); Joint Staff J-8; SAEs; PEOs
Expand Challenge-Based Acquisition	USD(A&S); ASD(A); SAEs; PEOs
Milestone-Based Prizes and Non-Dilutive Incentives	USD(A&S); ASD(A); USD(R&E); SBIR Offices
Prioritize Dual-Use Robotics for Acquisition	OSC; USD(A&S); USD(R&E); SAEs; PEOs
Leverage DoD OSC to Attract Private Financing	USD(A&S); SAEs; PEOs

RECOMMENDATIONS REQUIRING STATUTORY CHANGES

Establish a Government-Wide AS&R Commission

Table 12 - Details to Support Recommendation to Establish a Government-Wide AS&R Commission

Action	Leverage its procurement power to seed and secure U.S. and allied suppliers of critical robotics components and systems.
Responsible Office(s) or Individual(s)	<ul style="list-style-type: none"> • White House Office of Science and Technology Policy (OSTP)¹²⁹ • National AI Initiative Office¹³⁰
Supporting Office(s)	<ul style="list-style-type: none"> • Office of the Secretary of Defense

Rationale - The U.S. lacks a centralized office to coordinate robotics policy, despite growing demand across national security, industrial, and commercial sectors. As noted in the strategic environment section and by the Association for Advancing Automation (A3),¹³¹ fragmented agency efforts undermine scale and speed, while competitors like China treat robotics as a national priority.¹³² A White House-led commission would unify standards, align federal R&D, and strengthen the defense industrial base. The U.S. can close coordination gaps, steer dual-use investment, and preserve technological leadership by elevating robotics to a national strategic issue, similar to AI.

The President should direct OSTP and the National AI Initiative Office to establish a government-wide AS&R strategy, supported by a White House-chartered Robotics Commission. This body should include senior leaders from DoD, NIST, Commerce, and industry to advise on policy and coordinate across federal agencies. OSTP can fund initial operations through discretionary resources while seeking dedicated congressional appropriations. As a near-term

¹²⁹ White House Office of Science and Technology Policy. "About the Office of Science and Technology Policy." Accessed April 28, 2025. <https://www.whitehouse.gov/ostp/about/>.

¹³⁰ National Artificial Intelligence Initiative Office. "About the National AI Initiative Office." Accessed April 28, 2025. <https://www.ai.gov/about/>.

¹³¹ O'Brien, Matt. "US robotics companies push for a national strategy, including a central office, to compete with China." Associated Press. March 22, 2025.

¹³² Association for Advancing Automation, "A3 Policy Recommendations and Advocacy Principles for the U.S."

step, the White House should launch an interagency task force using existing structures like the AI Commission and Interagency Committee on Standards Policy (ICSP) to define scope, identify gaps, and recommend institutional frameworks.

Implement Targeted Tax Incentives for Adoption of Robotics and Autonomy R&D

Table 13 - Details to Support Recommendation to Implement Targeted Tax Incentives for Adoption of Robotics and Autonomy R&D

Action	Implement Targeted Tax Incentives for Adoption of Robotics and Autonomy R&D
Responsible Office(s) or Individual(s)	<ul style="list-style-type: none"> • U.S. Congress • President of the United States
Supporting Office(s)	<ul style="list-style-type: none"> • Secretary of the Treasury • Internal Revenue Service

Rationale - As outlined in the strategic environment section, high capital costs deter smaller manufacturers from adopting robotics, weakening the U.S. defense supply chain. Targeted tax incentives can accelerate automation, expand surge capacity, and reduce reliance on foreign sources. Congress should follow the model proposed by the Association for Advancing Automation (A3) and offer tax relief that lowers the cost of modernizing production and investing in domestic AS&R R&D. These incentives would support smaller firms' participation in defense markets and reinforce the innovation base critical to national security.¹³³

Congress should pass legislation that offers accelerated depreciation for robotics equipment, investment tax credits for automation and workforce training, and immediate expensing of R&D costs by fixing IRS Section 174.¹³⁴ Lawmakers should limit eligibility to suppliers supporting defense-critical sectors under the Defense Production Act to focus benefits on firms tied to national security. The policy should include a five-year sunset clause and a

¹³³ Association for Advancing Automation, "A3 Policy Recommendations and Advocacy Principles for the U.S."

¹³⁴ Internal Revenue Service. "Section 174 Research and Experimental Expenditures." Accessed April 28, 2025, <https://www.irs.gov/credits-deductions/section-174-research-and-experimental-expenditures>.

capped annual credit pool, similar to renewable energy tax credits, to manage fiscal impact while encouraging early adoption. Treasury and the IRS should issue clear guidance to ensure accessibility and compliance for small and mid-sized businesses.

Improve Effectiveness of Existing Federal Investment in Robotics and Autonomy Education and Government Workforce Development

Table 14 - Details to Support Recommendation to Improve Federal Investment in Robotics and Autonomy Education and Workforce Development

Action	Align Current DoD Funded Education Programs with SECDEF Priorities
Responsible Office(s) or Individual(s)	<ul style="list-style-type: none"> • USD(R&E) • Office of the Assistant Secretary of Defense for Readiness (OASD(R)) • DoD STEM Office
Supporting Office(s)	<ul style="list-style-type: none"> • Office of the Assistant Secretary of Defense for Readiness (OASD(R)) • Army, Navy, and Air Force STEM offices

Rationale - The U.S. faces a growing shortfall in robotics and AI talent, while competitors like China expand their technical workforce. As discussed in the strategic environment section, this gap threatens DoD’s ability to sustain innovation and field advanced systems. To close it, DoD must realign existing education programs with the Secretary of Defense's priorities¹³⁵ and invest in long-term workforce development. Targeted federal support will reduce reliance on foreign expertise, grow the defense innovation base, and ensure the DoD can staff, deploy, and maintain next-generation autonomous systems.¹³⁶ Without a concerted effort to train American workers and inspire the next generation of roboticists, the U.S. military will face a personnel and innovation deficit. Expanded federal investment in robotics education will reduce reliance on foreign technical talent, create high-paying jobs at home, and ensure the DoD has access to the

¹³⁵ Association for Advancing Automation, "A3 Policy Recommendations and Advocacy Principles for the U.S."

¹³⁶ Zwetsloot, Remco et al. "China is Fast Outpacing U.S. STEM PhD Growth." Data Brief, Center for Security and Emerging Technology, August 2021. <https://doi.org/10.51593/20210018>.

human capital needed to develop, maintain, and deploy advanced autonomous systems. This long-term capacity-building is essential for sustaining U.S. leadership in defense technology.

The Office of the Under Secretary of Defense for Research and Engineering (USD(R&E)), in coordination with the Office of the Assistant Secretary of Defense for Readiness (OASD(R)) and the DoD STEM Office, should immediately reprioritize autonomy and robotics within existing programs such as the SMART Scholarship, DCTC, and Pathways initiatives. In parallel, Congress should appropriate funds for new STEM and robotics education grants across K-12, trade schools, and universities. Instead of creating new bureaucracies, DoD should leverage existing grant mechanisms under the NSF, Department of Labor, and Department of Education. Where needed, a small coordination cell within DoD or the Department of Labor could track national robotics workforce needs and ensure interagency alignment. This approach balances near-term realignment with long-term pipeline growth while minimizing duplication of effort.¹³⁷ Notably, this does not remedy gaps in the commercial sector, however, the combination of industry recommendations will create a better business environment that makes it more attractive as a workforce career path.

Fund Public-Private Robotics Innovation Initiatives

Table 15 - Details to Support Recommendation to Fund Public-Private Robotics Innovation Initiatives

Action	Fund Public-Private Robotics Innovation Initiatives
Responsible Office(s) or Individual(s)	<ul style="list-style-type: none"> • U.S. Congress
Supporting Office(s)	<ul style="list-style-type: none"> • DoD • National Science Foundation

Rationale - Many breakthroughs in autonomous systems originate from universities, startups, and small businesses, but these entities struggle to bridge the gap from prototype to production

¹³⁷ Office of the Under Secretary of Defense for Research and Engineering. "DoD STEM Strategic Plan FY2021–FY2025." U.S. Department of Defense. 2021. <https://dodstem.us>.

without support. Public-private consortia have proven effective – for example, the Manufacturing USA institutes (like the ARM Institute for Robotics) bring together industry, academia, and government to solve technology transition challenges. Boosting federal co-investment in such collaborations will drive breakthrough advancements and ensure promising military-applicable technologies are not lost due to a lack of resources. Notably, A3's vision for a national strategy calls for strengthening public-private partnerships to spur robotics. A dedicated financing mechanism (akin to how the DFC supports critical infrastructure) could also provide growth capital to domestic robotics firms, encouraging private investors to follow suit. These steps will fortify the industrial base by moving more autonomous system innovations into the Defense Department's reach.¹³⁸

Launch a major federal initiative to accelerate robotics innovation through public-private collaboration. This could take the form of a “*National Robotics Initiative 2.0*” (building on the prior NSF-led program) to fund research with dual-use applications, significantly expanded funding for NIST’s Manufacturing Extension Partnership (to help small manufacturers adopt robotics), and consider leveraging the *Office of Strategic Capital (OSC)*¹³⁹ to scale up robotics and AI companies. Congress should also increase support for innovation hubs (e.g., the DoD-funded Advanced Robotics for Manufacturing Institute).

¹³⁸ Association for Advancing Automation, "A3 Policy Recommendations and Advocacy Principles for the U.S."

¹³⁹ Chief Technology Officer. “FY2025 Investment Strategy for the Office of Strategic Capital.” U.S. Department of Defense. 2024. <https://www.cto.mil/osc/credit-program/>.

Eliminate CSDR Reporting as a Barrier to Entry

Table 16 - Details to Support Recommendation to Eliminate CSDR Reporting as a Barrier to Entry

Action	Remove or streamline the Cost and Software Data Reporting (CSDR) obligations for software-focused programs or dual-use commercial technology.
Responsible Office(s) or Individual(s)	<ul style="list-style-type: none"> • Director, Cost Assessment and Program Evaluation (CAPE)
Supporting Office(s)	<ul style="list-style-type: none"> • USD(A&S) • Defense Pricing and Contracting (DPC)

Rationale - CSDR reporting is designed based on the assumption that software is analogous to traditional hardware programs with stable production costs but is poorly suited to modern software development practices, especially those involving agile methodologies or emerging commercial technologies. Dual-use software vendors often operate in fast-moving commercial markets. They are discouraged from engaging with DoD due to the burdens and misalignment of CSDR reporting. Additionally, CSDR reporting is perceived as an infringement on IP and trade secrets that provide companies with a competitive advantage in the commercial market. These requirements function as a deterrent for companies that otherwise offer critical national security value. Removing this barrier would increase participation, accelerate innovation, and improve alignment with the Department's software acquisition pathway and digital modernization goals.

The DoD should remove or streamline the Cost and Software Data Reporting (CSDR) obligations for software-focused programs or dual-use commercial technology, particularly for contracts below the Major Defense Acquisition Program threshold. In place of the old CSDR cost reporting, the Department can institute simplified metrics more suited to Agile development (e.g., progress burndowns, delivery frequency, etc.). This policy change could be enacted via an update to DoD Instruction 5000.73 – Cost and Software Data Reporting and DoD Manual 5000.04-M-1 – CSDR Plan Preparation Manual by the Office of the Director, Cost Assessment and Program Evaluation (CAPE). The goal is to reduce non-value-added burdens on firms that

do not have traditional cost systems. Oversight could be maintained through alternative transparency measures (like requiring on-site audits or data delivery only on key cost drivers) rather than blanket detailed reports.

Modify Cost Accounting Requirements to Reduce Barriers to Entry for Small to Medium-Sized Companies

Table 17 - Details to Support Recommendation to Modify Cost Accounting Requirements to Reduce Barriers to Entry for Small to Medium-Sized Companies

Action	Establish an alternate pathway for cost estimation and account for smaller acquisitions (e.g., under \$100 million) in emerging tech areas like robotics, where traditional cost data is scarce.
Responsible Office(s) or Individual(s)	<ul style="list-style-type: none"> • Cost Accounting Standards Board (CASB), which operates under the Office of Federal Procurement Policy (OFPP)
Supporting Office(s)	<ul style="list-style-type: none"> • CAPE • Defense Pricing and Contracting (DPC)

Rationale - For many small tech companies or startups, installing a government-approved cost accounting system and hiring compliance staff is impractical – it can cost hundreds of thousands of dollars – and these firms often lack decades of cost data to inform the elaborate cost-volume justifications the government typically expects. Requiring full CAS compliance on a <\$50M prototype drone program, for example, deters participation and slows down contracting. DoD has already seen that using OTAs, which bypass these rules, dramatically increases participation by non-traditional firms.¹⁴⁰ We should extend that lesson to more of our mainstream contracting. Suppose DoD treats more robotics and AI procurements as commercial-style purchases (where we care about end item price and performance, not the contractor's internal cost ledger). In that case, more companies will bid, yielding greater competition and innovation. This approach still protects the government's interests: competition or market pricing can ensure fair costs, and

¹⁴⁰ U.S. Government Accountability Office. “Defense Acquisitions: DOD’s Use of Other Transactions for Prototype Projects Has Increased.” GAO-20-84. November 2019. <https://www.gao.gov/products/GAO-20-84>.

program managers can concentrate on technical merit. Importantly, it also aligns with Congress's direction to make DoD more agile – the FY2024 National Defense Authorization Act, for instance, encouraged expanding commercial acquisition and OTA use for precisely these reasons. By right-sizing compliance to program risk, the Department can invite innovative tech firms into the defense marketplace rather than shutting them out. In sum, easing rigid cost accounting mandates for lower-dollar, high-innovation programs will broaden the industrial base as more small businesses find it viable to work with DoD without sacrificing their commercial business models.

DoD should establish an alternate pathway for cost estimation and account for smaller acquisitions (e.g., under \$100 million) in emerging tech areas like robotics, where traditional cost data is scarce. Concretely, this means raising the threshold for requiring certified Cost Accounting Standards (CAS) compliance and certified cost or pricing data, and instead allowing offers to be evaluated on price reasonableness or commercial pricing for these programs. DoD can pilot a “streamlined cost assessment” approach. Suppose a project is below a dollar value and is determined to have high innovation value. The program office can accept less formal cost proposals (for instance, parametric estimates or rough order-of-magnitude costs) without completely CAS-compliant systems. This change may require a regulatory class deviation or support from Congress to adjust the CAS application; however, even interim steps, like encouraging the use of FAR Part 12 commercial item designations or Other Transaction Authorities (OTAs) for such procurements, will help.

BEST BUSINESS PRACTICE RECOMMENDATIONS

Strategic Outreach for Emerging Defense Suppliers

Table 18 - Details to Support Recommendation to Establish Strategic Outreach for Emerging Defense Suppliers

Action	Establish a Strategic Outreach and Integration Program for Emerging Defense Suppliers
Responsible Office(s) or Individual(s)	<ul style="list-style-type: none"> • USD(A&S) • SAEs • Program Executive Offices

Rationale - Despite various innovation initiatives, many commercially successful tech firms struggle to break into DoD’s big programs – or to sustain momentum after an initial SBIR or prototype contract. The infamous “valley of death” between demonstration and full-scale adoption persists. One primary reason is structural: PEOs and program managers, who control the budgets to buy and field systems, are often disconnected from the universe of new suppliers.¹⁴¹ Conversely, startups frequently do not know whom in the vast DoD bureaucracy to engage after an early success. DoD has long recognized this chasm – a 2007 report noted that only close cooperation between developers, acquirers, and users can bridge the transition gap.¹⁴² We need to institutionalize that cooperation. An integration office focused on emerging suppliers would ensure promising technologies are not orphaned after Phase II trials; it would actively shepherd them into acquisition. This directly addresses the current policy gap: while DIU, AFWERX, and others create prototypes, there is no “concierge” to insert those into big-budget programs. For example, suppose a small company develops a great AI targeting module via an Army xTech prize. In that case, the office will work to get it evaluated by the Long-Range Precision Fires PEO for inclusion in their systems. By providing clear pathways and

¹⁴¹ Tucker, Patrick. “House Bill Aims to Bridge Acquisition ‘Valley of Death’ in Race to Counter China.” Defense One. August 25, 2021. <https://www.defenseone.com/technology/2021/08/house-bill-aims-bridge-acquisition-valley-death-race-counter-china/184867/>.

¹⁴² Tucker, “House Bill Aims to Bridge Acquisition ‘Valley of Death’ in Race to Counter China.”

matchmaking, DoD would dramatically increase its innovation transition rate, preventing good tech from languishing. The result is a more vibrant DIB where small businesses see a viable route to scale their contributions, and the services get faster access to innovative solutions.

The DoD, under the leadership of the Under Secretary of Defense for Acquisition and Sustainment (USD(A&S)), should establish a dedicated Strategic Outreach and Integration Office focused on connecting small and medium-sized businesses with established programs of record and acquisition professionals at the PEO level. This office would serve as a centralized coordination node that bridges the gap between emerging commercial innovators and traditional defense acquisition channels.

Infrastructure Sharing and Testbeds

Table 19 - Details to Support Recommendation to Establish Infrastructure Sharing and Testbeds

Action	Establish government-supported but commercially accessible test ranges, robotics proving grounds, and cyber-physical labs.
Responsible Office(s) or Individual(s)	<ul style="list-style-type: none"> • USD(R&E) • Service Component Labs • National Advanced Mobility Consortium (NAMC)

Rationale - Startups and small businesses lack the capital to build facilities that mirror the complexity of defense environments. Shared government infrastructure de-risks R&D for companies and accelerates military-relevant validation. This approach also improves DoD's ability to compare systems under uniform conditions, speeding up evaluation and integration.

The DoD should model to establish government-supported but commercially accessible test ranges, robotics proving grounds, and cyber-physical labs. These should include capabilities for contested environment simulations, AI performance assessments, and modular system validation. Many robotics startups and smaller companies cannot afford the large-scale testing and evaluation facilities needed to validate systems for military use (e.g., secure proving grounds, realistic urban test sites, or specialized labs for autonomy in GPS-denied

environments). DoD can fill this gap by providing shared test infrastructure and sandboxes that companies and researchers can use. For instance, the Department could expand access to military training ranges for testing autonomous vehicles or establish an open robotics test center (in collaboration with an academic institution or the National Labs) equipped with mock battle environments, obstacle courses, and instrumentation for data collection. Making such facilities available at low or no cost to vetted companies would significantly lower the barrier to entry – a startup could refine its drone or UGV using world-class test sites that it otherwise could never afford. We have models for this: the Army and the ARM Institute in Pittsburgh have launched a Robotics Manufacturing Hub to help SMEs explore and adopt robotics, providing a form of shared resource.¹⁴³ Likewise, NASA has long provided its wind tunnels and labs to aerospace firms under Space Act Agreements.¹⁴⁴ DoD should do the same for autonomy. Additionally, DoD can host “challenge trials” – open invitations for companies to bring their systems to a military-run event where they can test against military scenarios (like DARPA Challenges¹⁴⁵ or the Navy's ANTX exercises¹⁴⁶). Infrastructure sharing enhances innovation by enabling companies to test their technology in realistic settings and identify issues early. It also helps DoD personnel become acquainted with emerging systems. In addition to physical testbeds, the Department should transition to open-source simulation environments for AI, robotics, autonomy, and digital testbeds for software, digital twin validation, and RL shared with industry. This will help develop and assess performance under conditions relevant to the military.

¹⁴³ ARM Institute. "ARM Institute Marks Eight Years of Impact." January 15, 2025.

<https://arminstitute.org/news/eight-years/>.

¹⁴⁴ NASA Office of Technology Transfer, “Agreements,” accessed May 6, 2025, <https://ott.jpl.nasa.gov/agreements>.

¹⁴⁵ Defense Advanced Research Projects Agency (DARPA), “DARPA Subterranean Challenge,” accessed May 5, 2025, <https://www.darpa.mil/program/darpa-subterranean-challenge>.

¹⁴⁶ Naval Sea Systems Command, “ANTX 2019,” Naval Undersea Warfare Center Division Newport, accessed May 5, 2025, <https://www.navsea.navy.mil/Home/Warfare-Centers/NUWC-Newport/What-We-Do/ANTX-2019/>.

The government must ensure that intellectual property is protected to gain the trust of industry partners. The DoD will attract more private entities to address defense-related challenges by facilitating testing and experimentation. Ultimately, this approach leads to more mature, validated products ready for acquisition, all developed with substantial private investment while utilizing public facilities. It is important to recognize that transitioning from current business practices will require time, and results may not be immediate without significant investment. Leveraging DoD's unique assets in this innovative manner amplifies private research and development efforts and strengthens the ecosystem of companies proficient in meeting military requirements.

Ensure Procurement Follow-Through to Bridge the “Valley of Death”

Table 20 - Details to Support Recommendation to Ensure Procurement Follow-Through to Bridge the “Valley of Death”

Action	Institutionalize small-scale procurement for successful prototype technologies by establishing a dedicated “prototype transition fund” within each Military Department.
Responsible Office(s) or Individual(s)	<ul style="list-style-type: none"> • USD(A&S) • USD(Comptroller) • DPC • Service Component Comptrollers

Rationale - DoD’s failure to move from prototyping to procurement discourages private sector investment in defense technology. Firms often engage in pilot efforts that yield no production orders, signaling to investors that defense markets are unpredictable and risky. This undermines confidence and restricts the flow of capital into national security innovations. A small LRIP order serves as market validation, demonstrating that the DoD is a credible and committed buyer.

It also provides firms a financial bridge to maintain operations and refine offerings.¹⁴⁷ The Army's recent decision to procure commercially developed tactical drones after field trials exemplifies how modest purchases can catalyze innovation, signal seriousness to investors, and enhance readiness. In contrast, shelving successful prototypes deepens the so-called “valley of death” and starves the defense sector of viable, venture-backed suppliers. By budgeting for and executing limited procurements of successful prototypes, the Department strengthens its innovation base, retains critical industrial partners, and improves strategic responsiveness at low cost with high strategic return.

USD(A&S), DPC, and SAEs should institutionalize small-scale procurement for successful prototype technologies by establishing a dedicated “prototype transition fund” within each Military Department. This fund should be specifically reserved to finance low-rate initial production (LRIP) of prototypes that have met performance goals during experimentation or pilot phases. Even modest initial purchases—such as a dozen units of a new robotic platform—would provide critical financial bridges for firms transitioning from development to production. Program managers should be required to plan for this transition from the outset by incorporating clear production criteria and funding pathways into all prototype solicitations, including those executed under OTAs. These measures must be complemented by strong direction from senior acquisition leaders emphasizing production readiness and follow-through as a priority outcome of innovation initiatives.

¹⁴⁷ Clark, Joseph. "DOD Acquisition Official Underscores Importance of Production in Keeping U.S. Edge." U.S. Department of Defense. March 7, 2024. <https://www.defense.gov/News/News-Stories/Article/Article/3700194/dod-acquisition-official-underscores-importance-of-production-in-keeping-us-edge/>.

Make the DoD a Leading Adopter of Robotics and Autonomy Technologies

Table 21 - Details to Support Recommendation to Make DoD a Leading Adopter of Robotics and Autonomy Technologies

Action	Make the DoD a Leading Adopter of AS&R Technologies by evaluating new requirements that may benefit the operational readiness of the Department and/ or reduce cost.
Responsible Office(s) or Individual(s)	<ul style="list-style-type: none"> • Joint Requirements Oversight Counsel (JROC) • Service Component Requirements Oversight bodies

Rationale - By acting as a leading robotics customer, DoD can improve its efficiency and stimulate the industry. Civilian agencies and companies often wait for proven results – if the Pentagon leads by example, it lowers perceived risk and sets an example for broader industry adoption. Militarily, these technologies offer immediate benefits: warehouse automation and autonomous convoys reduce manpower needs and risk to personnel. At the same time, robotic tools in depots and airfields can speed up repairs and improve readiness. The U.S. Army's early use of ground robots for explosive ordnance disposal and the Navy's testing of autonomous supply delivery vessels show that such systems can reduce danger and cost. By broadly integrating robotics into non-combat roles, DoD also provides a large testbed to refine dual-use technologies. Lessons learned in military logistics automation can translate into better commercial warehouse robots and vice versa. In sum, DoD's demand pull will strengthen the market for domestic robotics, reinforce supply chains, and ensure the U.S. military is not lagging in adopting productivity-enhancing tools that adversaries may employ.¹⁴⁸

The DoD should prioritize deploying automation and robotics at scale, especially in logistics, base operations, maintenance, and other support functions. This means expanding pilot programs and funding for autonomous warehouse robots on bases, self-driving vehicles for convoys and airfield logistics, robotic ordnance disposal and firefighting systems, and AI

¹⁴⁸ Association for Advancing Automation, "A3 Policy Recommendations and Advocacy Principles for the U.S."

assistants for maintenance diagnostics. Each military service should identify high-impact processes that could be improved with today's commercial robotics and set target adoption goals. Senior leadership (e.g., the USD(A&S)) should champion these efforts, using rapid acquisition methods to procure proven commercial solutions.¹⁴⁹

Incorporate AS&R into Acquisition Programs

Table 22 - Details to Support Recommendation to Incorporate AS&R into Acquisition Programs

Action	Incorporate AS&R into Acquisition Programs
Responsible Office(s) or Individual(s)	<ul style="list-style-type: none"> • USD(A&S) • USD(R&E) • SAEs • PEOs

Rationale - The pace of innovation in autonomous systems is rapid, driven by commercial tech advances. DoD's innovation pipeline must keep up. Notably, the Department's 2022 National Defense Strategy warned that market forces are producing new capabilities that the military must harness, calling for an “order of magnitude increase” in commercial technology adoption and urging the DoD to act as a “fast follower.” Prioritizing robotics in innovation programs ensures the Pentagon scouts and funds the best ideas in time to counter peer competitors. We already see examples of success: the Air Force's collaboration with Australia on the MQ-28 Ghost Bat loyal wingman UAS shows how sustained investment in an autonomous platform can yield a game-changing capability. By baking robotics into DoD's core modernization priorities and acquisition plans, we ensure technologies like uncrewed vehicles, autonomous sensors, and AI-driven maintenance systems transition from prototypes to fielded systems on relevant timelines. This will keep the U.S. military at the forefront and signal to

¹⁴⁹ The DoD's existing authorities allow for this policy change.

industry that DoD is serious about buying and deploying advanced robotic systems.¹⁵⁰ This change does not require a statutory change and can be implemented by policy with existing authorities.

The USD(R&E), USD(A&S), and the SAEs should explicitly prioritize embodied AI and autonomous robotics in their portfolios and rapid acquisition pathways. This means directing organizations like DARPA, the DIU, service labs, and the new Rapid Defense Experimentation Reserve to issue regular solicitations and challenges focused on military-applicable robotics (swarm drones, autonomous ground vehicles, robotic combat wingmen, etc.). Additionally, as programs move from R&D to acquisition, the DoD should use flexible acquisition mechanisms – e.g., Middle Tier Acquisition (Section 804 authority) or OTA – to field prototypes quickly and iteratively. New major defense acquisition programs should evaluate where incorporating robotics or AI could add value, and acquisition strategies should plan for those insertions from the outset.

Institutionalize Leading Commercial Product Development Principles

Table 23 - Details to Support Recommendation to Institutionalize Leading Commercial Product Development Principles

Action	Institutionalize leading commercial product development principles by incorporating them into DoD acquisition programs
Responsible Office(s) or Individual(s)	<ul style="list-style-type: none"> • USD(A&S) • USD(R&E) • SAEs • PEOs

Rationale - Robotics and autonomous systems operate in a high-velocity innovation environment where traditional defense development timelines are incompatible with commercial

¹⁵⁰ Association for Advancing Automation, "A3 Policy Recommendations and Advocacy Principles for the U.S."

technological change. Leading technology firms, such as those in robotics, software, and aerospace, rely on these product development practices to deliver operationally relevant capabilities, adapt to user needs, and manage development risk. Applying these methods systematically would improve the Department's ability to deliver timely, relevant, and fieldable robotics and autonomous capabilities while avoiding costly rework and program delays. The GAO has observed these principles inconsistently applied across DoD programs, often resulting in avoidable design immaturity, schedule slips, and operational shortfalls. Institutionalizing these practices would ensure that DoD-sponsored robotics development remains aligned with commercial cycles and adaptable to future threat environments.

The DoD should institutionalize leading commercial product development principles by incorporating them into DoD Instruction 5000-series policies and requiring consistent application across all relevant acquisition pathways, including the Software Acquisition Pathway, the Middle Tier of Acquisition (MTA), and traditional Major Capability Acquisition programs. These principles, identified by the Government Accountability Office (GAO)¹⁵¹ and long-proven in the commercial industry, include:

- Establishing a sound business case early,
- Using iterative design and rapid prototyping,
- Off-ramping features to meet delivery timelines,
- Ensuring frequent, structured user feedback throughout development.

¹⁵¹ U.S. Government Accountability Office. "Best Practices: DOD Can Achieve Better Outcomes by Standardizing the Use of Product Development Principles." GAO-22-104513. March 2022. <https://www.gao.gov/products/gao-22-104513>.

To enforce compliance, the Office of the Under Secretary of Defense for Acquisition and Sustainment (USD(A&S)) should include product development reviews in milestone decision processes, require documented user feedback loops, and integrate these principles into program reporting requirements.

This recommendation reinforces policy goals outlined in the 2025 National Defense Strategy and Executive Order 14272, which call for agile development, increased industrial base resilience, and reduced reliance on traditional acquisition timelines and structures. By adopting proven commercial methods, the Department will improve collaboration with U.S. robotics firms and minimize friction between government and industry development cultures.

Reinstate and Expand Advanced Acquisition Workforce Training in Modern Development Practices

Table 24 - Details to Support Recommendation to Reinstate and Expand Advanced Acquisition Workforce Training in Modern Development Practices

Action	Reinstate and Expand Advanced Acquisition Workforce Training in Modern Development Practices
Responsible Office(s) or Individual(s)	<ul style="list-style-type: none"> • USD(A&S)
Supporting Office(s)	<ul style="list-style-type: none"> • Human Capital Initiatives (HCI) • Defense Acquisition University • Service Component Defense Acquisition Career Managers

Rationale - The 2020 “Back to Basics” reform narrowed DAU's core curriculum and placed responsibility for advanced and mission-specific training on the services. However, most services have not established sufficient training capacity or content in modern development methods. As a result, many senior acquisition leaders and technical personnel, particularly those certified before 2020, lack familiarity with iterative software development, commercial product

design cycles, or modular open architectures.¹⁵² These gaps undermine efforts to rapidly field autonomous systems, robotic platforms, and software-intensive capabilities.

The FY2025 NDAA recognizes this shortfall and directs DAU to deploy field training teams to support workforce upskilling and ensure alignment with modern acquisition practices. This provides an immediate statutory mechanism to bridge the current training gap. Empowering DAU to deliver these teams and expanding its advanced course catalog will ensure consistent, enterprise-wide proficiency in developing and acquiring emerging technologies. This recommendation aligns with the priorities outlined in the 2025 NDAA¹⁵³ and Executive Order 14265.¹⁵⁴ Both emphasize the need for a technically capable workforce to partner with industry, leverage commercial innovation, and restore U.S. military overmatch through agile acquisition and digital modernization.

The DoD should direct the DAU, under the authority of the Under Secretary of Defense for Acquisition and Sustainment (USD(A&S)), to reinstate and incorporate training in modern development practices, including agile software development, modular open systems approach (MOSA), DevSecOps, digital engineering, iterative prototyping, and user-centered design. This training should be mandatory for key acquisition roles such as PEOs, Program Managers (PMs), Chief Engineers, and Contracting Officers. Such training exists, but it is optional and offered as elective courses.

¹⁵² U.S. Department of Defense. "Back to Basics: Revitalizing the Defense Acquisition Workforce." Memorandum. September 2, 2020.

¹⁵³ U.S. Congress. "National Defense Authorization Act for Fiscal Year 2025." S.4638, 118th Cong., 2nd sess., introduced July 8, 2024. <https://www.congress.gov/bill/118th-congress/senate-bill/4638>.

¹⁵⁴ Trump, Donald J. "Executive Order 14265: Modernizing Defense Acquisitions and Spurring Innovation in the Defense Industrial Base." The White House. April 9, 2025. <https://www.whitehouse.gov/presidential-actions/2025/04/modernizing-defense-acquisitions-and-spurring-innovation-in-the-defense-industrial-base/>.

DAU should also accelerate the implementation of the FY2025 NDAA mandate to deploy field training teams. These mobile instructional units should deliver customized, mission-specific training directly to acquisition organizations and major programs, particularly where services have not developed post-certification technical curricula as expected under the 2020 Back to Basics initiative.¹⁵⁵

Use Demand Signaling and Procurement Commitments to Attract Private Capital

Table 25 - Details on Demand Signaling and Procurement Commitments to Attract Private Capital

Action	Use Demand Signaling and Procurement Commitments to Attract Private Capital
Responsible Office(s) or Individual(s)	<ul style="list-style-type: none"> • USD(A&S) • Joint Staff J-8
Supporting Office(s)	<ul style="list-style-type: none"> • SAEs • PEOs

Rationale - The main body’s profit policy recommendation (Table 7) outlines that the DoD must better reward private-sector risk-taking. In addition to reforming profit margins, this recommendation proposes stage-gated ‘prize’ mechanisms that mirror commercial investment practices. These milestone-based incentives complement regulatory profit reforms and provide non-dilutive support to high-performing firms.

To maintain a technological edge in autonomous systems without relying solely on federal funding, DoD must better align its procurement strategies with commercial innovation cycles and incentivize private capital to invest in defense-relevant tech. The following policy initiatives outline how the Department can harness private investment to strengthen the DIB in robotics and AI.

¹⁵⁵ U.S. Congress. “National Defense Authorization Act for Fiscal Year 2025, Defense Acquisition University Field Training Requirement.” S.4638, 118th Cong., 2nd sess., introduced July 8, 2024. <https://www.congress.gov/bill/118th-congress/senate-bill/4638>.

DoD should communicate its future needs for autonomous systems and commit to buying successful innovations at scale. This could include publishing technology roadmaps with specific objectives (e.g., “By 2028, the Army intends to procure X number of autonomous supply vehicles”) and pilot contracts that promise a production option if milestones are met. When the Pentagon articulates a credible demand forecast, it gives venture capital and industry investors confidence that a market will exist for the technology, spurring them to pour in resources ahead of time.¹⁵⁶ Conversely, inconsistent or opaque demand signals leave potential investors wary that even superior technology might not find a buyer. By aligning defense modernization plans with industry outreach (for instance, through industry days and public “problem statements” for robotics needs), the DoD can effectively guide private sector R&D. A notable example is the Air Force's stated requirement for uncrewed wingmen or Collaborative Combat Aircraft (CCA) as part of its next-generation fighter program – this kind of clarity has drawn significant industry investment in uncrewed combat aircraft. In short, if DoD makes its intentions and commitments to procure known (and follows through), the private sector will help build the required capacity and innovation, strengthening the domestic base of suppliers ready to deliver new autonomous capabilities.

Expand Challenge-Based Acquisition

Table 26 - Details to Support Recommendation to Expand Challenge-Based Acquisition

Action	Expand Challenge-Based Acquisition
Responsible Office(s) or Individual(s)	<ul style="list-style-type: none"> • USD(A&S) • ASD(A) - Defense Pricing, Contracting, and Acquisition Policy (DPCAP) Contract Policy (CP), • SAEs.
Supporting Office(s)	<ul style="list-style-type: none"> • PEOs

¹⁵⁶ U.S. Department of Defense. “Office of Strategic Capital Announces Release of Fiscal Year 2025 Investment Strategy.” January 2, 2025. <https://www.defense.gov/news/releases/release/article/4020461/office-of-strategic-capital-announces-release-of-fiscal-year-2025-investment-st/>.

Rationale - OTAs and innovation challenges lower the barrier to entry by bypassing the FAR-based acquisition process, which often discourages smaller commercial entrants. Challenge-based models also shift risk to the private sector and require firms to prove their capability before receiving government funding. This “skin in the game” approach mirrors commercial market dynamics and increases government investment returns.

The DoD should expand the use of prize competitions and challenge programs to solve specific robotics problems – for example, a “counter-drone swarming challenge” that offers cash prizes or a procurement contract to winners. Congress has given the DoD permanent authority to award prizes for advanced technology achievements, and these competitions are recognized as a legitimate competitive procedure under DFARS 206.102-70.¹⁵⁷ By crafting challenges where firms compete using their R&D funds for the reward of a DoD contract, the Department effectively taps private investment and ingenuity at low upfront costs. Such challenge-based acquisition also widens the solution space by engaging academia, small innovators, and international partners. The result is a broader industrial base and potentially breakthrough solutions that traditional requirements writing might miss. DoD should increase the use of OTA agreements and challenge-based procurement frameworks such as Commercial Solutions Openings (CSOs). These should be formalized as preferred entry points for non-traditional vendors in robotics and autonomy competitions.

¹⁵⁷ U.S. Department of Defense. “Defense Federal Acquisition Regulation Supplement, Subpart 206.1 – Full and Open Competition.” Updated January 17, 2025. <https://www.acquisition.gov/dfars/subpart-206.1-full-and-open-competition>.

Milestone-Based “Prizes” and Non-Dilutive Incentives

Table 27 - Details to Support Recommendation to Establish Milestone-Based “Prizes” and Non-Dilutive Incentives

Action	Use Milestone-Based “Prizes” and Non-Dilutive Incentives
Responsible Office(s) or Individual(s)	<ul style="list-style-type: none"> • USD(A&S) • ASD(A) • USD(R&E) • SBIR Program Offices

Rationale - Upfront, large federal grants encourage dependence rather than innovation. In contrast, milestone-based “prize” models ensure that taxpayer funds go only to technically viable efforts. These programs mimic how venture capital stages investment, giving companies performance goals and validation. Making these awards non-dilutive increases their appeal to startups concerned about equity dilution.

Rather than only using large upfront grants or contracts, DoD can structure its support to private sector projects in a stage-gated, pay-for-performance manner. For example, the Department could offer to increase “prize” payments or follow-on contract options as a company's technology meets defined milestones (e.g., successful flight test, achieving a specific endurance, then completing operational demo). This model, akin to venture capital tranche investing, ensures that government funds flow only when technical progress is proven, signaling a clear runway for companies that deliver. The Air Force has piloted such concepts through programs like AFVentures/STRATFI,¹⁵⁸ where small businesses that obtain matching private investment and hit development targets receive larger government awards. Expanding this concept, DoD could announce that specific capabilities will provide matched private capital 1-to-1 up to a certain amount for companies that meet performance gates. This encourages private co-investment at each stage – investors know that if the company achieves the next milestone, DoD

¹⁵⁸ AFWERX. “STRATFI/TACFI.” AFWERX. Accessed May 6, 2025. <https://afwerx.com/divisions/ventures/stratfi-tacfi/>.

will boost funding or issue a procurement contract, de-risking their involvement. Milestone-based incentives align the interests of the developers, private investors, and DoD around delivering real, usable capability. It avoids the problem of the government sinking much money into a prototype that never transitions and, conversely, helps startups avoid the cliff of losing support after a Phase II SBIR. By guaranteeing that successful demonstrations lead to tangible rewards (contracts, not just kudos), DoD makes itself a more attractive customer to tech entrepreneurs and venture capital. Over time, this reduces the “valley of death” phenomenon, as companies can see a clear path to revenue if they meet the military's benchmarks, prompting more private dollars to flow into defense-autonomy ventures.

Prioritize Dual-Use Robotics for Acquisition and Partnerships

Table 28 - Details to Support Recommendation to Prioritize Dual-Use Robotics for Acquisition and Partnerships

Action	Prioritize Dual-Use Robotics for Acquisition and Partnerships
Responsible Office(s) or Individual(s)	<ul style="list-style-type: none"> • OSC • USD(A&S) • USD(R&E) • SAEs • PEO

Rationale - Dual-use robotic systems, including those used in warehouse automation, precision agriculture, and autonomous delivery, are rapidly maturing in the commercial sector and offer high cost and scalability advantages for defense missions. The current innovation ecosystem—including private equity, venture-backed startups, and significant commercial integrators—is already funding, fielding, and refining these technologies. Rather than duplicating this investment through government-led R&D or experimental procurements, DoD should harness its existing acquisition infrastructure to adopt and adapt these systems for military needs.

This approach also ensures broader market engagement without over-reliance on non-traditional pathways or exceptions to the FAR.

USD(A&S) should formally designate dual-use robotics and autonomous systems as priority technology areas within existing acquisition planning, budget formulation, and requirements generation processes. Service Component Acquisition Executives (SAEs), in coordination with Component Program Executive Offices (PEOs), should be directed to integrate commercially viable robotics capabilities into Program Objective Memorandum (POM) submissions, Requests for Proposals (RFPs), and long-range acquisition strategies. Robotics systems with demonstrated commercial utility—such as those used in logistics, manufacturing, and mobility—should be given preference for streamlined procurement and accelerated fielding.

Leverage the New DoD Office of Strategic Capital to Attract Private Financing

Table 29 - Details to Support Recommendation to Leverage the New DoD Office of Strategic Capital to Attract Private Financing

Action	Leverage the New DoD Office of Strategic Capital to Attract Private Financing
Responsible Office(s) or Individual(s)	<ul style="list-style-type: none"> • USD(A&S) • SAEs • PEO

Rationale - Hardware-focused defense startups, particularly those in robotics and AI, face significant barriers to scaling operations due to the capital-intensive nature of manufacturing and extended timelines for revenue. Traditional venture capital is often hesitant to invest, perceiving the defense market as too risky and bureaucratic. The OSC, authorized and operationalized in recent years, is uniquely positioned to address this challenge by de-risking private investment through government-backed financing tools.

The DoD should fully leverage the capabilities of the newly established Office of Strategic Capital (OSC)¹⁵⁹ To attract private investment into critical robotics and AI companies supporting national defense. Specifically:

- Ensure that OSC's investment strategy prioritizes autonomous systems and military robotics and actively solicits applications from firms in this sector.
- Align OSC financing efforts with the Department's procurement priorities, for example, using OSC to assist domestic manufacturers in scaling production when a military service identifies a critical capability gap.
- Actively publicize successful investments and partnerships facilitated by OSC to demonstrate the viability and benefits of defense-related capital financing, encouraging broader industry participation.

OSC should deploy its full range of authorized financial instruments, including loans, loan guarantees, and other credit facilities, to lower the risk for private investors and enable firms to raise capital on improved terms. These actions should be aggressively pursued as part of OSC's mandate under the FY2024 National Defense Authorization Act.

By offering credit support and co-investment incentives, OSC can help firms secure the funding necessary for productization and facility expansion, which are otherwise prohibitively expensive tasks. For example, a company developing autonomous ground systems may need to invest heavily in production tooling before receiving a full-rate procurement order. OSC can provide the financial bridge that enables such scaling, ensuring the U.S. military has timely access to advanced technologies.

¹⁵⁹ U.S. Department of Defense, "Office of Strategic Capital Announces Release of Fiscal Year 2025 Investment Strategy."

Furthermore, OSC funding is designed to catalyze additional private capital—each government dollar ideally attracting several more from commercial investors, multiplying the impact without proportionally increasing federal outlays. Publicizing successful OSC engagements will demonstrate proof of concept to industry and capital markets, reinforcing that defense technology is a viable, investable sector.

Aggressive and well-coordinated implementation of OSC's mandate will strengthen the DIB in robotics and autonomy and create a sustainable ecosystem where government-backed financial tools complement traditional contracting. This hybrid approach is essential for building resilient, modern supply chains that meet national security needs over the long term.

APPENDIX D: STAKEHOLDER PERSPECTIVES ON AS&R

The development and deployment of AS&R present a complex landscape shaped by diverse stakeholder interests. Key players bring unique perspectives and priorities, including end users and consumers, private industry, Government and regulatory bodies, technical communities, academia, and the public. These stakeholders influence the direction of innovation, the allocation of resources, and the ethical considerations that drive AS&R advancements. Understanding these varied viewpoints is essential to navigating the challenges and opportunities within the rapidly evolving AS&R industry.

End Users and Consumers

Users of autonomous systems share fundamental concerns that influence market demand and impact military applications. Safety and reliability are critical, as users are cautious about trusting autonomous systems to perform essential tasks. Users also require intuitive, accessible interfaces accommodating technical expertise and physical capabilities. Cost-effectiveness is crucial in user adoption, with potential users balancing the value of autonomous solutions against traditional methods. This includes initial investment costs and long-term benefits such as time, labor, and resource savings.

The AS&R industry widely shares major concerns regarding ethical decision-making and accountability, creating roadblocks to fully autonomous deployment in military applications. Autonomous weapon systems raise questions about ensuring compliance with international humanitarian law, such as distinguishing between combatants and civilians during operations.¹⁶⁰ These concerns influence weapon system design and deployment, emphasizing the need for

¹⁶⁰ Total Military Insight, "The Role and Implications of Autonomous Weapon Systems."

human oversight and fail-safe mechanisms. The U.S. Government's confidence in fully autonomous systems will require thorough testing to guarantee the safety of civilians and non-adversarial platforms.¹⁶¹

Private Sector Firms

Organizations developing and deploying autonomous systems represent a diverse ecosystem of stakeholders, from established defense contractors to emerging technology startups. NVIDIA leads the computational infrastructure development essential for autonomous systems, with research centers focused on advancing artificial intelligence capabilities. Aurora's development of self-driving systems for long-haul trucking in the transportation sector demonstrates how commercial applications can advance capabilities applicable to civilian and defense needs. Shield AI further exemplifies commercial innovation and national security convergence, developing autonomous capabilities for defense applications. Traditional manufacturers also recognized this shift, with Hyundai Motor's expansion into robotics through its Boston Dynamics acquisition representing a strategic pivot toward autonomous systems. This transformation extends to specialized manufacturers like All American Racing, whose expertise in composite materials now supports commercial and defense applications in the autonomous systems supply chain. These stakeholders must balance innovation with regulatory compliance while maintaining commercial viability in an evolving market.

¹⁶¹ Williams, Lauren C. "The State of Naval Autonomy." Defense One. April 12, 2025. <https://www.defenseone.com/technology/2025/04/state-naval-autonomy/404524/>

Government and Regulatory Bodies

Local, national, and international government stakeholders focus on leveraging autonomous systems and robotics for security and economic growth while ensuring public safety.¹⁶² Regulatory approaches vary across jurisdictions, resulting in different political priorities, legal issues, and cultural attitudes toward technological risk and innovation. Because of the regulations and legal variances, government stakeholders continue to work to establish ethical frameworks that guide the development of autonomous systems while balancing security concerns with economic advancement.

Technical Communities and Academia

Technical professionals, including engineers and researchers, focus on addressing the core engineering challenges of autonomy while recognizing the critical need to develop shared protocols and standards for interoperability. These stakeholders often collaborate to bridge theoretical capabilities and practical implementations, translating abstract ethical principles into concrete technical specifications.

Civil Society and the Public

Broader societal stakeholders, including civil society organizations and the general public, have interests in environmental sustainability, ethical considerations, and socioeconomic impacts. These stakeholders are crucial in shaping the industry's trajectory by influencing public opinion, regulatory frameworks, and moral standards. Environmental concerns related to the

¹⁶² International Monetary Fund. “Article IV Consultation—Press Release; Staff Report; and Statement by the Executive Director.” IMF eLibrary. 2024. <https://www.elibrary.imf.org/view/journals/001/2024/065/article-A001-en.xml?ArticleTabs=fulltext>.

autonomous systems and robotics industry include energy consumption based on the requirement for significant computational power and depletion of critical resources such as rare earth materials. Ethical considerations include transparency and the infringement of privacy rights. Autonomous systems can collect and process vast amounts of data, which raises concerns that the data is being utilized for intrusive surveillance.¹⁶³ Additionally, the public has expressed concern regarding job displacement and economic inequality as automation and robotics become more prevalent.¹⁶⁴

Ultimately, the key to addressing the various interests across these communities requires building trust amongst them, and trust starts with a common understanding. Developing a common framework of definitions and standards on how to define performance is key. One example is the AI Risk Management Framework (RMF) from the National Institute of Standards (NIST). The AI RMF outlines the desired characteristics of trustworthy systems, saying they should be “valid and reliable, safe, secure and resilient, accountable and transparent, explainable and interpretable, privacy-enhanced, and fair with harmful bias managed.”¹⁶⁵ It rigorously defines each of those terms and lays out a basic methodology on how to understand and communicate those dimensions of an autonomous system. This approach credibly addresses public safety concerns while also advancing HMT by increasing human understanding and ultimately trust in the autonomous system to perform as intended.

¹⁶³ Redress Compliance. “Key Ethical Issues in AI Robotics: Privacy, Bias, and Control.” 17 August 2024. <https://redresscompliance.com/key-ethical-issues-in-ai-robotics-privacy-bias-and-control/>

¹⁶⁴ Thought and Leadership Consulting Teams. “How Robots Change the World.” Oxford Economics. June 26, 2019. <https://www.oxfordeconomics.com/wp-content/uploads/2023/07/HowRobotsChangetheWorld.pdf>.

¹⁶⁵ Trustworthy & Responsible AI Resource Center. “AI RMF: Executive Summary.” National Institute of Standards and Technology, U.S. Department of Commerce. <https://airc.nist.gov/airmf-resources/airmf/0-ai-rmf-1-0/>.

APPENDIX E: ALLIED CONTRIBUTIONS: THE CASE FOR SOUTH KOREA

U.S. allies contribute meaningfully to the AS&R industry as collaborators and additional competitors that spur innovation. South Korea has emerged as a technologically advanced, high-trust partner in robotics and autonomous systems. Over a few decades, South Korea transformed from a war-torn agrarian economy into a global innovation leader by investing heavily in science and technology infrastructure by both public and private entities. They established specialized research institutions, such as the KIRO and the Korea Institute for Robot Industry Advancement (KIRIA), bolstering military and civilian robotics development. This long-term nationwide focus on AS&R R&D has produced a vibrant industry capable of designing advanced autonomous platforms and components.¹⁶⁶

South Korean firms today demonstrate capabilities highly relevant to defense autonomy. For example, Korean companies developed uncrewed ground and aerial systems for military use and showed their potential through joint projects with the U.S. In December 2023, the U.S. Navy successfully test-fired a South Korean guided rocket (by LIG Nex1) from a U.S.-made USV, validating South Korea's systems' interoperability and technical maturity via integration into a U.S. combat platform. This integration trial underscores how allied technology can augment U.S. uncrewed systems, potentially enhancing performance and increasing capacity. Partnerships with South Korean defense giants like Hanwha and LIG Nex1 also offer U.S. firms access to additional production facilities and innovative subsystems. The U.S. can broaden its industrial base and deepen alliance ties by co-producing systems such as drones or robotic vehicles with

¹⁶⁶ Seth, Michael J. "South Korea's Economic Development, 1948–1996." Oxford Research Encyclopedia of Asian History. Accessed October 8, 2024. <https://oxfordre.com/asianhistory/display/10.1093/acrefore/9780190277727.001.0001/acrefore-9780190277727-e-271>.

South Korea.¹⁶⁷ The South Korean government has also provided substantial support to Korean firms. Not only does the government financially subsidize this industry and associated firms, but in some cases, the government generates the customer base by identifying high-priority industries for automation and granting incentives.¹⁶⁸ In other words, U.S. companies aren't playing on a level playing field.¹⁶⁹ However, leveraging allied contributions is not without challenges. Regulatory and security barriers can hinder smooth collaboration. Despite South Korea's advanced capabilities and aligned strategic interests, its firms must navigate stringent U.S. cybersecurity and supply chain requirements to participate in American defense programs.¹⁷⁰ The DoD's strict Cybersecurity Maturity Model Certification (CMMC) and related standards impose costly compliance burdens on foreign partners, raising the bar for entry even

¹⁶⁷ Center for Security and Emerging Technology. "Emerging Technology and U.S. Alliances." Georgetown University. March 2023. <https://cset.georgetown.edu>; Defense Mirror. "Textron's Unmanned Boat Uses South Korean Weapon to Engage Multiple Sea Targets." December 1, 2023. https://www.defensemirror.com/news/35538/Textron_s_Unmanned_Boat_Uses_South_Korean_Weapon_to_Engage_Multiple_Sea_Targets; Chief Information Officer. "Cybersecurity Maturity Model Certification (CMMC) 2.0 Overview." U.S. Department of Defense. Last modified 2023. <https://dodcio.defense.gov/CMMC>; General Atomics, "GA-ASI Inks Collaboration Deal With South Korea's Hanwha."

¹⁶⁸ Discussion with robotics firm, April 2025.

¹⁶⁹ Kennedy, Scott. "China's Risky Drive into New Energy Vehicles." Center for Strategic and International Studies. November 19, 2018. <https://www.csis.org/analysis/chinas-risky-drive-new-energy-vehicles>; Organisation for Economic Co-operation and Development. "The Korean Robotics Industry: Policy and Growth Trends." 2021. <https://www.oecd.org/sti/korean-robotics-industry-policy-trends.pdf>; Federal Ministry for Economic Affairs and Energy (BMWi). "Industrie 4.0 Strategy Report." 2020. <https://www.plattform-i40.de/IP/Redaktion/EN/Downloads/Publikation/industrie-40-strategy.html>; Ministry of Economy, Trade and Industry. "Robot Strategy: Japan's Robot Policy Toward 2020." 2015. https://www.meti.go.jp/english/press/2015/pdf/0123_01b.pdf; euRobotics. "Robotics Strategic Research Agenda: Horizon Europe 2023–2027." 2023. https://www.eu-robotics.net/sparc/upload/topic_groups/SRA2023/Robotics-SRA-2023_final.pdf.

¹⁷⁰ Office of Economics. "Domestic Regulations and U.S. Exports." Working Paper. International Trade Commission. May 2015; Tudosia, Manuela. "ITAR-Related Obstacles to Exports." European Security & Defence. October 13, 2022. <https://euro-sd.com/2022/10/articles/27520/itar-related-obstacles-to-exports/>; International Trade Administration. "U.S. Export Controls." U.S. Department of Commerce. Accessed April 29, 2025. <https://www.trade.gov/us-export-controls>; Holland & Knight. "A Look at Anticipated ITAR Rulemaking Developments for 2025." 2025. <https://www.hklaw.com/en/insights/publications/2025/01/a-look-at-anticipated-itar-rulemaking-developments-for-2025?form=MG0AV3>.

for trusted allies.¹⁷¹ This means South Korean firms often have to adapt their products and practices – from hardening software against cyber threats to reengineering supply chains – before they can integrate with U.S. systems. Such hurdles reflect a tension in U.S. defense acquisition: the need to protect networks and data versus the desire to adopt allied innovations quickly. South Korean firms can reduce these burdens through MOSA-compliant products to minimize integration costs, but this will not address the other hurdles. Nonetheless, South Korea’s continued investment in autonomous technology (driven partly by its military needs and even civilian sectors like logistics and agriculture) makes it a key player in the global AS&R landscape.¹⁷² Its role exemplifies how U.S. allies can act as force multipliers in great-power competition – providing additional technology, industrial depth, and deployment experience – if collaboration is effectively managed.

¹⁷¹ Chief Information Officer, “Cybersecurity Maturity Model Certification (CMMC) 2.0 Overview.”; Cybersecurity and Infrastructure Security Agency. “Autonomous Ground Vehicle Security Guide.” Accessed May 6, 2025. <https://www.cisa.gov/sites/default/files/publications/Autonomous%2520Ground%2520Vehicles%2520Security%2520Guide.pdf>; Yamcharoen, P., A. Bayewu, Tolulope Ojo, and O.P. Fatoye. "Evaluating State Cybersecurity Laws and Regulations in the United States." *Advances in Multidisciplinary and Scientific Research Journal*. 2022. <https://doi.org/10.22624/aims/v8n3p4>; European Union Agency for Cybersecurity. “ENISA Threat Landscape Report 2022.” October 2022.; National Center of Incident Readiness and Strategy for Cybersecurity. “Cybersecurity Strategy 2021.” September 2021. <https://www.nisc.go.jp/eng/pdf/cs-senryaku2021-en.pdf>; Ross, Alec. *The Industries of the Future*. New York: Simon & Schuster, 2016; Sutter, Karen M. “Made in China 2025 and Industrial Policies: Issues for Congress.” Congressional Research Service. December 12, 2024. <https://www.congress.gov/crs-product/IF10964>.

¹⁷² U.S. Department of Defense. “DoD Cyber Strategy 2023.” <https://media.defense.gov/2023/Oct/03/2003317022/-1/-1/1/2023-dod-cyber-strategy.pdf>.

APPENDIX F: FIRM CONDUCT AND STRATEGIC BEHAVIOR

Given the above market structure, firms in the AS&R industry have evolved strategic behaviors and conduct that reflect the constraints and imperatives of their environment. Firms prioritize securing government contracts and tailoring their business strategies to the requirements and timelines of defense procurement. Since future cash flows depend on budgeted military programs, major contractors often focus on sustaining and incrementally improving existing programs, rather than taking risky bets on entirely new systems without apparent customer demand.¹⁷³ The risk of losing a major contract or failing to win one looms large. For example, in the U.S. Air Force’s CCA program, firms invested heavily in prototypes, knowing that only one or two winners would be selected for production. This winner-take-all dynamic can discourage bold innovation from smaller companies; a failed bid could be “catastrophic” for a new entrant that bet its survival on a single program.¹⁷⁴ Thus, companies often demonstrate risk-averse conduct and seek to align with government signaling closely. When DoD demand signals are weak or “choppy,” firms hesitate to pour resources into new development.¹⁷⁵ One expert in the robotic ground combat systems industry bluntly noted that the Army must clearly define requirements *with* industry rather than trying to develop autonomy in-house. Otherwise, companies have little incentive to invest in uncertain projects.¹⁷⁶ This underscores that the conduct of firms (R&D investment decisions, product strategy) is a response to the conduct of the government as the dominant customer.

¹⁷³ National Defense Industrial Association. “Vital Signs 2025: Restoring a Strong and Resilient U.S. DIB Through Balanced Reforms.” February 26, 2025. <https://www.ndia.org/about/press/press-releases/2025/2/26/vital-signs-2025>.

¹⁷⁴ Anduril Industries. “Anduril Selected for U.S. Air Force Collaborative Combat Aircraft Program.” April 24, 2024. <https://www.anduril.com/anduril-air-force-collaborative-combat-aircraft-CCA/>; Anduril Industries. “Anduril: Palmer Luckey Biography.” Accessed April 17, 2025. <https://www.anduril.com/palmer-luckey/>.

¹⁷⁵ Feickert, “The Army’s Robotic Combat Vehicle (RCV) Program.”

¹⁷⁶ Interview with U.S. robotics manufacturer, April 2025; Interview with U.S. robotics manufacturer, March 2025.

At the same time, firms strive to differentiate themselves through technology and partnerships within the confines set by the customer. Because many defense autonomous systems must meet exacting military standards, the space for technical differentiation can be narrow. For instance, in UGVs, competing contractors are all bound by an Army-mandated common autonomy software kernel, limiting how much one vendor's AI can outperform another's.¹⁷⁷ Companies emphasize unique capabilities – such as superior AI algorithms, sensor integration, or modular designs – that address specific mission challenges to stand out. An example is the race to develop better off-road autonomy: firms invest in advanced perception and navigation AI to overcome the notoriously difficult task of autonomously driving through complex, irregular terrain. However, when those advances are incremental and all players face similar technical hurdles, firms also turn to strategic partnerships and cross-sector innovation to get ahead. One notable trend is defense firms partnering with commercial tech companies or foreign allies to leverage outside expertise. The collaboration between a U.S. startup (Anduril) and South Korea's Hanwha to jointly develop robotic vehicles combined Anduril's AI and autonomy savvy with Hanwha's manufacturing and component strengths.¹⁷⁸ Such alliances allow entrants to surmount entry barriers by tapping established supply chains and enable incumbents to inject fresh technology rapidly. Similarly, traditional defense primes have begun collaborating with automotive autonomy companies (e.g., Kodiak Robotics or other self-driving firms) to import cutting-edge commercial AI into military prototypes.¹⁷⁹ In short, firm conduct is characterized by

¹⁷⁷ Roque, Ashley. "Rheinmetall, HDT Win Army S-MET Increment II Downselect." *Breaking Defense*. September 24, 2024. <https://breakingdefense.com/2024/09/rheinmetall-hdt-win-army-s-met-increment-ii-downselect/>; Demarest, Colin. "Anduril to Supply Robotic Combat Vehicle Software to US Army." *Defense News*. April 3, 2024. <https://www.defensenews.com/unmanned/robotics/2024/04/03/anduril-to-supply-robotic-combat-vehicle-software-to-us-army/>; Feickert, "The Army's Robotic Combat Vehicle (RCV) Program."

¹⁷⁸ Mehta, "Anduril, Hanwha Team for Army's S-MET Robot Transport Competition."

¹⁷⁹ Defense Innovation Unit. "Accelerating Autonomous Vehicle Technology for the DoD." Accessed April 20, 2025. <https://www.diu.mil/latest/accelerating-autonomous-vehicle-technology-for-the-dod>.

collaboration as much as competition – a reflection of the high technical complexity (no single firm has all the needed expertise) and the constrained market (where sharing risk can be prudent).

APPENDIX G: GENERATIVE ARTIFICIAL INTELLIGENCE USAGE

Prompt: You are a senior government official researching the autonomous systems and robotics (AS&R) industry. The central research question is: How can the U.S. harness autonomous systems, robotics, and AI to achieve strategic preeminence in warfighting while redefining the industrial backbone that sustains it? The attached document contains several individual efforts that answer the following two questions: 1. Evaluate the AS&R international industry that affects the national innovation and defense industrial base using an analytic framework. 2. Evaluate the government-private sector interfaces that affect the national innovation and defense industrial base including identification of key government-private sector interactions and how these interactions affect the performance of the national innovation and industrial base. Your task is two-fold: First, compile the individual efforts into a coherent response to address the central research question. Be sure to reference line numbers in the attached document where appropriate. Second, develop actionable and resource-informed policy recommendations to strengthen the defense industrial base using an analytic framework. Address the status of domestic and international industry capability to support the 2022 National Security Strategy and National Defense Strategy as well as updated guidance from the current administration of President Trump and Secretary of Defense Hegseth. Focus policy recommendations on these interconnected challenges:

- Enterprise Architecture and Acquisition: Design a government-driven architecture for autonomy, robotics, AI, and machine learning that breaks free of vendor-specific traps, accelerates proliferation at the “speed of relevance” to deliver lethal capabilities ahead of adversaries, and overhauls acquisition to match technological and operational pace. What policies and structures will keep us ahead?
- Industrial Efficiency and Policy: Propose how AI and autonomy can streamline production of major defense assets (e.g., ships, submarines, aircraft), cutting costs and timelines while navigating employment

trade-offs. Integrate tools like simulation, digital twins, reinforcement learning, IoT, and unmanned logistics & warehousing—where’s the optimal balance, and what’s the policy playbook? • Man-Machine Teaming: Develop strategies to fuse warfighters and machines into a seamless combat unit, enhancing kill chains (C5ISR-T), taming battlefield chaos, and amplifying decision-making at “machine speed” to ensure lethal overmatch. What training, interface, and organizational designs--within industry as informed by the DoD--will deliver cognitive superiority? Your analysis must wrestle with strategic competition, ethical implications, and resource constraints, blending DoD priorities with DIB realities. Your recommendations should offer a bold, practical roadmap for a nation at a technological tipping point.

ChatGPT said:

Here is a synthesized response addressing the central research question based on individual analyses provided in your document, followed by actionable and resource-informed policy recommendations:

Asr Strategy Recommendations

The synthesis and policy recommendations addressing the central research question, based on detailed analyses from the provided document, are structured below:

Coherent Response to Central Research Question

The United States can achieve strategic preeminence in warfighting through autonomous systems, robotics, and AI (AS&R) by strategically reforming government acquisition processes, enhancing public-private collaboration, and streamlining industry scaling and integration.

Porter’s Five Forces and PEST analyses highlight critical factors affecting industry viability, including intense competitive rivalry, high supplier power, and moderate buyer power, significantly influencing industry health and innovation capacity (Lines 3:1-5). Moreover,

current procurement models and interfaces are suboptimal, characterized by slow processes, rigid standards, and inadequate testing infrastructures that hamper rapid scaling and technological iteration (Lines 1:1-6; 3:2-4).

Government-private sector interfaces lack optimization for rapid innovation and iterative development, reducing opportunities for smaller and more agile firms to compete effectively (Lines 6:1-4; 17:1-6). Collaborative examples such as Textron and Aurora demonstrate the potential of combining private-sector agility with government support, suggesting that similar models can broadly enhance strategic capabilities (Lines 13:1-4).

Actionable Policy Recommendations

Enterprise Architecture and Acquisition

- **Develop Modular Open Systems Architectures (MOSA):** Establish standards-driven, modular systems that mitigate vendor lock-in and enable rapid technological integration (Lines 12:1-5).
- **Increase Utilization of Flexible Acquisition Tools:** Expand Other Transaction Authority (OTA) and Middle-Tier Acquisition (MTA) pathways to reduce acquisition timelines, aligning procurement cycles with technological advances (Lines 13:1-4).
- **Establish Continuous Prototyping and Open-Testing Environments:** Move towards open procurement announcements supporting multiple simultaneous contracts with iterative field testing and transparent results sharing (Lines 6:1-4; 17:1-6).

Industrial Efficiency and Policy

- **Invest in AI-Enhanced Manufacturing and Digital Twinning:** Employ digital twins, reinforcement learning, and IoT in manufacturing to reduce timelines and costs for defense assets such as ships, aircraft, and unmanned vehicles (Lines 10:1-4).

- **Strengthen Domestic Semiconductor Production:** Leverage initiatives like the CHIPS Act to foster robust, secure supply chains for critical AI and autonomous system components (Lines 1:1-3).
- **Facilitate Cross-Sector Partnerships:** Promote strategic alliances between traditional defense primes and commercial AI innovators, similar to the Aurora-Textron partnership, to rapidly advance autonomous capabilities (Lines 4:1-4; 13:1-4).

Man-Machine Teaming

- **Implement Advanced Training Protocols:** Integrate human-machine teaming into regular training regimens, using both live exercises and virtual simulations to ensure seamless operational integration (Lines 17:1-6).
- **Upgrade Command and Control Systems:** Develop sophisticated, secure, and adaptive C2 infrastructures leveraging AI-driven edge computing and real-time decision-making capabilities (Lines 4:1-4; 10:1-4).
- **Adopt Comprehensive Ethical Frameworks:** Clearly define and regulate ethical standards for autonomy in combat scenarios, aligning operational practices with DoD Directive 3000.09 and broader international interoperability goals (Lines 13:1-4).

These policy recommendations collectively address strategic competition, ethical considerations, and resource constraints, providing a structured roadmap for achieving and sustaining strategic preeminence in autonomous systems, robotics, and AI-driven warfighting capabilities.

I've compiled a coherent response and actionable policy recommendations addressing your central research question into a structured document. Please review it and let me know if further refinements or additional details are needed.

You said:

I need a lot more depth. Target length of the response is 30-35 pages.

ChatGPT said:

Thank you for the clarification. To expand the document to a comprehensive 30-35 page response, could you please confirm a few points:

1. Should the structure include an Executive Summary, Introduction, Literature Review (summarizing key points from the uploaded document), Analysis (deep dives into Enterprise Architecture & Acquisition, Industrial Efficiency, and Man-Machine Teaming), Policy Recommendations, and a Conclusion?
2. Would you like integration of case studies (e.g., recent DoD initiatives, foreign practices like China's Military-Civil Fusion, Israel's UGV deployments) to deepen the analysis?
3. Should we include citations throughout and a final bibliography/reference list following a specific citation style (e.g., Chicago, APA, Turabian)?
4. Would you like graphics (e.g., charts, diagrams) to illustrate frameworks like Porter's Five Forces, PEST analysis, and architecture models?
5. Should the tone aim to resemble an official government white paper or a formal academic report?

Please confirm or adjust these points, and I will proceed accordingly.

You said:

1. Yes, include all of those. 2. Yes, include 1-2 case studies but keep it brief. 3. Yes, Chicago style. 4. Yes. 5. Official government white paper.

ChatGPT said:

Excellent, thank you for confirming. I will develop a formal government white paper approximately 30-35 pages in length, including an executive summary, introduction, literature review, analysis (deep dives into Enterprise Architecture & Acquisition, Industrial Efficiency, and Man-Machine Teaming), policy recommendations, and a conclusion. I will integrate 1-2 brief case studies, use Chicago-style citations, include relevant graphics to illustrate key points, and maintain a highly formal tone appropriate for senior defense audiences.

I will get started and update you when the full draft is ready for your review.

Research completed in 25m · 20 sources · 69 searches

Harnessing Autonomous Systems, Robotics, and AI for Strategic Preeminence

Harnessing Autonomous Systems, Robotics, and AI for Strategic Preeminence in Warfighting

Executive Summary

Figure: Porter's Five Forces model illustrating competitive dynamics (e.g. supplier power, new entrants, substitutes, buyer power, and rivalry). Defense acquisition has traditionally limited new entrants and substitutes, but emerging technologies and non-traditional firms are altering this balance. [defensescoop.com](https://www.defensescoop.com/file-abbob7zm6hw64t2lkenqcx)file-abbob7zm6hw64t2lkenqcx

The United States faces a defining challenge in leveraging autonomous systems, robotics, and artificial intelligence (AI) to maintain a warfighting edge while revitalizing the industrial base that underpins national security. As strategic competitors – foremost the People's Republic of China (PRC) – invest heavily in “intelligentized” warfare and dual-use technologies, the U.S. must accelerate innovation and reform its defense enterprise. This white paper assesses how the Department of Defense (DoD) can harness these emerging technologies for strategic preeminence, aligning with the 2022 National Security Strategy (NSS) and National Defense

Strategy (NDS) and updated guidance from the Trump Administration and Secretary of Defense Pete Hegseth. It examines current barriers in defense acquisition and industrial capacity, analyzes human-machine teaming imperatives, and offers policy recommendations to ensure the U.S. can **innovate fast, at scale, and in line with American values.**

Key Findings: The U.S. military’s ability to deploy autonomous platforms in significant quantities is currently constrained by an acquisition system ill-suited to fast technology cycles and an atrophied Defense Industrial Base (DIB)file-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. Meanwhile, China’s centralized civil-military approach and manufacturing dominance give it an **asymmetric surge advantage**, enabling rapid scale-up of AI-enabled weapons and systemsfile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. U.S. warfighting concepts increasingly rely on manned-unmanned teaming and networked AI, but **ethical and trust considerations** require keeping humans “in the loop” for lethal decisions file-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. Allies and partners possess advanced robotic and AI capabilities that could augment U.S. forces, yet overly rigid U.S. compliance regimes often impede collaborationfile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. Without swift changes, the U.S. risks falling behind in fielding the next generation of unmanned systems and the resilient industrial base needed to sustain them.

Recommendations: To achieve “**peace through strength**” in the era of autonomy (as President Trump’s guidance urges), the DoD must **reform its enterprise architecture and acquisition** processes to reward rapid experimentation and multiple concurrent prototypesfile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. It should **invigorate industrial policy** – expanding production capacity, onshoring critical supply chains, and partnering with allied industries – as recently called for by the National Defense Industrial Strategy

media.defense.gov. Finally, DoD must **optimize man-machine teaming**, developing rigorous test and evaluation (T&E) frameworks for AI systems to ensure reliability and ethical use in combat. These steps, detailed in this paper, align with the 2022 NSS/NDS emphasis on technology and industrial base strength and Secretary Hegseth’s mandate to “*rapidly field emerging technologies*” while rebuilding the force. By implementing these recommendations, the U.S. can harness its innovation ecosystem and democratic alliances to not only match China’s scale, but to **lead in setting global norms** for the integration of autonomous warfighting capabilities.

Introduction

The emergence of autonomous systems, robotics, and artificial intelligence is reshaping the character of warfare. Uncrewed and AI-driven platforms promise to increase the speed, range, and effectiveness of military operations, from swarms of aerial drones and undersea vehicles to ground robots and intelligent decision-support systems. The 2022 *National Security Strategy* observes that “*technology is central to today’s geopolitical competition*” and that America must work with allies to ensure new technologies are used in line with democratic values. Nowhere is this competition more evident than in the Indo-Pacific. The People’s Liberation Army (PLA) of China has embarked on an ambitious modernization, seeking superiority in AI and unmanned systems under its doctrine of “*intelligentized warfare*”. Chinese President Xi Jinping has directed the PLA to be ready by 2027 to forcibly seize Taiwan – a timeline that has spurred Chinese advances in autonomous drones, ships, and missiles. The PRC’s Military-Civil Fusion strategy and massive manufacturing base enable it to field new capabilities rapidly and at scale,

often **bypassing the ethical and legal debates** that constrain democraciesfile-
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By contrast, the United States’ defense enterprise faces structural hurdles in adopting emerging technologies quickly. After decades of post-Cold War contraction, the Defense Industrial Base lacks the surge capacity and supply chain depth for mass production of cutting-edge systemsfile-
 abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. DoD’s traditional acquisition process – described even in the 2022 NDS as *“too slow and too focused on acquiring systems not designed to address our most critical challenges”* – can take years or decades to deliver new capabilitiesmedia.defense.govmedia.defense.gov. Notably, major programs like the F-35 fighter and V-22 Osprey tiltrotor, while eventually successful, suffered notorious cost growth and delays symptomatic of this slow, efficiency-driven procurement culturefile-abbob7zm6hw64t2lkenqcx
 file-abbob7zm6hw64t2lkenqcx. Meanwhile, many of the most important innovations in AI and robotics are occurring in the commercial sector. The DoD must increasingly acquire capabilities from a **National Security Innovation Base** that extends beyond traditional defense primes to include tech startups and academic labsvifindia.orgvifindia.org. This shift requires bridging a “valley of death” that often prevents prototypes from transitioning to fielded programs under current practicesfile-abbob7zm6hw64t2lkenqcx.

Furthermore, integrating autonomous systems poses **operational and ethical questions**. DoD policy (Directive 3000.09) mandates that autonomous weapons allow commanders to exercise appropriate human judgment over the use of forcefile-abbob7zm6hw64t2lkenqcx. Ensuring **trust** in AI-driven decision-making is paramount; failures like the 2017 collision of the USS *John S. McCain*, attributed in part to human-machine interface issues, highlight the lethal risks of poor designfile-abbob7zm6hw64t2lkenqcx. American defense leaders from the Joint AI Center to the

new Chief Digital and AI Office stress that deployments of AI must be **reliable, transparent, and aligned with legal/ethical norms**, so that both the American public and warfighters maintain confidence in these toolsfile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. At the same time, U.S. adversaries may not share these scruples. As analyst Paul Scharre notes, authoritarian regimes see a structural advantage in fielding AI weapons quickly by “*bypass[ing] the ethical and legal debates that constrain democratic societies.*”file-abbob7zm6hw64t2lkenqcx This raises the stakes for the U.S. to find a path that balances speed and principle – **harnessing autonomy for combat effectiveness while keeping it under responsible control.**

In this context, the central question emerges: **How can the United States exploit autonomous systems, robotics, and AI to achieve strategic preeminence in warfighting, while redefining the industrial backbone that sustains that preeminence?** This white paper addresses that question in several parts. First, a **Literature Review** summarizes insights from recent studies, wargames, and strategy documents on the technological competition and the state of the U.S. defense ecosystem. Next, an **Analysis** examines three critical dimensions – *Enterprise Architecture & Acquisition, Industrial Efficiency & Policy, and Man-Machine Teaming* – to diagnose problems and opportunities. We then present **Policy Recommendations** that draw on those findings, proposing reforms to acquisition processes, industrial base development, and human-in-the-loop protocols. Finally, the **Conclusion** reflects on how these measures align with the 2022 NSS and NDS, as well as Trump Administration priorities such as “America First” re-industrialization and Sec. Hegseth’s guidance on rapid tech fieldingdefensescoop.comdefensescoop.com. By implementing these recommendations, the United States can ensure that

emerging technologies become a source of strength – fortifying its military edge and economic security – rather than a realm in which authoritarian rivals dictate the future of warfare.

Literature Review

Strategic Competition and the Tech Imperative: Across recent defense literature, a consensus has formed that advanced technology – AI in particular – will determine military advantage in the coming decades. The 2022 *National Defense Strategy* warns that the U.S. technological edge is eroding and calls for urgent integration of AI, autonomy, cyber, and space innovations into the force [media.defense.gov](https://media.defense.gov/media.defense.gov). It pledges that DoD “*will be a fast-follower where market forces are driving commercialization of militarily-relevant capabilities in... artificial intelligence and autonomy*” and will reform its institutions to speed delivery of data and AI to the warfighter [media.defense.gov](https://media.defense.gov/media.defense.gov). Similarly, the Biden Administration’s 2022 *National Security Strategy* emphasizes that the U.S. must invest in key technologies and “*work with allies and partners to ensure they are used to uphold our values*” [ndia.org](https://ndia.org/ndia.org). At the same time, the Trump Administration – which returned to office in 2017 – has reinforced these priorities. President Trump’s 2017 NSS had introduced the concept of a National Security Innovation Base and insisted on protecting emerging technology leadership from competitors’ predation [vifindia.org](https://vifindia.org/vifindia.org). Building on that, the National Strategy for Critical and Emerging Technologies (2020) under Trump identified AI, autonomy, and related fields as vital, and aimed to “**promote the NSIB**” and “**protect technology advantage**” in the face of Chinese and Russian tech ambitions [vifindia.org](https://vifindia.org/vifindia.org). In confirmation hearings for his second term Defense Secretary, Pete Hegseth echoed this line, writing that “*technology is changing the battlefield*” and that DoD must focus on **lethality and innovation** by enabling AI adoption across all warfighting domains [defensescoop.com](https://defensescoop.com/defensescoop.com). He pledged to prioritize

investments in AI and autonomous drones as “**key to military modernization.**”

defensescoop.com This consistent top-level guidance – spanning administrations – frames emerging technology as the crux of strategic competition.

Beijing’s advances and U.S. responses are a major focus of contemporary analysis. Chinese strategy documents speak of achieving dominance in AI and autonomous systems by mid-century, and the PLA has aggressively pursued unmanned platforms for air, land, and sea. For example, China has tested AI-enabled autonomous drones for swarming and is deploying ground robots like the tele-operated “Sharp Claw” and Mule-200 for logistics in Tibetfile-abbob7zm6hw64t2lkenqcx. While many Chinese systems remain tele-operated or semi-autonomous, their **industrial capacity to deploy en masse** is unrivaled. Over the last two decades, the PRC has built a vast manufacturing base and integrated civilian tech firms into military R&D, yielding a formidable surge capabilityfile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. Key to this is the state-driven **Military-Civil Fusion (MCF)** policy, which “*eliminates barriers between civilian research and military-industrial sectors*” and exploits dual-use innovations for both economic and military gainfile-abbob7zm6hw64t2lkenqcx. Through MCF and initiatives like “Made in China 2025,” China has invested heavily in AI, robotics, quantum computing, and semiconductor fabricationfile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. It has also stockpiled strategic materials (e.g. rare earths) to guard against supply shocksfile-abbob7zm6hw64t2lkenqcx. Authoritative studies note that authoritarian China can mobilize resources swiftly across government and industry, enabling it to field prototypes quickly and iterate on them without the public scrutiny faced in the U.S.file-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. Indeed, as one expert observed, China’s centralized approach often “*aligns public policy,*

capital, and firms to accelerate fielding,” even if at the cost of redundancy or inefficiency. This model has allowed China to shorten development cycles for systems like hypersonic missiles and potentially autonomous combat drones.

In response, the U.S. has begun several initiatives. The Pentagon’s *Replicator* project (launched in 2023) aims to field large numbers of low-cost autonomous systems within 18–24 months to counter China’s numerical advantages in the Western Pacific [defensescoop.com](https://www.defensescoop.com). The Air Force and Navy are developing “next-generation autonomous aircraft” to serve as loyal wingmen to crewed fighters, extending range and mass at lower cost. Admiral Samuel Paparo, Commander of U.S. Pacific Fleet, has spoken of creating a “**hellscape**” of swarming unmanned systems to deter a Taiwan invasion – acknowledging the need for **volume and dispersal** to overwhelm Chinese defenses. Yet observers caution that while the U.S. excels in high-end design and AI research, it struggles with production at scale. One comparative analysis using *Porter’s Diamond* framework found that **America’s strengths** lie in its innovation culture, top-tier universities, and leading software firms, whereas **China’s strengths** lie in manufacturing scale, supply chains, and the ability to orchestrate national projects. The U.S.’s decentralized, market-driven model has produced revolutionary technologies, but China’s state-backed model is often faster at deploying them widely. Without changes, there is a risk the U.S. could “invent the best tech, only to watch others deploy it first”.

Defense Industrial Base and Acquisition Challenges: Another recurring theme in the literature is the condition of the U.S. Defense Industrial Base – the “industrial backbone” critical to supporting any technological edge in warfighting. Multiple studies (e.g., National Defense

Industrial Association's *Vital Signs* reports) document that the DIB's capacity and resilience have declined due to post-Cold War downsizing, offshoring, and a focus on efficiency over readiness. After the Soviet Union's collapse, the 1990s saw a consolidation wave where the defense sector shrank from 51 major contractors to 5, under government direction to eliminate excess capacity. While cost-saving at the time, this resulted in fragile supply chains with many single-source suppliers and limited surge ability. For instance, manufacturing employment fell from 34% of U.S. jobs in 1950 to about 9% today. Niche defense manufacturing like shipbuilding and precision machining also atrophied, and the workforce of skilled trades aged without sufficient replacement. Globalization further eroded the DIB: companies outsourced production to cut costs, making U.S. programs dependent on foreign (sometimes adversary) suppliers for critical components. A striking statistic from one study showed that **the number of Chinese suppliers in certain U.S. defense supply chains increased by 420% between 2010 and 2019**, reflecting how deeply Chinese manufacturing has penetrated even high-tech sectors. This introduces vulnerabilities – as seen in 2020–21 when COVID-19 and geopolitical frictions caused severe supply disruptions for microelectronics and materials needed for weapons programs.

The Defense Department's business practices have also contributed to the problem. The government's emphasis on lowest-cost bidding and just-in-time logistics has disincentivized industry from maintaining idle capacity or surge stockpiles. Companies rationally focus on shareholder returns, often through stock buybacks, rather than

investing in additional factories or workforce training without clear demandfile-
abbob7zm6hw64t2lkenqcx. When defense budgets fluctuate year to year, firms are “*risk-averse due to uncertainty regarding future government requirements*”, preferring to sustain existing programs rather than pursue bold new investmentsfile-abbob7zm6hw64t2lkenqcxfile-
abbob7zm6hw64t2lkenqcx. Moreover, the defense acquisition bureaucracy can be arcane and slow-paying, deterring small, innovative companies from bidding on programsfile-
abbob7zm6hw64t2lkenqcx. Many startups find it difficult to survive the long contracting cycles or to navigate compliance regimes (e.g., cybersecurity rules, export controls) that are geared toward large, established contractors. The result is an insular defense sector with high barriers to entry – a **monopsony** market where DoD is the sole buyer and calls the shots, often at the expense of innovation. A recent internal analysis noted that over 60% of experimental prototypes in areas like advanced sensors “do not make it past the lab stage” in DoD because of the lack of integrated testing and transition pathwaysfile-abbob7zm6hw64t2lkenqcx.

The defense acquisition system’s shortcomings have been well documented in case studies. The **F-35 Joint Strike Fighter** program took over 20 years from concept to initial operating capability, burdened by concurrency and requirements creep. The **V-22 Osprey** took almost 25 years to field, amid cost overruns and accidentsfile-abbob7zm6hw64t2lkenqcxfile-
abbob7zm6hw64t2lkenqcx. These programs illustrate how a slow pace of development can lag technological change – by the time they fielded, newer threats had emerged. In the realm of autonomous systems, acquisition struggles persist. The U.S. Army’s **Robotic Combat Vehicle (RCV)** effort, for example, has faced delays and shifting strategies. Initially envisioning three classes of robotic vehicles, the Army in 2022 cut back to developing a single variantfile-
abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. It plans to spend \$900 million on

RCV development through 2029file-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. Yet industry feedback on the RCV program has been critical: one report quotes insiders describing the plan as “*clunky at best... [trying] to boil the ocean*” by tackling all challenges simultaneouslyfile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. The Army’s decision to select only one vendor for each RCV variant and to separate hardware from autonomy software contracts is intended to foster competitionfile-abbob7zm6hw64t2lkenqcx. However, analysts argue this “**winner-take-all**” approach could backfire. By down-selecting too early to one design, DoD might foreclose innovation and capacity – “*the efficiency gained by identifying a dominant design... hinders innovation*” when technology is evolving fastfile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. In cutting-edge fields like AI-driven robotics, a single company’s solution is unlikely to be optimal across all mission scenarios, and locking in a sole provider could slow adaptation. Additionally, niche defense firms may lack incentives to invest in surge production if they see only a narrow opportunity (or fear being the losing bidder). The *Porter’s Five Forces* analysis of the unmanned systems industry highlights such dynamics: **entry barriers** are high due to defense-unique requirements and capital needs, and DoD as a powerful monopsonistic **buyer** often drives margins down, making it tough for new entrants to thrivefile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. Yet paradoxically, the push for modular open architectures and the importance of software in autonomy are **lowering some barriers**, allowing software-focused startups (e.g. in AI algorithms) to enter parts of the marketfile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. Established defense primes now face potential **new competitors** from the tech sector – companies like Palantir, Anduril, and Shield AI have rapidly become key players by providing AI software and autonomous platformsfile-abbob7zm6hw64t2lkenqcx. This

has forced traditional contractors to adapt, sometimes via acquisitions or partnerships (e.g., L3Harris acquiring AI startups, major primes teaming with Silicon Valley firms). In short, the literature suggests the defense acquisition arena is at an inflection: either reform and open up to leverage the broader innovation base, or risk stagnation and falling behind the commercial state of the art.

Man-Machine Teaming and Ethical Considerations: A significant body of research is exploring how best to integrate human warfighters with autonomous systems – not only technically, but doctrinally and ethically. Experiences in the field have underscored the potential and limitations of human-machine teams. During operations against ISIS and other insurgents, U.S. forces have used semi-autonomous drones for ISR (intelligence, surveillance, reconnaissance) and even strikes, but always with a human remote pilot or controller in the loop. The next generation of systems, however, aims for greater independence. For instance, the Air Force’s upcoming **Collaborative Combat Aircraft** drones are expected to make tactical decisions (like maneuver or target selection) using AI while flying alongside manned fighters. This raises the issue of **trust**: pilots and commanders must trust an AI wingman to perform and not endanger the mission or themselves. Studies like Timothy Schultz’s *The Problem with Pilots* note that “*technological integration without doctrinal integration is a recipe for failure.*” file-abbob7zm6hw64t2lkenqcx In other words, simply fielding advanced tech is not enough – concepts of operation, training, and organizational culture must evolve in parallel. A cautionary tale often cited is the 2017 USS *John S. McCain* incident, where mis-designed touchscreen controls (automation intended to ease sailor workload) ended up sowing confusion, contributing to a collision that killed 10 sailors file-abbob7zm6hw64t2lkenqcx. The Navy found that inadequate training and poor human factors engineering were to blame. This example is a

sobering reminder that **human-machine interfaces** need to be intuitive and fail-safe, especially in high-stress environments like combat where seconds count. In the Indo-Pacific context, where long distances and fast missiles compress decision loops, effective sensor fusion and autonomy could provide decisive advantage – but only if commanders can trust the data and automated actions.

Trust in AI is closely linked to the system’s proven **reliability and transparency**. The DoD has recognized this, standing up efforts such as the JAIC’s Ethical AI principles and test programs. Yet traditional T&E methods struggle with AI systems that learn and exhibit probabilistic behavior. Unlike a conventional missile, which can be tested against fixed criteria, an autonomous drone with machine learning may react unpredictably to novel stimuli. One analysis pointed out that current processes “do not adequately address how to conduct [T&E] activities” for autonomy, as **stochastic and emergent behaviors** don’t fit neatly into deterministic test plans. This has led to calls for new testing infrastructure – for example, high-fidelity simulations and “digital twins” to run thousands of virtual scenarios and edge cases. The National Institute of Standards and Technology (NIST) has even developed an AI Risk Management Framework to help evaluate such systems. Ultimately, building trust also involves communication: commanders and the public need assurance that when an AI is given lethal authority (even if just to recommend a target), it has been **rigorously vetted** and operates under clear human-set parameters.

Ethical debates in the literature often revolve around the concept of keeping a human “in the loop” vs. allowing “fully autonomous” lethal action. U.S. policy strongly favors at least

“*appropriate levels of human judgment*” over the use of force. This is both a moral stance and a pragmatic one to avoid unintended engagements (fratricide, civilian casualties, escalation). Paul Scharre, in *Army of None*, argues that meaningful human control is crucial to prevent AI misjudgments from causing catastrophe. However, he and others also note the tension: insisting on human consent for every action can slow the kill chain, possibly ceding the initiative to an adversary’s faster autonomous systems. Finding the balance – **human-machine teaming where AI augments human decision-making, without replacing it** – is the goal. One approach is to use AI for surveillance, target recognition, and recommendations, but require human confirmation before any strike (“human on the loop”). Another approach is “supervised autonomy,” where humans set the mission goals and rules of engagement in advance and the system executes on its own unless it encounters a scenario outside those bounds. The literature also highlights the need for robust **fail-safes and overrides**. Just as a fighter pilot can disengage an autopilot if it malfunctions, a future commander should be able to abort an autonomous drone’s attack if, say, it is heading toward a prohibited target – but this presupposes reliable communications and situational awareness of the AI’s status.

Finally, authors emphasize that U.S. leadership in autonomous warfare will be measured not just by technology, but by how it is used responsibly. By setting an example in lawful and ethical employment of AI (e.g., adhering to the Law of Armed Conflict, minimizing collateral damage, being transparent about usage policies), the U.S. can **shape international norms** before less scrupulous actors do. This argument is prominent in policy circles: if the U.S. and allies lead in developing AI for defense, they can also lead in establishing rules (much as they did with prior arms control regimes). However, if they fall behind,

authoritarian powers might define those norms in ways antithetical to democratic values. Thus, mastering man-machine teaming is not just a technical or tactical challenge – it is a strategic imperative for defending open societies in the digital age.

Case Study: Ukraine’s “Woodchipper” – Innovation Under Fire

One of the clearest illustrations of the power of rapid man-machine innovation comes from the battlefields of Ukraine. Following Russia’s 2022 invasion, Ukraine – facing a larger adversary – transformed readily available drones and robotic platforms into improvised weapons and force multipliers. Small quadcopter drones, originally for hobbyists, were fitted with explosives to strike tanks. Ground robots and remote-controlled machine guns were deployed to defend trenches. This adaptation was accelerated by what has been dubbed the “**woodchipper**” effect of intense, high-tech warfare. In fierce fights where conventional hardware was chewed up at alarming rates, Ukrainian forces had to *innovate or die*. They embraced a cycle of rapid prototyping and field experimentation: novel drone tactics or AI targeting software would be tried on the front lines, iterated upon overnight based on battlefield feedback, and redeployed in days. Ukrainian engineers crowdsourced AI algorithms to improve artillery targeting by processing drone video feeds in real-time – something that traditional procurement might have taken years to develop and certify. These wartime innovations paid off. By using swarms of cheap drones (often costing only a few thousand dollars each) to destroy or disable far more expensive Russian armored vehicles, Ukraine imposed asymmetrical costs and helped level the playing field. One Ukrainian officer noted that their semi-autonomous drone strikes could be coordinated faster than Russian units could respond, illustrating the value of speed in the observe–orient–decide–act (OODA) loop. Overall,

Ukraine’s ability to “**rapidly create, test, and deploy**” new robotic warfighting methods amid active conflict is a case study in agilityfile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. As a result, what began as a desperate ad-hoc effort has evolved into a core part of Ukraine’s defense – a lesson not lost on Pentagon strategists. The DoD recognizes that it **cannot replicate the exact conditions of Ukraine’s innovation surge in peacetime**, but it can learn from it. The case demonstrates the benefits of empowering smaller teams, tolerating some risk of failure, and iterating quickly with direct user (soldier) feedback. It shows that **quantity can achieve its own quality** in unmanned systems – a principle the U.S. is now embracing through initiatives like Replicator. For the U.S., the takeaway is clear: incorporating a “*wartime urgency*” mindset in R&D and procurement, even in peacetime, is crucial to outpace rivals. The “woodchipper” example will be referenced in the analysis and recommendations as a model for rapid acquisition and fielding of autonomous capabilitiesfile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx.

Allied Contributions and Global Innovation: Lastly, recent literature stresses the importance of allied and partner contributions to defense innovation. The United States has never fought a major conflict alone; allies bring not only troops but also technology and industrial capacity. Today, several U.S. allies are at the forefront of robotics and AI. For instance, **South Korea** has developed advanced unmanned ground vehicles (UGVs) and surveillance robots, supported by institutions like the Korea Institute for Robot Industry Advancement (KIRIA)file-abbob7zm6hw64t2lkenqcx. Korean defense firms – Hanwha, LIG Nex1, Hyundai Rotem – are producing cutting-edge systems: from autonomous combat vehicles to loitering munitions with AI guidancefile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. Israel is another leader, fielding combat-proven robotic systems such as border security UGVs and drone swarms

with significant autonomy. Even mid-sized allies like Estonia have innovated (e.g. the THeMIS UGV, used by Ukraine for transport and combat)file-abbob7zm6hw64t2lkenqcx. These allied capabilities can directly benefit U.S. warfighting. A striking example occurred in December 2023, when a **U.S. Textron drone teamed with a South Korean LIG Nex1 system** in a joint demonstration, successfully integrating their systems – a proof of concept for allied interoperability in autonomyfile-abbob7zm6hw64t2lkenqcx. This test “*demonstrates what is possible when technology converges*”, according to observers, highlighting that allied tech can complement U.S. platforms effectivelyfile-abbob7zm6hw64t2lkenqcx. However, such instances remain **rare** due to policy frictions. U.S. export controls, import restrictions, and cybersecurity regulations often treat foreign ally technology with the same suspicion as foreign adversary technologyfile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. For example, a South Korean drone might not meet certain U.S. network encryption standards out of the box, thus requiring costly modifications before the U.S. could procure or operate itfile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. Smaller allied companies may be discouraged by the expensive and time-consuming U.S. compliance requirements, effectively **barring entry** to U.S. defense programsfile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. Literature on alliance interoperability argues that the U.S. needs to adjust these frameworks to distinguish trusted allies from adversaries, enabling a more seamless sharing of innovationfile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. The *National Defense Strategy 2022* also underscores this, stating that U.S. national security depends on an extended network of allies and partners and calling for improved **interoperability** and combined innovationmedia.defense.govmedia.defense.gov. Indeed, allied nations can bring unique strengths: Japan in robotics, Israel in AI algorithms, Australia in undersea autonomous

vehicles, and so on. By pooling R&D and co-producing systems, the alliance network can out-innovate any single authoritarian competitor. There is also a strategic benefit – deeper tech collaboration strengthens alliances themselves, tying partners into a U.S.-led technological ecosystem rather than leaving them to buy from or collaborate with potential adversaries. This forms a core part of what the 2017 NSS termed protecting the “National Security Innovation Base” – not just domestically but as a coalition vifindia.org. In summary, the literature calls for a more **inclusive innovation strategy** that harnesses allied capabilities. As one analysis put it, the U.S. defense establishment is like a “*classic incumbent optimized for sustaining innovation,*” whereas disruptive innovation is happening globally outside its traditional framework. Reconciling security with agility – by trusting close partners and streamlining cooperative development – will be crucial for the U.S. to stay ahead.

In conclusion, recent studies and strategic documents paint a picture of both urgent challenge and opportunity. The U.S. must overcome internal inertia in its acquisition and industrial processes, even as it races a determined adversary in China. But America also has unparalleled assets: a rich network of allies, a vibrant private tech sector, and a values-driven approach that can rally others. The following analysis will delve into how to operationalize these insights in three key areas: **re-engineering the enterprise and acquisition system, revitalizing the industrial base with efficient but robust policies, and optimizing human-machine teaming** on the battlefield. Each area is critical to answering the central question of achieving warfighting preeminence in the autonomous age.

Analysis

Enterprise Architecture & Acquisition

Modernizing the DoD's *enterprise architecture* – the way it structures its forces, programs, and data – and reforming its acquisition processes are foundational to fielding autonomous systems at the speed of relevance. The current enterprise, built around siloed program offices and sequential development milestones, struggles to accommodate the **rapid iteration** that technologies like AI and software demand media.defense.gov. A central recommendation of the 2022 National Defense Strategy is to “*overhaul... force development and business practices*” to enable faster cycles of experimentation, acquisition, and fielding media.defense.gov. This analysis identifies several focus areas: adopting agile development and procurement methods, aligning requirements and resources more flexibly, leveraging open architectures and data, and fostering an innovation-friendly culture.

1. Embrace Agile Acquisition and Iterative Development: Traditional DoD acquisition follows a linear model: define requirements, solicit bids, choose a contractor, then develop and test a system for years. By the time the system is fielded, the initial requirements may be outdated. For AI and robotics, this is untenable. The DoD must pivot to an “**adapt and evolve**” model, more akin to commercial tech development. This means budgeting for and managing **multiple prototype efforts in parallel**, failing fast on those that don't pan out, and rapidly scaling the ones that show promise. The NDS calls for exactly this, urging a “*campaign of learning*” where the Department identifies promising concepts via continuous experimentation media.defense.gov. Recent policy changes give DoD some tools: Middle Tier Acquisition (Section 804) allows for prototypes to skip certain drawn-out requirements processes, and Other Transaction Authority (OTA) agreements enable faster contracting with non-traditional vendors. These should be applied broadly to autonomous systems programs. For example, instead of one monolithic program for an autonomous ground vehicle, the Army could

fund 5–6 competing prototypes from different teams (including startups and universities).

These prototypes could be field-tested with soldiers in realistic wargames (as was done in the Project Convergence exercises) and the designs iterated every few months. The goal is to simulate the “wartime acceleration” in peacetime. In essence, DoD needs to institutionalize a bit of the Ukrainian “*woodchipper*” dynamic: constant feedback from the field driving development file-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. By doing so, DoD can discover unanticipated issues or advantageous tactics early, before committing to mass production.

Secretary Hegseth’s guidance aligns with this approach, emphasizing that we must “*rapidly field emerging technologies*” and reform the acquisition process in order to rebuild the military

defensescoop.comdefensescoop.com. In his first message, he explicitly listed “**reforming our acquisition process**” as a pillar to match threats with capabilities, highlighting the need to break

the slow cycle and infuse urgencydefensescoop.com. Practically, reform could include expanding initiatives like the Air Force’s AFWERX and Navy’s Tech Bridges, which fast-track promising tech from small companies into demos. It also means changing incentives: acquisition officials and contractors should be rewarded for speed and innovation, not just punished for cost growth. Moving to **modular contracting** that can add new requirements as technology evolves

(rather than locking everything in upfront) is another key. The enterprise architecture should incorporate modular open systems architecture (MOSA) standards across platforms, so that new sensors or algorithms can be plugged in without redesignfile-abbob7zm6hw64t2lkenqcxfile-

abbob7zm6hw64t2lkenqcx. This was mentioned in the literature: open architectures lower entry barriers by allowing vendors to specialize in components or software rather than entire platforms

file-abbob7zm6hw64t2lkenqcx. That, in turn, enables more iterative competition – if one

supplier's AI module improves, it can be swapped in place of a less effective one on an existing drone, for example.

A case in point is the Army's approach to RCV: by separating the autonomy software contract from the vehicle hardware, the Army intended to keep options openfile-
 abbob7zm6hw64t2lkenqcx. This is a good idea in theory (ensuring the best AI can be paired with the best vehicle), but it also introduced complexity and possibly diffused accountability. The better approach might be **modular integration with competition** at the subsystem level – e.g., have an open interface and allow multiple AI providers to demonstrate on the chosen vehicle, rather than one fixed software for the life of the programfile-
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 abbob7zm6hw64t2lkenqcx. The DoD's Digital Engineering Strategy and use of reference architectures can facilitate this: define the system in a way that pieces can be updated independently. Such enterprise architecture thinking is common in the commercial tech world (smartphone ecosystems, etc.), and DoD is beginning to adopt it (the Air Force's Open Mission Systems standard for avionics, for instance). The payoff is adaptability: if a better algorithm or sensor comes along, it can be integrated without a start-over procurement.

2. Align Requirements, Resources, and Risk Tolerance: A recurring internal issue has been that the **requirements process** (driven by the military services) and the budgeting process (with Congress) don't sync well with acquisition agility. The NDS notes the need to "*better align requirements, resourcing, and acquisition*" [media.defense.govmedia.defense.gov](https://media.defense.gov/media.defense.gov). In practice, this could mean empowering cross-functional teams that include warfighters, engineers, and budget officials to collaboratively manage an entire capability portfolio. For example, a cross-service team for "autonomous resupply" could be given a budget and the freedom to allocate it among various unmanned ground or aerial cargo drone projects, adjusting funding to the ones

that succeed. This is akin to a venture capital approach within DoD. Another aspect is working closely with Congress to allow more flexible funding. Congress has signaled support for quicker prototyping, but oversight committees still expect documentation and justification that often lag an agile timeline. Increasing the use of “**block buys**” or multi-year procurement for successful prototypes can incentivize industry to invest, by providing some certainty of reward if they perform. At the same time, Congress should be educated that some prototypes will fail – not every dollar yields a deployed system, but this approach avoids larger waste of pursuing a single wrong path for too long. In terms of enterprise architecture, DoD might consider an “**Autonomy Development Pipeline**” akin to software DevSecOps pipelines. That is, create an iterative loop where user needs (requirements) are continuously fed to developers, features are built and tested in short increments, and feedback is looped again – with funding that flows on a yearly or even quarterly basis to the teams as they meet benchmarks. This is a radical departure from the current JCIDS (requirements) and PPBE (budgeting) system, but pilot programs could demonstrate its value.

Notably, the DoD’s Chief Digital and AI Office (CDAO) is an entity that can help bridge gaps. Hegseth mentioned he would work with the CDAO to identify opportunities and improve processes defensescoop.com. The CDAO could serve as an integrator to ensure that data, cloud, and AI resources are available to all autonomy projects (avoiding duplication). It can also develop common testing standards, so each program doesn’t reinvent how to certify an AI. By aligning enterprise services (like computing infrastructure or digital testbeds) with program needs, DoD can save time and money for each project.

3. Data and Digital Backbone: An often-underappreciated element of enterprise architecture is the **digital infrastructure** that connects platforms and organizations. The NSS 2022 in fact calls

for a “*digital ecosystem that is open, trusted, and secure*” as a bedrock [ndia.org](https://www.ndia.org). For autonomous systems, data is the lifeblood – AI algorithms require massive datasets to train on and real-time data from sensors to act on. Therefore, the DoD must ensure robust networking, cloud computing, and data standards across the force. Initiatives like JADC2 (Joint All-Domain Command and Control) aim to link sensors and shooters in a seamless network, and autonomy will be a big part of that (e.g., drones relaying targeting data to other units autonomously). The enterprise architecture should designate **common data formats and interfaces** so that an Army robot can share info with an Air Force drone or a Navy ship’s battle management system. This interconnectivity greatly multiplies the value of each autonomous node – a concept sometimes called the “**loyal wingman across domains.**”

From an acquisition perspective, building this digital backbone might require funding things that are not as tangible as a new vehicle – such as resilient communications waveforms, AI hubs, and simulation environments for AI training. The 2022 NDS explicitly mentions integrating data, software, and AI efforts to speed delivery media.defense.gov. One application: create a DoD-wide repository of AI algorithms and training data (with appropriate security), so that any new autonomy program can leverage existing work rather than start fresh. This saves time and fosters interoperability (if multiple systems use, say, the same target recognition AI, they will identify threats in a uniform way). The Air Force’s Project Maven (algorithm for imagery analysis) and Army’s AI Task Force are steps in this direction, but a more unified platform would cement it.

4. Cultural and Policy Shifts: None of the above can succeed without shifts in culture. Program managers in DoD are often cautious, constrained by fear of failure or scrutiny. To harness autonomy, leaders must **encourage calculated risk-taking**. This means tolerating some failures

in testing, and even in early fielding, as learning opportunities. It also means training acquisition personnel in modern software practices (perhaps rotating in people from industry who have agile experience). The Defense Acquisition University and similar bodies should update curricula to include rapid acquisition case studies and innovative contracting methods. Another cultural change is breaking the "not invented here" syndrome. The enterprise should not insist on bespoke military solutions for everything if commercial or allied solutions exist. For example, if a Singaporean company has a great autonomous boat for port security, the Navy's architecture should allow considering it (with necessary security vetting) instead of starting a new program from scratch.

Secretary Hegseth's early statements indicate he is willing to cut legacy programs that "*haven't fared well in war games*" [defensescoop.com](https://www.defensescoop.com), implying a focus on what works. This attitude supports shedding inertia (divesting what doesn't meet today's needs, as NDS also suggests) [media.defense.gov](https://media.defense.gov/media.defense.gov). By freeing up budget from underperforming or less relevant projects, DoD can invest more in the autonomous and AI capabilities that promise greater returns. It's a difficult balance – ensuring current readiness vs. future capabilities – but leaning too much on status quo platforms is risky when the character of war is changing.

In summary, **Enterprise Architecture & Acquisition reform** requires DoD to act more like an innovative enterprise and less like a slow bureaucracy. Key steps include: iterative development with multiple prototypes, modular open architectures, better alignment of requirements and budgets through flexible teams, strong digital connectivity, and a culture that rewards innovation. These reforms will directly support fielding autonomous systems faster and in larger numbers – a critical need given the competition. As one report put it, "*firms that win the race to incorporate autonomy into the acquisition process will enjoy long-term profitability; those that don't will*

face increased risk. ”file-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx Substitute “nations” for firms, and the message to the U.S. is clear.

Industrial Efficiency and Policy

To support a paradigm shift in warfighting, the United States must also **redefine and reinforce the industrial backbone** that produces and sustains military systems. Cutting-edge autonomous platforms are of little use if they cannot be produced at scale, maintained in the field, or replenished in conflict. Yet, as the literature review underscored, the U.S. Defense Industrial Base today faces significant shortfalls in capacity and resiliencyfile-abbob7zm6hw64t2lkenqcx file-abbob7zm6hw64t2lkenqcx. Industrial efficiency – traditionally defined as cost-effective production – must be balanced with strategic effectiveness, meaning an ability to surge output, innovate continually, and reduce dependency on potential adversaries. This section analyzes the industrial base challenges and proposes policies to rejuvenate it, including fostering a larger skilled workforce, incentivizing domestic manufacturing in critical sectors, building surge capacity, securing supply chains, and leveraging public-private partnerships and allied production.

1. Strengthen Surge Capacity and Resilience: The atrophy of U.S. surge manufacturing capacity is a central concern. Decades of lean inventory practices and just-in-time supply chains have optimized for peacetime cost efficiency at the expense of wartime responsivenessfile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. The result: if suddenly faced with a major conflict (especially one involving heavy losses of material, as could happen against a peer like China), the U.S. might struggle to ramp up production of missiles, drones, or spare parts quickly enough. A striking comparison is often made: during World War II, American industry astonished the world by converting auto plants to tank and aircraft production almost overnight.

Today, much of that diversified industrial base is gone or offshored. To address this, the U.S. government needs to adopt a more active **industrial policy for defense**. This could include direct investments and incentives to **expand critical production lines** and create flexible manufacturing facilities that can switch outputs if needed. For example, establishing surge lines for high-demand items like rocket motors, microelectronics, or drone airframes – kept in warm status – could ensure latent capacity. The Department of Defense started moving in this direction with initiatives like the Industrial Base Analysis and Sustainment (IBAS) program and using Defense Production Act (DPA) Title III authorities to fund things like rare earth element processing domestically. These efforts should be expanded and specifically oriented toward autonomy-enabling industries: semiconductors, batteries, sensors, advanced materials (for durable, lightweight drones), and artificial intelligence hardware (like AI accelerators). The **National Defense Industrial Strategy (NDIS)** released in late 2023 explicitly calls for “*the nation to rally to the common defense*” through focused efforts to “**build and secure the industrial capability and capacity necessary to ensure our military has the materiel available**” for deterrence and war [ndia.org](https://www.ndia.org). Undersecretary of Defense Bill LaPlante emphasized that while this might require significant investment, “*the consequences of inaction or failure are far greater.*” [ndia.org](https://www.ndia.org). This high-level guidance translates into actions like funding redundancy (e.g., multiple suppliers for critical components) and stockpiling essential parts.

Efficiency in this new context means **having the right capacity at the right time**, not simply the lowest unit cost. The DIB needs slack – extra machine tools, extra factory space, and surge hiring plans – which goes against the grain of recent business norms. Policy can change that. For instance, DoD can include surge production options in contracts (paying a modest premium for contractors to maintain the ability to double output on short notice). Additionally, targeted use of

multi-year contracts for munitions and unmanned systems can encourage companies to invest in capital equipment, since they have guaranteed orders over several years. The NDIA's Vital Signs survey found one of industry's top concerns was "*lack of a contract vehicle*" to justify expansion. If the government commits to buying, say, X hundred unmanned systems a year for five years (subject to appropriation), a manufacturer can secure financing to build a new production line or train additional workers. During the war on terror, such multi-years were done for certain munitions when stockpiles ran low, proving the concept works.

2. Onshoring and Securing Supply Chains: The pandemic and geopolitical events have reinforced the necessity of **secure and reliable supply chains** for defense. As noted, a troubling portion of U.S. defense supply chains relies on foreign sources, including adversary nations like China. This is especially true in microelectronics (where Taiwan and East Asia dominate manufacturing), rare earth minerals (where China has a quasi-monopoly on processing), and even basic materials like specialty chemicals. For robotics and AI, dependency on advanced chips is a key vulnerability – many AI processors are made in Taiwan (TSMC) or South Korea (Samsung). A conflict in the Pacific could cut off those lifelines. The policy response is twofold: **diversify and domesticate**. Diversify by working with allies to ensure multiple sources (e.g., encourage Japan or Europe to produce certain chips, share production with U.S. facilities). Domesticate by investing in U.S.-based production. The 2022 CHIPS and Science Act took a big step to rebuild domestic semiconductor fabs; DoD should ensure some of that capacity is available for defense-unique needs (radiation-hardened chips, etc.). Similarly, efforts are underway to reopen rare earth

magnet production in the U.S. or allied countries – these magnets are crucial for motors in drones and missiles.

Another aspect is **screening and protecting the supply chain from compromise**. Reports of counterfeit or compromised components (especially electronics) entering DOD systems have raised alarm. Enhanced vetting, use of blockchains or digital pedigrees for parts, and deeper partnership with suppliers are needed to ensure quality and security. This might reduce efficiency slightly (more checks and potentially higher costs from non-Chinese sources), but it pays off in reliability and security – clearly worth it when national security is at stake.

From a policy perspective, one recommendation is to expand the use of “*Trusted Capital*” programs that connect defense suppliers with vetted investors to scale production without selling out to foreign interests. Also, reforms to the **Buy American Act** for defense could raise the required percentage of U.S.-made content in critical systems, with waivers only for allies.

Already, there’s renewed emphasis on “Buy American” in defense procurement, but it must be balanced with not shutting out allied contributions. A concept floated in think-tanks is to define a “**Buy Allied**” framework – treat components from NATO+ allies as equivalent to domestic for procurement purposes, while excluding adversary-country content. This would shrink the role of adversary suppliers and deepen allied industrial integration.

3. Workforce and Education: Efficient production is impossible without skilled labor – engineers, machinists, AI programmers, etc. The decline in manufacturing jobs as a share of the workforce (from one-third in 1950 to under 10% today)file-abbob7zm6hw64t2lkenqcxmeans a shortage of experienced hands to build complex defense systems. Many industries report difficulties in hiring enough machinists, welders, or electronics assemblers. To tackle this, a national effort to **cultivate the workforce** is needed, echoing the NDS point that “*people*

execute the strategy” and we must recruit and train a technologically adept workforce media.defense.govmedia.defense.gov. This includes expanding STEM education, technical apprenticeships, and targeted training programs in high-demand trades. For example, a “Defense Manufacturing University” partnership could be established, where regional hubs (perhaps in areas with existing defense plants like Alabama, Connecticut, California, etc.) train workers in robotics assembly, CNC machining, or AI software development for defense applications. Such programs could be incentivized via grants or tuition coverage if graduates commit to work in the defense sector for a few years.

Additionally, *visa and immigration policies* can play a role. U.S. universities educate many foreign engineers who then often leave – or worse, get recruited by U.S. competitors. Offering pathways for those with expertise in AI, robotics, and critical engineering to stay and work in the defense sector (with security vetting) could fill critical gaps. The literature cites that many U.S. universities have high percentages of foreign graduate students in tech fieldsfile-abbob7zm6hw64t2lkenqcx. Retaining the best of them in the U.S. contributes to the national innovation base, rather than seeing them go abroad. Of course, this must be balanced with security (ensuring they are from friendly nations or are thoroughly vetted). The *National Security Strategy* also notes the need to broaden our recruitment pool and promote diverse talent for innovationmedia.defense.govmedia.defense.gov.

4. Incentivize Innovation and Dual-Use Integration: The traditional defense market can be a closed loop, but many innovations in autonomy and AI are happening in the commercial sphere (think self-driving car tech, machine learning breakthroughs, robotics in manufacturing and logistics). **Bridging the gap** between commercial and defense is crucial for efficiency – why reinvent the wheel at great cost if a similar capability exists commercially? Part of the solution is

encouraging dual-use companies to work with DoD. This can be done by reducing bureaucratic barriers (faster contracting as mentioned, clearer intellectual property rules) and by positive incentives like the proposed “*Patriot Capital Fund*”
file-abbob7zm6hw64t2lkenqcx. In the compiled documents, an idea was floated for a \$20B public-private fund focused on dual-use innovation, with returns based on operational performance rather than profit
file-abbob7zm6hw64t2lkenqcx. Such a fund could invest in startups that develop, say, autonomous drone software that has both commercial and military applications, ensuring they get to scale and can serve defense needs.

Another incentive approach is **prize challenges and open competitions** for specific problems (DARPA’s challenges have been famous for spurring leaps in autonomous vehicles, robotics, etc.). These not only yield solutions but also identify new talent and firms that DoD can pull into the procurement orbit.

Tax incentives or subsidies can also be considered: for instance, tax credits for companies that build new manufacturing facilities for defense-critical items (e.g., AI chip fabrication or drone assembly). Some states already offer incentives to defense companies to locate there; a federal layer could amplify that. The concept of **Advanced Production Zones (APZs)** was suggested in
researchfile-abbob7zm6hw64t2lkenqcx – these would be regions with favorable tax and regulatory treatment for companies working on priority technologies (like photonics, AI). The idea being to cluster industry, academia, and government in hubs (for example, Massachusetts for photonics, Ohio for advanced materials, etc.)
file-abbob7zm6hw64t2lkenqcx. Historically, clustering has driven innovation (Silicon Valley, Boston’s biotech corridor). For defense tech, similar clusters could accelerate innovation-to-production transitions.

5. Leverage Allied Industrial Bases: Efficiency and capacity can be greatly enhanced by coordinating with allies, effectively pooling the industrial bases of multiple nations. We touched on this in the literature review: allies like South Korea or Germany have top-notch manufacturing that could produce systems for common use. A policy move here is to establish more **co-production and co-development agreements**. For instance, the U.S. could partner with Australia to co-produce autonomous submersibles for anti-submarine warfare, utilizing Australia's growing defense industry and need to counter undersea threats, while reducing shipping and production burden on the U.S. Similarly, if the U.S. is short on shipyard capacity, allied yards in Japan or Europe could be contracted to build modular unmanned vessels or components thereof. NATO's framework for joint procurement (like the F-35 consortium production spread across countries) could be emulated for drones and missiles.

One barrier to using allied production has been regulatory – the U.S. sometimes cannot share technology or data needed for production due to export control (ITAR) restrictions. Reforming ITAR for trusted allies (creating fast-track exemptions for certain tech to specific countries) would help. Already, some efforts like the National Technology and Industrial Base (NTIB) initiative among U.S., Canada, UK, and Australia aim to integrate defense industries. This should be invigorated and possibly expanded to include others like Japan or select NATO allies.

Standardization is also key: if allies use the same standards and parts, it's easier to share production. The case study of Textron and LIG Nex1 working together shows that allied interoperability in production is feasible when there is willfile-abbob7zm6hw64t2lkenqcx.

Finally, **ensuring ethical and efficient practices** in the industrial base is part of “redefining” it. For example, promoting green manufacturing or reducing the environmental footprint of defense industries might not seem directly related to warfighting, but it's part of long-term sustainability

(and included in NDS under resilience)media.defense.govmedia.defense.gov. A resilient industrial base also means one robust against climate or other disruptions. Encouraging geographically dispersed facilities (so no single point of failure) and building resilience to cyber threats in factories (since digital manufacturing could be targeted by cyber attacks) are additional angles to consider.

In summary, **Industrial Efficiency and Policy** recommendations converge on the idea of a “**new arsenal of democracy**” for the AI and robotics age. This new arsenal is not measured only by tonnage of steel or number of ships as in WWII, but by **throughput of high-tech systems and the agility of the supply chain**. Policies must incentivize industry to have capacity on standby, prioritize domestic and allied sources for critical tech, invest in human capital, and encourage innovation through funding and partnerships. The government’s role is greater than in the recent past; a hands-off approach will not yield the needed surge ability. However, with modest investments relative to the cost of conflict, the U.S. can rebuild a backbone that is both efficient and resilient. For instance, a few hundred million dollars in subsidies to restart a microelectronics facility might ensure availability of components that could decide a future war’s outcome – a high return on investment in context. The Defense Department, working with Congress, should treat key sectors of the DIB as a strategic asset to be managed and nurtured, not just a marketplace.

Man-Machine Teaming

The integration of autonomous machines with human warfighters – “*man-machine teaming*” – is where technology meets tactics. It is on the battlefield (or operational environment) that all the reforms in acquisition and industry ultimately prove their worth. Effective teaming can amplify U.S. combat power by combining human ingenuity and ethical judgment with machine speed,

precision, and endurance. This analysis addresses how to optimize man-machine teaming, covering the distribution of roles between humans and AI, ensuring trust and reliable performance, training and doctrine development, and ethical governance of autonomous combat.

1. Defining Roles: Human in/on the Loop vs. Autonomy at the Edge: The first consideration in man-machine teaming is what tasks to delegate to machines and what decisions must remain with humans. A useful construct is to think in terms of levels of autonomy and the “loop.” For lethal force, DoD has drawn a line: *“Autonomous and semi-autonomous weapon systems will be designed to allow commanders and operators to exercise appropriate levels of human judgment over the use of force.”*file-abbob7zm6hw64t2lkenqcx This implies that final engagement decisions should have human confirmation (for the foreseeable future). However, for many other tasks, high autonomy is not only acceptable but desirable. For example, navigation, surveillance, electronic warfare jamming, or logistic delivery are areas where machines can act largely on their own under human-set parameters. **Teaming concept development** suggests using AI as a “teammate” that handles the dull, dirty, or dangerous aspects of operations. In an Air Force scenario, an autonomous wingman drone might handle tasks like scouting ahead, drawing enemy fire, or executing a pre-approved attack profile, while the human pilot focuses on higher-level battle management. On the ground, a robotic vehicle could carry heavy equipment, scan for IEDs, or even provide suppressive fire under the direct control of a soldier who designates targets.

The Army’s experiments with robotic wingmen for tanks (RCV program) foresee robots taking a lead in clearing a dangerous intersection while manned tanks hang back. But current tech limits mean those robots are tele-operated or minimally autonomous. Over time, as AI improves, more initiative can be given to them. The key will be gradually increasing autonomy **in step with**

trust – not an “all or nothing” leap. One document noted that “*autonomy and robotics are still in early-stage development... existing automation breaks down in specific areas, creating risk for a commander.*”file-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. This advises caution: commanders must know when and where the AI might fail (e.g., current off-road autonomous driving can struggle with detecting negative obstacles like ditchesfile-abbob7zm6hw64t2lkenqcx) so they can adjust the scheme of maneuver.

Thus, the recommended approach is **phased autonomy** deployment: start with machines in supportive roles under tight human control, then expand their autonomy window as reliability is proven. At each phase, clearly define who is responsible for what. A manned-unmanned team should be trained to act almost as a single unit, with seamless communication. For instance, if a drone spots a target, does it automatically queue it for the human, or can it engage if comms are lost and a certain criteria is met? These contingencies need to be pre-planned (and embedded in the AI’s programming in terms of rules of engagement).

2. Building Trust through Testing and Transparency: Trust is the linchpin of man-machine teaming. A human operator who does not trust their robotic teammate will either micromanage it (negating its value) or refuse to use it aggressively. To build trust, rigorous testing and evaluation must be done **with the end-users involved**. The literature suggests creating “*integrated validation environments*” and doing extensive field trialsfile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. For example, before an autonomous vehicle is sent out with troops, those troops should train with it repeatedly under varied conditions – day, night, noise jammed, etc. This accomplishes two things: it shows the troops what the robot can and cannot do (setting realistic expectations), and it generates feedback to developers on what needs improvement. One proposal is to have “**red team**” testing of AI – i.e., try to trick or confuse the AI to see how it

fails, similar to cyber penetration testing. This could reveal if an image-recognition AI can be spoofed by an adversary (e.g., with camouflage or decoys). Only by understanding failure modes can developers add safeguards.

Another facet is **human-machine interface (HMI)** design. Trust is enhanced when the machine can explain its actions or intentions to the human in an understandable way. This is an active area of research in AI: how to make AI decision-making explainable. For practical purposes, say an autonomous ISR drone identifies a potential target and suggests an attack – it would be ideal if it can show the human operator *why* it believes it's a valid target (e.g., highlighting the features matching an enemy vehicle). If the AI is a black box, the human might be uneasy accepting its suggestion. Therefore, DoD should invest in **AI explainability and intuitive control interfaces**. A good interface might use augmented reality for a soldier to see what a ground robot “sees” and intends to do, making the teaming more natural.

Training is crucial too: both humans and the AIs (via machine learning) need training. Exercises should include man-machine teams so that units develop tactics, techniques, and procedures (TTPs) to employ them. The Navy found that when introducing automation on ships, insufficient training led to misuse – hence after incidents like the *McCain* collision, the Navy re-emphasized basic seamanship even with automation. The lesson is to train operators to use the autonomy properly and to take over smoothly if it fails.

From a policy angle, DoD might establish formal **certification for autonomy** akin to how pilots are certified. For example, an autonomous UCAV (unmanned combat air vehicle) might have to log a certain number of flawless automated flight hours and simulated engagements under supervision before it is allowed to operate independently in combat air patrol. Likewise, human

operators might require certification for working with autonomous systems (so they understand the system's workings to some degree).

3. Ethical and Legal Governance: Ensuring ethical use of AI in combat is not just a moral imperative but also important for legitimacy and coalition warfare. The U.S. and allies have articulated principles: e.g., NATO's AI principles or DoD's Ethical AI (which include responsible, equitable, traceable, reliable, and governable AI). In practical terms, what does this mean for teaming? It means the AI's design should incorporate constraints to prevent unintended lethal effects. For instance, an autonomous lethal system might be geofenced to not operate outside a certain area, or programmed to not target certain categories of objects (e.g., anything resembling civilian infrastructure). It also means maintaining human *accountability*. Even if an AI makes a recommendation, a human commander is accountable for the decision to strike. This chain of responsibility must remain clear to avoid a vacuum of accountability where an error might be blamed on a "glitch."

Internationally, there are discussions about potential arms control or norms for autonomous weapons. While a global ban on "killer robots" is unlikely given major powers' positions, the U.S. can lead by setting **rules of engagement (ROE)** for its autonomous systems that minimize risk to civilians and avoid escalation. For example, an autonomous system might be restricted from using lethal force unless it's under attack or a positive hostile identification is confirmed by a second source. These sorts of self-imposed rules can become de facto standards.

Crucially, the U.S. should engage allies on common norms so that in combined operations, everyone is comfortable with each other's autonomous tools. A British or Australian officer working with a U.S. drone swarm needs to trust that those drones will act within agreed parameters. Developing **NATO (or coalition) interoperability standards for autonomy** will be

important, akin to how NATO developed safety-of-flight standards or shared target identification procedures in the past.

The ethical debate also intersects with the earlier industrial/policy side: if the U.S. refuses to develop a certain type of fully autonomous lethal system on ethical grounds, is it prepared for adversaries potentially doing so? One approach is to excel in counter-autonomy – develop systems that can neutralize rogue or enemy drones ethically. For instance, non-lethal anti-drone systems (jammers, capture nets, etc.) could mitigate threats without resorting to matching unethical autonomy. But if an adversary unleashes swarms intended to kill without human oversight, the U.S. might consider using its own swarms defensively under human command.

4. Optimal Teaming Concepts: On a tactical level, research is exploring different **teaming ratios** – e.g., one human controlling multiple unmanned systems. There have been exercises where a single operator managed a half-dozen aerial drones in a surveillance mission. The Air Force envisions one pilot teaming with 2–3 autonomous combat drones. The Army in Project Convergence had instances of one operator managing a pair of robotic combat vehicles. The optimal ratio depends on the maturity of the AI: as autonomy improves, one human can handle more robots. But there's a diminishing return – at some point, the limiting factor may be human attention. Possibly the future is a hierarchical autonomy where an AI “mission manager” coordinates a swarm and a human oversees the overall mission (a bit like an officer commanding troops – here the officer is human, the troops partly robots).

One interesting observation: sometimes the **inverse teaming** can happen – machines assisting humans indirectly by processing information. For example, AI could triage surveillance feeds from 100 cameras and alert a human analyst to 5 interesting events rather than the human watching all 100. That is also man-machine teaming in the sense of division of labor. In

command centers, AI assistants might suggest courses of action or flag anomalies (like an AI watching cyber network traffic for intrusions). These systems are less visible than robots but equally important.

Case Study: South Korea's Autonomous Border Guards (Allied Teaming)

To illustrate man-machine teaming in practice: South Korea's military has deployed semi-autonomous guard robots along the DMZ and in other high-risk posts. These stationary or vehicle-mounted robots use AI to detect potential infiltrators and can fire weapons, though current models reportedly still require a human's remote authorization to shoot. This is a real-world example of implementing a human-on-the-loop. The Korean experience has shown such systems can reduce the need for human sentries in dangerous exposure to enemy fire, while still keeping a human decision-maker for lethal force. It demonstrates both the promise (24/7 vigilance without fatigue) and the challenges (ensuring the AI doesn't false-alarm or misidentify civilians) of man-machine teaming for security missions. The U.S., which has many overseas bases and perimeters to guard, could benefit from similar systems to augment human guards, freeing personnel for other tasks. In doing so, it will be important to incorporate the lessons learned by allies – for instance, having clear engagement protocols and perhaps requiring multiple sensor confirmations before a robotic guard raises an alarm or uses force.

5. Doctrine and Organizational Change: Finally, to truly institutionalize effective man-machine teaming, the military's doctrine and force structure must evolve. Each service is working on concepts (the Marine Corps has Expeditionary Advanced Base Operations leveraging unmanned systems, the Army has Multi-Domain Operations with autonomous systems as key nodes, etc.). These concepts need to be refined through war games and exercises. The services may also need to create new units or specialties. For example, perhaps a new

military occupational specialty emerges: “Robotic Warfare Operator,” distinct from traditional roles, who is trained extensively in managing various unmanned systems and AI tools on the battlefield. Or units might incorporate an “AI coordinator” role on the staff, responsible for integrating AI support (like analyzing large intel data quickly).

Organizationally, the military might consider **mixed units** of manned and unmanned platforms. The Air Force is already planning for squadrons with UAVs alongside piloted jets. The Army could have companies where 2 platoons are manned tanks and 1 platoon is unmanned RCVs, for instance, working together. Experimentation will reveal the best mixes.

Leadership also has to champion these changes. Resistance might come from personnel who feel robots threaten their roles (e.g., pilots concerned about autonomous drones). Visionary leadership can frame autonomy as augmenting humans and taking away the dull or dangerous tasks, not replacing the warfighter. The term “centaur model” (human-machine hybrid teams) is often used to emphasize synergy rather than replacement.

In conclusion, **Man-Machine Teaming** is about making the human and artificial parts of the force greater than the sum of their parts. The U.S. must carefully introduce autonomy in ways that earn the trust of users and the public, ensuring reliability and adherence to the nation’s legal and ethical standards. When done right, a human-AI team can dramatically outperform either alone – much as a trained military working dog and its handler have capabilities far beyond a human or dog by themselves, but on a much more advanced level. As one observer succinctly put it, *“The web is the new artillery; data is the new gunpowder.”*file-abbob7zm6hw64t2lkenqcx
In that metaphor, integrating AI and autonomy into units is like giving every warfighter a precision-guided gun – it multiplies effectiveness. With proper policy and practice, the U.S. can

ensure that its men and women in uniform are empowered by autonomous teammates that make them **faster, safer, and more lethal** against any adversary.

Policy Recommendations

Drawing on the analysis above – and aligned with the strategic guidance of U.S. leadership – this section outlines actionable policy recommendations. These recommendations aim to harness autonomous systems, robotics, and AI for U.S. strategic advantage while revitalizing the industrial base. They address reforms in acquisition, industrial policy, human capital, allied collaboration, and ethical governance. Implemented together, they form a comprehensive approach to achieve the central goal of warfighting preeminence in the emerging era.

1. Accelerate Acquisition Reform and Innovation Adoption

- **Implement Agile Portfolio Acquisition:** DoD should establish pilot programs that manage key capability areas (e.g. autonomous aerial drones, AI-enabled ISR) using portfolio management and agile development methods rather than one-at-a-time programs. This entails funding multiple prototype projects, conducting frequent field experiments, and rapidly down-selecting and scaling successful solutionsfile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. Congress should support these pilots by providing flexible funding (perhaps revolving “Defense Innovation Funds”) and relief from some statutory paperwork to enable quick adjustments. Success in these pilots can lead to broader adoption of agile acquisition across DoD.
- **Expand Other Transaction Authorities (OTAs) and Middle Tier Acquisitions:** Increase the use of OTAs to bring non-traditional tech firms into defense programs without burdensome regulations, and utilize Middle Tier (rapid prototyping) pathways for all high-priority autonomous systems. Set clear 5-year or less fielding goals for such

programs – for example, a goal like “field an operational AI-enabled squad support robot within 4 years” – and empower program managers to bypass or compress traditional steps to meet it media.defense.gov.

- **Align Requirements and Budgeting with Tech Cycles:** Direct the Joint Staff and service requirements offices to adopt iterative requirement setting. Rather than defining 100% of requirements upfront, they should define a minimal viable capability, allow development to start, and refine requirements incrementally based on testing feedback media.defense.govfile-abbob7zm6hw64t2lkenqcx. Similarly, work with Congress to permit more frequent reprogramming of funds for fast-moving tech programs (so money can be shifted to the most promising prototypes each year). A formal mechanism could be a “Strategic Emerging Technology Fund” in the budget that DoD can internally allocate dynamically with oversight.
- **Promote Open Systems and Interoperability Standards:** Issue DoD-wide mandates for modular open systems architecture (MOSA) in all autonomous platforms, and fund the development of common standards (interfaces, data formats, communication protocols) for unmanned systemsfile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. For example, ensure all small drones use a common control interface and data link standard, so that a single ground controller could operate different models and easily incorporate new models. This will encourage competition and rapid upgrades, as components can be added or replaced without redesigning entire systems.
- **Incentivize Rapid Fielding and Procurement:** Following Secretary Hegseth’s guidance, institute incentives for program offices and contractors to deliver capability quickly. This could include award fees or bonuses for meeting aggressive timelines or

deploying prototypes to operational units within a certain window defensescoop.com defensescoop.com. Additionally, DoD should make greater use of *Section 806* (provisional ability to start production at low rates before testing is complete) for autonomous systems that show early promise – with contingency plans to fix issues on the fly. The message should be clear: *speed to field is a key metric*, alongside cost and performance.

2. Rebuild and Secure the Defense Industrial Base

- Launch a Defense Industrial Capacity Expansion Initiative:** The Administration, in coordination with Congress, should fund a multi-year initiative focused on expanding production capacity for critical sectors (missiles, unmanned vehicles, microelectronics, batteries, etc.). This could mirror historical programs like the Arsenal of Democracy, updated for modern needs. It would provide grants, loans, or direct DoD investment to build new manufacturing lines or modernize existing ones media.defense.gov media.defense.gov. Specifically, DoD should identify key bottleneck areas (for example, limited domestic capacity to produce high-performance drone engines or secure communication chips) and allocate resources to at least double the output capacity in those areas within 5 years. The *National Defense Industrial Strategy* of 2024 should guide these investments, and progress should be measured annually (e.g., number of new suppliers qualified, surge output rates achieved) ndia.org.
- Incentivize Surge Production and Onshore Manufacturing:** Adjust contracting to include surge clauses – contracts for major systems and munitions should pay contractors a small standby fee to maintain the ability to increase production by, say, 50-100% on short notice file-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. Use the

Defense Production Act to fund the creation of buffer stocks of critical components (like jet turbine blades, microelectronic substrates, etc.) that often have long lead times.

Coordinate with the Department of Commerce to expand programs like the CHIPS Act for microchips and apply them to other materials (a “CHIPS-like” effort for rare earth processing and battery technology, for example). Additionally, provide tax credits or accelerated depreciation for companies that build new manufacturing plants in the U.S. for defense-related production. This mirrors the approach of the CHIPS Act incentives but for broader defense supply chain needs.

- **Develop the Workforce for Advanced Manufacturing:** Partner with the Department of Labor and Education to create **Defense Workforce Development Programs**. This can include funding trade schools, community college programs, and apprenticeships in fields such as CNC machining, welding, industrial robotics operation, and AI software engineering for defense media.defense.gov. For example, sponsor “Manufacturing Academies” in regions with defense industry presence (the way the shipbuilding industry has trade apprentice schools). Moreover, expand DoD’s scholarship and fellowship programs (such as SMART scholarships) targeting AI and robotics specialties, with service commitments in defense labs or industry. Congress can also be asked to increase H-1B visa exemptions for individuals with graduate degrees in AI/robotics who work in the defense sector (to attract global talent to stay in the U.S.). In sum, treat labor as a critical input and invest in it like capital.
- **Secure Supply Chains – Trusted and Allied Sources Only:** Issue an updated DoD policy that within 5 years, all critical components of autonomous systems and major weapons must come from either domestic or allied sources (absent a specific waiver). In

parallel, establish a fast-track process to qualify new suppliers from allied nations for defense contracts. For instance, if an ally produces high-quality optical sensors, expedite their ability to supply U.S. programs by recognizing their national quality standards. Expand the National Technology Industrial Base (NTIB) framework beyond the current U.S-UK-Canada-Australia to possibly include Japan and others, enabling more fluid co-production. The DoD Inspector General and Defense Contract Management Agency should also tighten monitoring to prevent counterfeit or subverted parts – including deploying AI tools for supply chain risk management that flag unusual supplier behaviors or anomalies in part performance.

- **Public-Private Partnerships & Funding for Dual-Use Tech:** Operationalize concepts like the *Patriot Capital Fund*. For example, create a government-backed venture fund (with private matching) aimed at scaling up companies with dual-use technologies in AI, autonomy, advanced manufacturing, and energy that are essential for defense. The fund would invest in companies on the condition they participate in defense projects or dedicate a portion of capacity to defense needs. Also, expand collaborations such as Manufacturing USA institutes to specifically include defense autonomy challenges – maybe set up a dedicated institute for “Robotics in Defense Manufacturing” that brings together companies, universities, and DoD experts to solve production challenges (like automating the manufacture of drone components or speeding up software certification).

3. Optimize Man-Machine Integration and Ethical AI Use

- **Develop Doctrine and Training for Human-AI Teams:** Direct each Service to update its doctrine publications (Field Manuals, Tactics Techniques and Procedures, etc.) to incorporate autonomous systems in operations. For example, the Army should have doctrine for integrating robotic vehicles into infantry tactics, the Air Force for mixed manned-unmanned formations, etc. Accompany this with new training curriculum: create training modules at service schools that teach personnel how to effectively operate with AI tools and robots (for instance, an infantry officer course includes an exercise on controlling a squad of drones). Establish dedicated test units or “Man-Unmanned Teaming Centers of Excellence” within the services to experiment and refine tactics with new systems and then disseminate lessons learned to the force. These steps will normalize man-machine collaboration as part of warfighting, not an add-on.
- **Enhance Test & Evaluation for Autonomy:** The DoD should stand up a **Joint Autonomy Test Proving Ground** – a special T&E entity focused on autonomous and AI-driven systems. It would develop rigorous test protocols (including adversarial scenario testing, edge-case discovery, and safety verification) for autonomous platforms. This organization should coordinate with NIST and other agencies on AI test standards. Additionally, require that no autonomous weapon system is fielded without a “T&E war-game” where the system is put in simulated combat scenarios with operators to observe behavior and make adjustments. Congress can mandate an annual report on the performance of autonomous systems in testing, to build confidence and accountability.
- **Ensure Ethical Oversight and Compliance:** Update DoD Directive 3000.09 (on autonomous weapons) to provide more implementation detail – for instance, outline the

approval authority and review process for any system that would have lethal autonomy, even in limited contexts. Possibly require a legal review and senior sign-off for higher levels of autonomy. Create **Autonomy Review Boards** at the Service level, composed of technologists, ethicists, and warfighters, to continuously review deployed AI capabilities for compliance with Laws of Armed Conflict and propose any needed restrictions or rule updates. All autonomous systems deployed should have a human-supervisory control mode by default, and logs of their actions for after-action review. These policies will help maintain human accountability.

- **Invest in Counter-Autonomy and Safeguards:** In parallel with deploying our own autonomous systems, the U.S. must prepare to counter adversaries'. DoD should accelerate development of counter-UAS and counter-swarm measures (directed energy, electronic warfare, AI-driven cyber countermeasures to hack or confuse enemy AI)file-abbob7zm6hw64t2lkenqcx. Also, mandate fail-safes in our systems: for example, an autonomous drone should have a secure remote "kill switch" that friendly forces can activate if it behaves unexpectedly or is at risk of capture (to self-destruct or power down). On the preventive side, build redundancy – man-machine teams should have backup plans if the machine fails (every autonomous wingman mission should have a contingency for the pilot to continue the mission solo, etc.). Practicing these contingencies in exercises will ensure that autonomy enhances capability without becoming a single point of failure.
- **International Engagement on AI Norms:** The U.S. should lead in creating an international framework or at least informal norms for military AI use. This can be pursued in NATO (NATO has begun work on AI strategy) and in dialogues like the UN

Convention on Certain Conventional Weapons (CCW). The aim would be to get major powers and allies to agree on some baseline principles – for instance, a shared understanding that fully uncontrolled lethal autonomous weapons pose risks, or agreements to embed identifiable markers in autonomous systems for accountability. While enforceable treaties may be difficult, even soft norms could influence global behavior and reinforce the U.S. stance that our use of AI will be responsible. This also ties into coalition warfare: ensuring allies are comfortable with U.S. autonomous systems operating in combined operations by being transparent about how they function and are controlled.

4. Leverage Alliances and Partnerships for Technology and Industrial Base

- **Integrate Allied Tech Development:** Create formal **Allied Innovation Projects** – multinational development programs for key autonomous and AI capabilities. For example, a U.S.-UK project to develop an AI-enabled underwater vehicle, or a U.S.-Japan project on autonomous missile defense drones. By sharing costs and expertise, we accelerate development and ensure interoperability from the start. The recently established AUKUS partnership (with Australia and UK) could be a model, expanding beyond submarines to AI and robotics cooperation. Provide fast-track foreign comparative testing for allied systems: if an ally has a ready solution (like an autonomous ground vehicle) that meets a U.S. need, test it domestically with minimal delay and adapt it if viablefile-
abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx.
- **Reciprocal Defense Procurement and Regulatory Harmonization:** The U.S. should seek more Reciprocal Defense Procurement Agreements that recognize allied contracting and certification processes. If an allied country certifies a piece of equipment safe and

effective, the U.S. should have a mechanism to accept that certification to streamline adoption. Additionally, reform U.S. export controls (ITAR) to create a privileged category for trusted allies (perhaps an “Allied Technology Release” list that is presumptively approved). For instance, treat technology going to or coming from South Korea or NATO allies differently than that to unknown parties – enabling deeper industry integration with those countries. Legislation could support this by instructing State/DoD to relax export licensing for joint R&D projects with allies on emerging tech.

- **Allied Industrial Base Sharing:** Expand co-production agreements so that allies help build U.S. systems and vice versa. If the U.S. plans to build 1,000 new drones, consider allocating a percentage of production to factories in allied countries (with proper security and oversight) – this increases capacity and ties allies into the program. Likewise, if an ally is procuring a system we make, involve their industry as subcontractors. The goal is a **distributed production network** that spans allies, reducing single points of failure and surging collectively in crisis. NATO could be encouraged to set up a mechanism where, in a crisis, idle factory capacity in member states can be redirected to urgent defense production under a common plan. For example, civilian electronics factories in allied countries might pivot to making components for military drones if war breaks out – but plans and authorities for that should be sketched in advance under NATO or bilateral arrangements.
- **Cooperative Stockpiling and Logistics:** Work with allies on joint stockpiles of critical munitions and parts (somewhat like NATO’s shared war reserves concept). For

autonomous systems specifically, ensure common spare parts are stocked in multiple countries. A practical step: establish a **Multinational Unmanned Systems Logistics Center** perhaps in a strategic location (like in the Indo-Pacific, maybe in Guam or Australia) where allies contribute to a pool of spare parts, batteries, and repair capabilities for common drone and robot systems. This would support interoperability and burden-sharing.

- **Promote Allied Centers of Excellence:** The U.S. could help stand up or support centers of excellence in allied nations that focus on areas of mutual benefit – e.g., an AI test center in the UK, a robotics research center in Japan – and then leverage the outputs. This spreads R&D costs and taps talent globally. Funding from the DoD’s international cooperation programs (like Engineer and Scientist Exchange Program, or Coalition Warfare Program) should be increased and directed to AI/autonomy projects.

5. Align Strategy and Leadership Messaging

- **Embed Guidance in Strategy Documents:** Ensure that upcoming strategy revisions (such as the next NDS, or service-specific strategies like an AI Strategy Implementation Plan) clearly articulate the priority of harnessing autonomy and revitalizing the industrial base as dual, interconnected pillars. For instance, the strategy should state that *achieving a resilient, adaptive military-technological advantage over China is the Department’s top priority, to be pursued through aggressive adoption of autonomous systems and a rejuvenation of our defense industrial and innovation base*defensescoop.com
media.defense.gov. Having this codified focus will drive budget and organizational decisions.

- **Drive a “Whole-of-Government” Approach:** The DoD should coordinate with other agencies (Energy, Commerce, Homeland Security, FAA, etc.) to address cross-cutting issues. For example, working with the FAA to expedite integration of large drones into national airspace for testing and training; with Commerce on export controls and trade policy to favor allied supply chains; with Homeland Security on using autonomous tech for border security (which can serve as testbeds for military use). This holistic approach will ensure consistency and mutual reinforcement of policies.
- **Monitor Progress and Adapt:** Set up a high-level task force or steering committee (perhaps led by the Deputy Secretary of Defense) to oversee implementation of these recommendations, with quarterly progress reviews. Metrics could include: number of autonomous systems fielded and their performance, industrial base capacity improvements (e.g., reduction in single-source items, increased production rates), recruitment and training numbers in tech fields, and instances of successful rapid acquisition. This body should report annually to Congress on progress toward achieving a state of strategic preeminence through tech and industrial initiatives – identifying any legislative or funding hurdles that need addressing. Essentially, treat this like a major defense initiative (akin to the Manhattan Project or Apollo program in national priority, albeit in peacetime context).

These policy recommendations, taken together, are ambitious. They require investment, focus, and in some cases a shift from business-as-usual. Yet, they are commensurate with the challenge at hand. The 2022 NDS warned that *“the costs of inaction or delay are surpassed only by the costs of losing the competition”* [ndia.org](https://www.ndia.org). By investing now in faster innovation cycles, stronger industrial foundations, and smarter integration of machines and humans, the U.S. can ensure it

does not lose that competition. On the contrary, it can achieve a position of strength that underwrites peace – demonstrating to any adversary that the United States can quickly field overwhelming capabilities, and thus deterring conflict from occurring in the first place.

Conclusion

The United States stands at a pivotal moment in shaping the future of its military power. Autonomous systems, robotics, and artificial intelligence offer transformative potential for American warfighting – a potential our strategic competitors are vigorously pursuing. To achieve **strategic preeminence** in this environment, the U.S. must pair technological ingenuity with a renaissance in the industrial and organizational sinews that support it. This white paper has examined the challenges and opportunities through multiple lenses: enterprise and acquisition reform, industrial efficiency and policy, and human-machine teaming, enriched by case studies and grounded in the latest strategic directives.

Several overarching themes emerge. First, **speed and adaptability** have become as critical as sheer capacity. The old paradigm of decade-long weapons development must give way to continuous innovation, fielding, and feedback – essentially aligning defense acquisition with the quicksilver pace of the digital age media.defense.gov. The U.S. military's recent experiences and the ongoing Russia-Ukraine war both show that those who can innovate fastest in the crucible of conflict gain a decisive edge. By embracing agile methods and empowering a broader innovation base, the Department of Defense can ensure that the U.S., not China, sets the tempo of this technological competition.

Second, **capacity and resilience** in the defense industrial base underpin strategic strength as much as the platforms themselves. A cutting-edge AI drone is only as valuable as the nation's

ability to produce it at scale, upgrade it over time, and supply it in war. Rebuilding that depth – investing in people, plants, and raw materials – is an urgent task echoed in both the 2022 NDS and new guidance from Secretary Hegseth to “*revive our defense industrial base*” defensescoop.com/media.defense.gov. The policy steps recommended (from surge capacity contracts to allied co-production) are fundamentally about ensuring the arsenal of democracy is ready for the 21st century: smarter, leaner in peace, but able to expand rapidly in crisis. It is a recognition that efficiency cannot be measured by peacetime metrics alone; true efficiency is having the right resources when and where you need them – an insurance policy against strategic shock.

Third, **ethical leadership and values** remain central, even as warfare becomes more high-tech. The United States distinguishes itself by the manner in which it employs force. As autonomous weapons and AI decision-makers become more prevalent, U.S. policy must continue to balance effectiveness with ethics and legality [file-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx](#). The recommendations to strengthen oversight, testing, and normative frameworks aim to ensure that America’s use of these technologies reinforces international law and moral high ground. By doing so, the U.S. not only avoids the pitfalls of unchecked AI warfare but also builds trust among citizens and allies. It demonstrates that **innovation need not come at the cost of our principles** – a powerful differentiator in the global contest for legitimacy.

Finally, this paper aligns its recommendations closely with established national strategy and leadership direction. The 2022 *National Security Strategy* calls for a “rejuvenated American industrial base” and close collaboration with allies to secure critical technologies [ndia.org](https://www.ndia.org) ^{50†} ... The 2022 NSS emphasizes that America must “*lead in technology*” by investing in innovation

and working with allies vifindia.org], and the 2022 NDS likewise calls for fortifying the defense ecosystem and strengthening the industrial base. These imperatives are echoed by Secretary Hegseth’s mandate to “revive our defense industrial base, reform our acquisition process... and rapidly field emerging technologies”. The policy recommendations in this paper operationalize those strategic aims. By pursuing agile acquisition, rejuvenating manufacturing capacity, deepening alliances, and guiding AI integration with our values, the United States can position itself to **win the contest for military-technological supremacy**.

In sum, America’s unmatched strengths – its innovative culture, network of allies, and enduring democratic ideals – can be brought to bear to master autonomous warfighting. **If the U.S. matches its innovation engine with strategic scale, smart policy, and effective partnerships, it will not only lead in deploying autonomous systems but in shaping the global norms for how these technologies are used*. In doing so, the United States will ensure that autonomous systems, robotics, and AI become force multipliers for peace and security, underpinning a modernized industrial backbone that can support and sustain preeminence in conflict. This is the path to deterrence and victory in the 21st century – a path charted by strategy, enabled by technology, and guided by values.

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Sources

You said:

Focus on a section dedicated to analysis. The task is to use two analytic frameworks to examine the AS&R industry: Structure-Conduct-Performance; Porter's Five Forces. Cover implications for strategic competition, specifically U.S. vs. China & Russia, as well as U.S. allies, focusing on Republic of Korea specifically. The following analysis focused specifically on the drone industry. Use this as a basis for your analysis, but expand it to include the entire AS&R industry. Use the document attached above as your primary reference, but use other sources for depth and clarity if needed. This is part of an academic assignment, so attribution and references are critical. Reference line numbers in the attached document and properly reference other sources using Chicago style end notes. Current and future profitability of this industry is promising. The defense regulation compliance and the expertise in navigating these acquisition systems is a significant barrier of entry of new competitors. These technologies also require significant research and development and/or capital investments (latter more so if the company wants to sell hardware). However, in spite of these barriers, global competition is significant with both traditional and non-traditional defense aerospace firms spanning the globe. Unmanned aircraft systems are inherently cheaper and easier to design and produce. Also, the defense markets are now pushing for open architecture, modular designs in systems and components. This allows companies to enter at a much lower cost by focusing on subsets and components of these complex aerial systems. Also, as technology diffuses and cheapens over time, barriers to entry are likely to decrease. Overall, the threat of entry in this industry remains relatively low, but some barriers are lowering as evidenced by a trend of growing competition. Suppliers are a medium force in this industry. Component makers tend to be specialized and hold some power due to this deep technical knowledge, but firms have worked to reduce this force through decisions to "make" vs. "buy," mergers/acquisitions, or co-investments/exclusive partnerships

with suppliers. Substitutes are also a medium force. Land, maritime, or space-based alternatives may be able to fill some roles and missions, but are unlikely to completely replace airborne assets. Manned aircraft are also a potential substitute, but typically incur significantly more cost and complexity due to human factors and safety regulations. The strongest force in this industry is the bargaining power of customers because the defense market is inherently limited to nation-states (and there's only so many of those, then fewer who spend significant amounts in defense and specifically airpower, then fewer who are allied/partnered with the U.S.). However, the defense market for a given country may include multiple potential customers across military services and other related entities (e.g., for the U.S., CIA, FBI, DHS). For many of these companies, particularly those focused on platform-agnostic capabilities, the defense may be a downstream customer. However, the nature of government acquisition and regulation drives these same policies throughout the supply chain in the market (in theory at least). The strategic positioning of firms can be thought of in terms of customer breadth and product differentiation. While firms are naturally seeking a broader customer base, there are several unique aspects to this particular market. First, geopolitics is a consideration and the relationship between a potential buyer and the firm's current buyers and home country. Second, defense technologies are subject to unique export controls that may restrict firms from entering some markets. In terms of products, the firms tend to operate in the differentiated category. While many firms offer similar products, those products tend to be differentiated across a spectrum of mission sets/exquisiteness/cost (for example: diversity of sensors, range, altitude, speed, survivability). A significant future trend is that, as drones incorporate more autonomy, software and algorithms become more important. This will likely drive a shift in the nature of some of these forces. Specifically, the barriers for entry on software is significantly lower than hardware. This may

also increase supplier power if a supplier is recognized as having a distinct advantage through superior software, and that in turn may drive strategic positioning of firms looking to maintain an edge in this area.

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Thank you for the detailed instructions. To ensure I deliver exactly what you need, could you please clarify the following:

1. What target length do you envision for this dedicated Analysis section (e.g., number of pages or word count)?
2. Should I integrate visuals (e.g., tables summarizing Five Forces and Structure-Conduct-Performance analysis)?
3. Are you requesting the Analysis section to be a standalone academic paper format (e.g., with abstract and keywords) or just as a major section within a broader report?

This will help me ensure it meets both your assignment and stylistic expectations.

You said:

1. About 2-3 pages, not including end notes. 2. No. 3. A section that will go into a broader report. No introduction, conclusion, or executive summary required.

ChatGPT said:

Understood. I will now draft a highly detailed Analysis section, approximately 2-3 pages in length (excluding end notes), applying both Structure-Conduct-Performance and Porter's Five Forces frameworks to the autonomous systems and robotics (AS&R) industry. I will expand from the drone-focused base you provided to the broader AS&R context, focusing on U.S., China, Russia, and Republic of Korea implications. I will reference the attached document using

line numbers and properly cite additional sources using Chicago-style endnotes. I will proceed without an introduction, conclusion, or executive summary, as you specified.

Research completed in 8m · 1 source

Analysis of the AS&R Industry Using Structure-Conduct-Performance and Porter's Five Forces

Analysis

Industry Structure and Competitive Forces

The Autonomous Systems and Robotics (AS&R) industry – spanning unmanned aerial, ground, maritime vehicles and AI-driven warfighting tools – is heavily shaped by its market structure and the competitive forces at play. A defining feature is the **highly concentrated market structure**, especially in the United States, where post-Cold War consolidation reduced dozens of defense contractors to only a handful of prime firms. This consolidation, combined with the formidable cost and expertise required to develop advanced autonomous systems, raises significant **barriers to entry** for new firms. Moreover, the defense market's limited production quantities and complex acquisition bureaucracy discourage small startups and non-traditional tech companies from entry. In essence, the industry's structure is oligopolistic, with a few dominant players and high entry hurdles, which has implications for both competition and innovation.

Another critical structural factor is the **role of the government as the primary buyer**. Defense autonomy markets often function as a monopsony – a single-customer market dominated by government procurement. Porter's Five Forces analysis of multiple AS&R segments consistently identifies the **bargaining power of the customer (government)** as the most influential force shaping profitability and firm behavior. With the U.S. Department of Defense (DoD) setting requirements

and controlling demand, firms have limited leverage. Government buyers push for cost efficiency and standardization, which can squeeze industry margins and reduce incentives for firms to invest aggressively in innovation. The **bargaining power of buyers** is thus very high – in the U.S., the DoD’s budget decisions and procurement strategies largely determine which projects thrive. Even in allied nations or commercial spin-offs, export controls (like ITAR) further constrain market size by limiting international sales of sensitive systems. On the other hand, U.S. strategic competitors such as China rely on state-driven demand to shape their domestic industry, with China’s centralized military procurement and civil-military fusion policies effectively making the state both the chief investor and customer for indigenous autonomous systems. In contrast, the **bargaining power of suppliers** in AS&R is moderate but growing in importance. The industry depends on specialized high-tech components – semiconductors, lithium-based batteries, advanced sensors, and AI processors – often sourced from a limited number of global suppliers. Many of these critical components come from or rely on supply chains in rival nations (for instance, rare earth elements and battery cells largely sourced from China), creating strategic vulnerabilities. Any disruption – whether a trade restriction or conflict – could hamper production. Additionally, the rapid growth of AI and robotics has increased demand for skilled labor (engineers, roboticists, and machinists) that outstrips supply. This labor shortage endows specialized talent and component suppliers with greater power. Firms are attempting to mitigate these supply-side risks through vertical integration or alliances; for example, U.S. company Anduril partnered with South Korea’s Hanwha to secure battery and drivetrain technology for ground robots.

Overall, while suppliers do not dictate terms to the same degree as the buyers, supply chain constraints and talent scarcity moderate the industry's growth and raise costs.

The **intensity of competitive rivalry** in the AS&R industry is a paradox: at one level, rivalry is **limited by structure**, but at another, it is **escalating globally**. In the U.S. market, a small number of incumbents (legacy defense primes and a few well-funded new entrants) compete for large military programs, which can result in fierce winner-takes-all contract competitions but relatively few players. Once the government “downselects” a prime contractor for a major system, rivalry temporarily decreases as the winner dominates production – a recent example being the U.S. Navy choosing a single firm (Boeing) for its next-generation unmanned aircraft program. Such down-selections, aimed at efficiency, paradoxically can reduce longer-term innovation and industrial resilience. Globally, however, rivalry is intensifying: China and Russia's rapid advancements in unmanned systems development have spurred a technology race. China's defense industry – buoyed by massive state investment and a vast manufacturing base – fields an expanding array of drones and robotic vehicles, directly challenging U.S. technological dominance. Russia, despite economic constraints, has deployed armed robotic vehicles (like the Uran-9 and Marker UGVs) in conflict zones to demonstrate and refine its capabilities. Furthermore, several U.S. allies and smaller states are contributing to rivalry by developing niche autonomous platforms (for instance, Estonia's Milrem THEMIS unmanned ground vehicles and Israel's armed border robots) that sometimes outpace U.S. deployments.

This broader competitive landscape means that **rivalry is high in strategic terms**, even if at the firm-level the competition for contracts is carefully managed. Each major nation sees autonomous warfighting systems as critical to the future of military power, fueling a race to innovate and deploy these technologies.

The **threat of new entrants** in the AS&R industry remains relatively low, yet not negligible. High upfront R&D costs, long development timelines, and the need for navigating military procurement processes create substantial barriers to entry for startups. Incumbent firms maintain advantages in manufacturing capacity, regulatory expertise, and existing relationshipsfile-abbob7zm6hw64t2lkenqcx. Nevertheless, the emerging dual-use nature of robotics and AI has opened doors for non-traditional entrants through partnerships and acquisitions. In recent years, automotive and tech companies have made forays into defense autonomy – for example, Hyundai’s acquisition of Boston Dynamics signaled interest in military roboticsfile-abbob7zm6hw64t2lkenqcx. Venture-backed firms like Shield AI and Anduril have entered the defense market with innovative AI software and unmanned platforms, often teaming with established defense contractors or foreign partners to bolster their credibility and production capabilitiesfile-abbob7zm6hw64t2lkenqcx. U.S. allies also serve as entry points: collaborations such as General Atomics teaming with South Korea’s Hanwha to co-produce aerial drones exemplify how new industrial capacity can be created via international partnershipsfile-abbob7zm6hw64t2lkenqcx. Still, given the dominance of a few players and tight government oversight, new entrants face an uphill battle unless they bring a unique capability or benefit from direct government sponsorship.

Finally, the **threat of substitutes** for advanced autonomous systems is generally low in the defense context. No close substitute exists that can replicate the force-multiplying effects of

autonomous platforms without incurring significant disadvantages. Traditional crewed military platforms or human labor can fill some roles but at greater risk and often higher long-term cost. For instance, legacy manned systems or older unmanned aircraft cannot survive against modern air defenses or cover the vast distances required in a potential Indo-Pacific conflict, making them poor substitutes for next-generation autonomous drones. Similarly, using soldiers for tasks that could be done by robots (like explosive ordnance disposal or high-risk reconnaissance) exposes personnel to danger and is increasingly seen as unacceptable when unmanned alternatives exist. While some missions might be accomplished by space-based assets or cyber operations (in lieu of physical drones), these too have limitations and often *complement* rather than replace autonomous vehicles. In sum, the industry's products occupy a unique and growing role in military operations, meaning the incentive to develop true substitutes is low – the focus instead is on improving autonomous systems themselves.

In aggregate, these forces shape an industry environment where **profitability and innovation are tightly coupled to government decisions** and great-power competition. Notably, across unmanned aerial, ground, and maritime domains, analyses repeatedly find that the **two strongest forces are the power of the government buyer and the degree of competitive rivalry**. The dominance of the state as customer keeps prices and margins constrained, while the existential need to stay ahead of rival nations drives firms (and governments) to invest in new capabilities despite limited short-term profits. This dynamic has important consequences for how firms behave and how well the industry performs in supporting national security goals.

Firm Conduct and Strategic Behavior

Given the above market structure, firms in the AS&R industry have evolved strategic behaviors and conduct that reflect both the constraints and imperatives of their environment. **Firms prioritize securing government contracts above all**, tailoring their business strategies to the requirements and timelines of defense procurement. Since future cash flows depend on budgeted military programs, major contractors often focus on sustaining existing programs and incrementally improving them, rather than taking risky bets on entirely new systems without clear customer demand. The risk of losing a major contract – or failing to win one – looms large. In the case of the U.S. Air Force’s Collaborative Combat Aircraft (CCA) drone program, for example, firms invested heavily in prototypes, knowing that only one or two winners would be selected for production. This winner-take-all dynamic can discourage bold innovation from smaller companies; a failed bid could be “catastrophic” for a new entrant that bet its survival on a single program. Thus, **company conduct is often risk-averse and closely aligned with government signaling**. When DoD demand signals are weak or “choppy,” firms hesitate to pour resources into new development. An industry source bluntly noted that the Army must clearly define requirements *with* industry rather than trying to develop autonomy in-house – otherwise companies have little incentive to invest in uncertain projects. This underscores that the conduct of firms (R&D investment decisions, product strategy) is largely a response to the conduct of the government as the dominant customer.

At the same time, firms strive to **differentiate themselves through technology and partnerships** within the confines set by the customer. Because many defense autonomous systems have to meet exacting military standards, the space for technical differentiation can be

narrow. For instance, in unmanned ground vehicles (UGVs), competing contractors might all be bound by an Army-mandated common autonomy software kernel, limiting how much one vendor's AI can outperform another's. To stand out, companies emphasize unique capabilities – such as superior AI algorithms, sensor integration, or modular designs – that address specific mission challenges. An example is the race to develop better off-road autonomy: firms are investing in advanced perception and navigation AI to overcome the notoriously difficult task of autonomously driving through unstructured terrain. However, when those advances are incremental and all players face similar technical hurdles, **firms also turn to strategic partnerships and cross-sector innovation** to get ahead. One notable trend is defense firms partnering with commercial tech companies or foreign allies to leverage outside expertise. The partnership between a U.S. startup (Anduril) and South Korea's Hanwha to jointly develop robotic vehicles combined Anduril's AI and autonomy savvy with Hanwha's manufacturing and component strengths. Such alliances allow entrants to surmount entry barriers by tapping established supply chains and allow incumbents to inject fresh technology rapidly. Similarly, traditional defense primes have begun collaborating with automotive autonomy companies (e.g. Kodiak Robotics or other self-driving firms) to import cutting-edge commercial AI into military prototypes. In short, firm conduct is characterized by **collaboration as much as competition** – a reflection of both the high technical complexity (no single firm has all the needed expertise) and the constrained market (where sharing risk can be prudent).

Another aspect of conduct is how companies manage their supply chains and production strategies in light of strategic competition. U.S. defense firms, recognizing the supply

vulnerabilities, are cautiously reshoring or diversifying suppliers away from adversary nations for critical components. They are also expanding manufacturing capacity where possible. For example, an American firm building a new drone production facility in partnership with an allied nation or U.S. state incentives is attempting to overcome the DIB's limited surge capacity. Still, due to pressure for efficiency and profitability, defense contractors often prefer to avoid maintaining idle excess capacity. This has led to reliance on just-in-time production and outsourcing, which, while cost-effective in peacetime, can leave the industry unprepared to **surge output in a crisis**. Firm conduct historically favored lean operations, but the renewed threat of great-power war is prompting companies (at the urging of government) to revisit the balance between efficiency and readiness.

From an international perspective, firm conduct is also shaped by national industrial policies. In China's state-directed system, companies in the autonomous systems sector behave as extensions of national strategy – blurring the line between firm conduct and government conduct. Under Beijing's Military-Civil Fusion strategy, private robotics and AI companies are expected to share innovations with the military, and state-owned enterprises receive direct infusions to achieve strategic targets. Chinese firms, therefore, emphasize **scale and speed**: rapidly prototyping and mass-producing new autonomous platforms, often by leveraging or outright copying foreign technologies. The conduct of Chinese enterprises is to flood the field – as seen in the 2024 World Robot Conference where over 27 Chinese companies showcased humanoid robots in a bid for dominance. In Russia, many robotics firms are either part of traditional defense conglomerates or closely tied to the military; their conduct has involved quick deployment and

field testing of systems in conflict zones (Syria, Ukraine) to iterate on designsfile-
 abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. This **combat experimentation**
 approach – using active battlefields as testing grounds – is a stark contrast to the U.S., where
 companies must go through lengthy development and testing cycles before fielding. Russian
 developers have demonstrated boldness in deploying semi-autonomous combat UGVs early,
 though not without setbacks (for instance, the much-hyped Uran-9 robot tank suffered serious
 performance problems, indicating overreach of its developers)file-abbob7zm6hw64t2lkenqcx.
 Thus, globally, we observe divergent conduct: U.S. firms operate within a tightly regulated,
 customer-driven model focusing on reliability; Chinese firms act under state patronage to
 achieve scale and speed; Russian efforts, while less technologically advanced, leverage
 opportunistic testing and urgent military needs.

Allied Contributions: The Case of South Korea

U.S. allies contribute meaningfully to the AS&R industry, both as collaborators and as additional
 competitors that spur innovation. Chief among these is the Republic of Korea (South Korea),
 which has emerged as a technologically advanced, **high-trust partner** in robotics and
 autonomous systems. In the span of a few decades, South Korea transformed from a war-torn
 agrarian economy into a global innovation leader by investing heavily in science and technology
 infrastructurefile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. Notably, South
 Korea established specialized research institutions – such as the Korea Institute of Robotics &
 Technology Convergence (KIRO) and the Korea Institute for Robot Industry Advancement
 (KIRIA) – that bolster both military and civilian robotics developmentfile-
 abbob7zm6hw64t2lkenqcx. This long-term nation-wide focus on robotics R&D has produced a
 vibrant industry capable of designing advanced autonomous platforms and components.

South Korean firms today demonstrate capabilities highly relevant to defense autonomy. For example, Korean companies have developed unmanned ground and aerial systems for military use and have shown their potential through joint projects with the United States. In December 2023, the U.S. Navy successfully test-fired a South Korean guided rocket (by LIG Nex1) from a U.S.-made unmanned surface vessel, validating the **interoperability and technical maturity** of South Korea's systems in a U.S. combat platform. This kind of integration trial underscores how allied technology can augment U.S. unmanned systems, potentially enhancing performance (in this case, giving a U.S. drone boat a new weapon) and increasing capacity. Indeed, partnerships with South Korean defense giants like Hanwha and LIG Nex1 offer U.S. firms access to additional production facilities and innovative subsystems. By co-producing systems such as drones or robotic vehicles with South Korea, the U.S. can both broaden its industrial base and deepen alliance ties.

However, leveraging allied contributions is not without challenges. **Regulatory and security barriers** can hinder smooth collaboration. Despite South Korea's advanced capabilities and aligned strategic interests, its companies must navigate stringent U.S. cybersecurity and supply chain requirements to participate in American defense programs. The DoD's strict Cybersecurity Maturity Model Certification (CMMC) and related standards impose costly compliance burdens on foreign partners, effectively raising the bar for entry even for trusted allies. This means South Korean firms often have to adapt their products and practices – from hardening software against cyber threats to reengineering supply chains – before they can integrate with U.S. systems. Such hurdles reflect a tension in U.S. defense acquisition: the need

to protect networks and data versus the desire to quickly adopt allied innovationsfile-abbob7zm6hw64t2lkenqcx. Nonetheless, South Korea’s continued investment in autonomous technology (driven partly by its own military needs and even civilian sectors like logistics and agriculture) makes it a key player in the global AS&R landscape. Its role exemplifies how U.S. allies can act as force multipliers in great-power competition – providing additional technology, industrial depth, and deployment experience – if collaboration is effectively managed.

Performance, Innovation, and Strategic Implications

The structure and conduct described above directly impact the **performance of the AS&R industry**, in terms of innovation pace, production capacity, and overall contribution to national strategic objectives. In many respects, the industry’s performance is a mixed picture. On one hand, the United States retains a **cutting-edge lead in key autonomous technologies** – particularly in AI software, high-end sensors, and complex integration of systems. American firms and research institutions have pioneered much of the autonomy and AI algorithms that underpin advanced drones and robots. The U.S. military also has unmatched operational experience integrating drones into warfare over two decades of counterterrorism operations, giving it a reservoir of doctrinal and tactical know-how. These are reflected in studies showing the U.S. still exporting the largest share of advanced UGVs worldwide through 2020file-abbob7zm6hw64t2lkenqcx and leading the world in humanoid robotics R&D through its vibrant private sector and defense programsfile-abbob7zm6hw64t2lkenqcx. The **performance of the U.S. innovation system** in autonomy remains strong: for example, U.S. companies like Boston Dynamics, Tesla, and Nvidia drive breakthroughs in robotics and AI that feed into defense applicationsfile-abbob7zm6hw64t2lkenqcx. However, the **translation of this technological edge into mass-fielded capability is slow and uncertain**. Bureaucratic acquisition processes,

cautious testing, and inconsistent demand have meant that truly game-changing systems (like robotic combat vehicles or autonomous wingmen drones) are not yet deployed at scale by the U.S. armed forces. By 2025, the U.S. is only on track to field a fraction of the autonomous platforms envisioned for a potential conflict with a peer adversary, well below what many strategists consider necessary. This indicates a performance gap between technological potential and industrial output.

Meanwhile, U.S. adversaries are **narrowing the gap**. China's performance in the AS&R sphere is characterized less by cutting-edge innovation and more by rapid commercialization and scaling of existing technologies. Analysts observe a "dual-track" competition: the U.S. excels in upstream innovation (autonomy algorithms, advanced prototypes), whereas China excels in downstream execution – i.e., manufacturing at scale and iterating hardware quickly. China's sprawling manufacturing base and state-backed companies enable it to produce drones and unmanned vehicles in large volumes, quickly turning designs (whether indigenous or acquired through espionage/duplication) into deployable units. This has strategic consequences. For instance, China's ability to churn out swarms of low-cost armed drones or to equip its ground forces with numerous robotic vehicles could offset qualitative advantages of U.S. systems. The "mass problem" cited by U.S. planners – the prospect of facing a numerically overwhelming force of Chinese autonomous and manned platforms – is very much a product of China's industrial performance advantage. By setting ambitious targets (like President Xi Jinping's call to be ready to take Taiwan by 2027) and investing accordingly, China is sharply compressing development timelines. The performance gap in quantity and speed

thus favors China unless the U.S. and allies respond with greater production output of their own next-gen systemsfile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx.

Russia's industry performance, on the other hand, has been more uneven. Russian developers have shown flashes of advanced capability – such as AI-augmented unmanned ground vehicles and lethal autonomous drones – but have struggled with reliability and scale. The Uran-9 UGV's much-publicized failures in Syria (loss of communication and system breakdowns) revealed shortcomings in Russia's ability to field robust autonomous techfile-abbob7zm6hw64t2lkenqcx. Yet Russia has proved adept at repurposing and deploying whatever systems it can produce. In the ongoing Ukraine conflict, Russia (and Ukraine) have improvised extensive use of drones (often commercial quadcopters or loitering munitions) and even fielded experimental combat robots in limited numbersfile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. This wartime improvisation underlines that performance in a real conflict is not just about having the best technology, but having *enough* of it and using it creatively. In that respect, Russia's heavy use of Iranian-made drones and jury-rigged autonomous weapons shows a different kind of performance metric: the ability to absorb and deploy foreign or low-cost systems at scale. For the AS&R industry globally, conflicts like Ukraine serve as testing grounds that accelerate innovation cycles – the so-called “learning by doing” under fire. U.S. and allied observers note that each new tactic (e.g., drone swarms against armor) forces countermeasures, spurring rapid adjustments and improvementsfile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. Thus, while Russia may be behind in R&D, its conflict-driven usage contributes to the overall evolution of autonomous warfare, indirectly pressuring U.S. and Chinese developers to advance capabilities further.

Crucially, the **strategic implications** of these performance trends are profound. Autonomous systems and robotics are now seen as a cornerstone of future military power – an area where technological leadership translates into battlefield superiority. As one analysis put it, this is a shift of the competition from human manpower to machine intelligence and quantityfile-abbob7zm6hw64t2lkenqcx. The country (or coalition) that best harnesses the AS&R industry will attain significant military advantages, such as reduced risk to soldiers, faster decision cycles through AI, and the ability to project power with swarms of expendable systems. For the United States and its allies, maintaining an edge will require addressing the weaknesses in the current industry-performance link. This means **improving surge manufacturing capacity, sustaining more competitors to stimulate innovation, and smoothing the path for new technologies from lab to battlefield**file-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. Current U.S. policy discussions, for instance, emphasize avoiding overly restrictive down-selections and instead keeping multiple suppliers in play for critical systems to ensure redundancy and innovation competitionfile-abbob7zm6hw64t2lkenqcx. They also stress strengthening the defense industrial base by investing in workforce and infrastructure – essentially reversing some of the post-Cold War downsizing that left the DIB without flexibility for rapid expansionfile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. Allies like South Korea, Japan, and NATO partners are recognized as crucial in this effort; integrating allied production and R&D could help democracies collectively match the scale that China can achieve alone.

On the other side, China’s strategic aim to become a “world-class military by 2049” with leading AI and robotics capabilities means the U.S.–China contest in this industry will likely define the next generation of warfarefile-abbob7zm6hw64t2lkenqcx. Beijing’s civil-military fusion model actively seeks to erode America’s qualitative lead by unifying academic, commercial, and

military resources towards common goalsfile-abbob7zm6hw64t2lkenqcx. The U.S. and allies must therefore consider not just the performance of individual firms, but the **performance of their entire innovation ecosystem** versus that of authoritarian competitors. As of mid-2020s, the U.S. holds an edge in many technologies but risks falling behind in speed of deployment and volume. The next few years – with milestones like the planned fielding of U.S. Air Force CCAs, Army Robotic Combat Vehicles, and analogous Chinese projects – will be critical in determining whether the Western AS&R industry can overcome its structural constraints to deliver on the promise of autonomy.

In conclusion (as an analytical summary), the application of the Structure-Conduct-Performance paradigm and Porter's Five Forces framework to the AS&R industry reveals a complex interplay between market structure, firm behavior, and outcomes. A concentrated industry and powerful government buyer have thus far limited the commercial dynamism of the sector, yet the urgency of great power competition is pushing all actors toward greater innovation and output. The United States and its allies, like South Korea, are working to adapt their industrial and collaborative strategies to regain the initiative – expanding the number of competitors, leveraging dual-use technologies, and investing in capacity – to ensure that they do not cede the strategic high ground of autonomous systems to China or any adversaryfile-abbob7zm6hw64t2lkenqcxfile-abbob7zm6hw64t2lkenqcx. The performance of this industry will directly influence the future balance of military power. As autonomous and AI-driven warfighting tools become ever more integral to national defense, *how* nations organize and stimulate their AS&R industries may well decide their security in the decades to come. The race for advantage in autonomous systems is not only a contest of technology, but also of industrial agility and strategic alignment between governments and innovators. The countries that master

both the technology and the industry dynamics will be best positioned to prevail in the unfolding era of autonomous warfare.

Prompt: I'm researching the impact of Artificial Intelligence capabilities on the Autonomous Systems & Robotics Industry. What are the key relationships between the two? How does "AI" differ from "autonomy"? Consider using the Levels of Autonomy for vehicles as a framework to discuss how the impact of AI depends on the level of autonomy a system is looking to achieve.

ChatGPT said:

The relationship between Artificial Intelligence (AI) and Autonomous Systems & Robotics (AS&R) is integral and mutually reinforcing. AI serves as a foundational technology that enables robotics and autonomous systems to perceive, reason, plan, and act independently or semi-independently, significantly expanding their capabilities and performance. Understanding the nuanced distinctions and interactions between AI and autonomy provides clarity on how AI drives innovation in this industry.

Key Relationships between AI and Autonomous Systems & Robotics

1. Perception and Sensing

- **AI Contribution:** Machine learning algorithms enhance perception capabilities, enabling systems to accurately interpret environmental data from sensors (e.g., LIDAR, radar, camera images).
- **Impact:** Increased accuracy and robustness in object detection, classification, and environmental mapping.

2. Decision-Making and Planning

- **AI Contribution:** AI-driven algorithms enable predictive modeling, scenario analysis, and adaptive decision-making in uncertain or dynamic environments.
- **Impact:** Autonomous systems can operate effectively in complex, changing scenarios without explicit human programming.

3. Control and Actuation

- **AI Contribution:** Reinforcement learning and adaptive control methods empower robots and vehicles to learn optimal actions through trial-and-error interactions with the environment.
- **Impact:** Continuous improvement in control behaviors and adaptability, especially in dynamic or unpredictable operational contexts.

4. Communication and Collaboration

- **AI Contribution:** Natural Language Processing (NLP) and collaborative AI algorithms facilitate enhanced human-system and system-to-system interactions.
- **Impact:** Better integration within teams and increased effectiveness in collaborative scenarios involving multiple autonomous systems.

5. Maintenance and Predictive Diagnostics

- **AI Contribution:** Predictive analytics enable anticipatory maintenance, fault detection, and optimization of system lifecycle management.
- **Impact:** Reduced operational downtime, increased system reliability, and lower maintenance costs.

Clarifying "AI" versus "Autonomy"

While often interrelated, the terms "AI" and "autonomy" represent distinct concepts:

Artificial Intelligence (AI)

Refers to technologies enabling machines to simulate human-like cognitive capabilities (perception, reasoning, learning, and decision-making).

Focuses on developing intelligence or cognitive behaviors through computational methods.

Can be present in systems with varying degrees of autonomy, including purely advisory or assistive roles.

Autonomy

Refers to the degree to which a system can operate independently of human intervention or external control.

Emphasizes operational independence, self-governance, and decision-making freedom.

Exists on a continuum from fully human-dependent operation (no autonomy) to complete independence (full autonomy).

Levels of Autonomy as a Framework

The SAE International standard (J3016) defines vehicle autonomy along six clearly delineated levels, each affected uniquely by the integration and sophistication of AI:

Level 0 (No Automation)

- **AI Impact:** Minimal; confined mostly to basic driver assistance alerts (e.g., collision warning).
- **Autonomy:** No autonomy; human controls all driving tasks.

Level 1 (Driver Assistance)

- **AI Impact:** AI enhances limited functions, such as adaptive cruise control or lane-keeping assist, but humans perform majority of tasks.
- **Autonomy:** Very low; partial, targeted support with active human oversight.

Level 2 (Partial Automation)

- **AI Impact:** AI integrates multiple driving assist functions simultaneously, enabling automated steering, acceleration, and braking under defined conditions.
- **Autonomy:** Limited; human required to actively supervise and intervene immediately if necessary.

Level 3 (Conditional Automation)

- **AI Impact:** Significant AI influence; system manages all critical driving tasks within certain scenarios but still requires human readiness for fallback.
- **Autonomy:** Moderate; AI autonomously handles scenarios like highway driving, yet demands human intervention for more complex environments.

Level 4 (High Automation)

- **AI Impact:** Advanced AI capabilities, including decision-making, scenario analysis, and robust perception enabling operations even in complex environments, within defined Operational Design Domains (ODD).
- **Autonomy:** High; human intervention unnecessary within specified conditions but possible outside defined boundaries.

Level 5 (Full Automation)

- **AI Impact:** Maximum AI sophistication, including near-human-level reasoning, planning, and general environmental adaptability.
- **Autonomy:** Complete; fully autonomous operation in all conditions and environments without human intervention or oversight.

Summary of AI Impact Based on Autonomy Level:

Autonomy Level	AI Complexity	Key AI Contributions	Degree of Human Involvement
Level 0-1	Low	Basic sensing, limited decision support	Human dominant, AI supportive
Level 2-3	Moderate	Integrated sensing, decision-making, and environmental adaptation	Human oversight, AI actively engaged
Level 4-5	High	Advanced planning, reasoning, adaptive learning, predictive analytics	AI dominant, minimal/no human oversight

Conclusion

Artificial Intelligence is central to the advancement of the Autonomous Systems & Robotics Industry, with its role and impact highly dependent upon the level of autonomy targeted. As autonomous systems progress along this continuum, AI becomes increasingly sophisticated and indispensable, driving deeper integration and wider capabilities across industry applications.

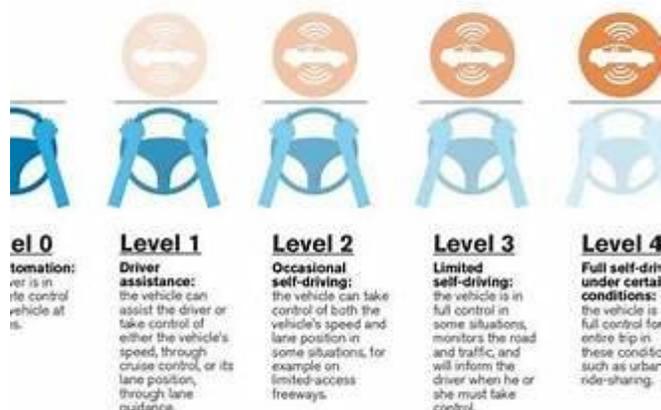
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You said:

Can you cite a few sources you used to find this information?

ChatGPT said:

Five Levels of Vehicle Autonomy



SAE J3016™ LEVELS OF DRIVING AUTOMATION™

Learn more here: [sae.org/standards/content/j3016_202104](https://www.sae.org/standards/content/j3016_202104)

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SAE LEVEL 0™	SAE LEVEL 1™	SAE LEVEL 2™	SAE LEVEL 3™	SAE LEVEL 4™	SAE LEVEL 5™
You are driving whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering.			You are not driving when these automated driving features are engaged – even if you are seated in "the driver's seat"		
You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety.			When the feature requests, you must drive.	These automated driving features will not require you to take over driving.	

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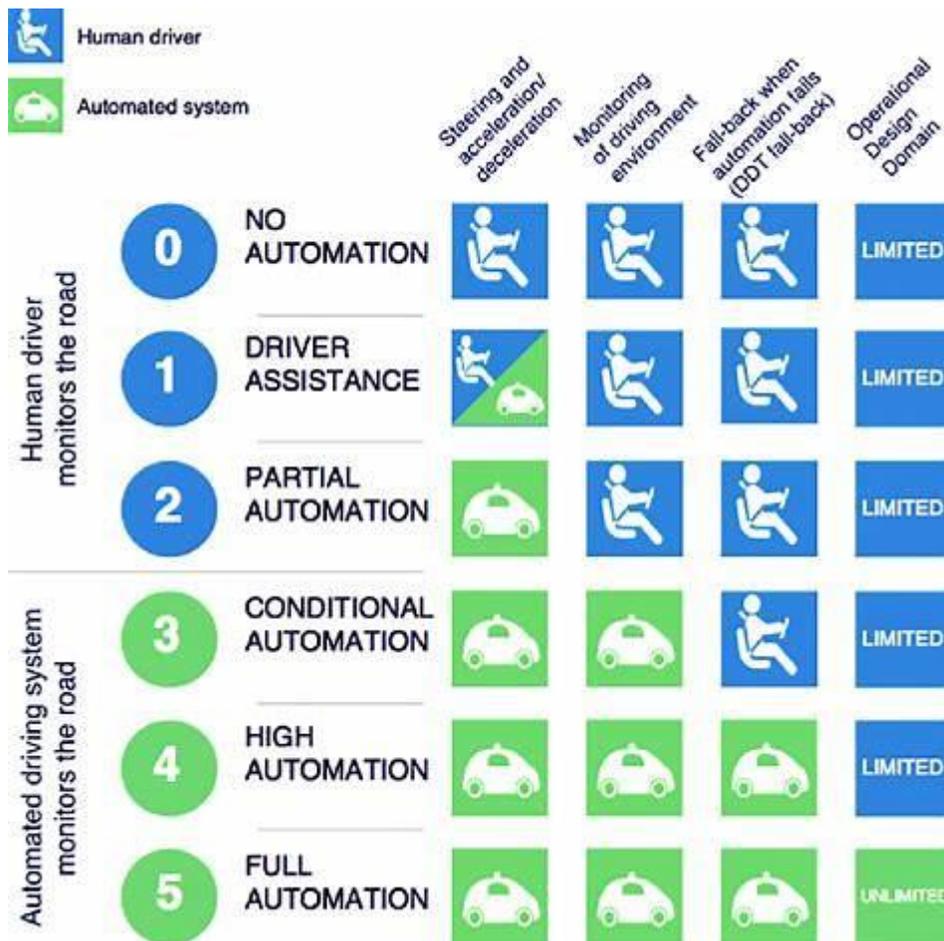
These are driver support features

These features are limited to providing warnings and momentary assistance	These features provide steering OR brake/acceleration support to the driver	These features provide steering AND brake/acceleration support to the driver
<ul style="list-style-type: none"> • automatic emergency braking • blind spot warning • lane departure warning 	<ul style="list-style-type: none"> • lane centering OR • adaptive cruise control 	<ul style="list-style-type: none"> • lane centering AND • adaptive cruise control at the same time

These are automated driving features

These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met	This feature can drive the vehicle in all conditions
<ul style="list-style-type: none"> • traffic jam chauffeur • local driverless taxi • pedals/steering wheel may or may not be installed 	<ul style="list-style-type: none"> • same as level 4, but feature can drive everywhere in all conditions

LEVELS OF DRIVING AUTOMATION



Certainly. Here are several authoritative sources that inform the discussion on the interplay between Artificial Intelligence (AI) and the Autonomous Systems & Robotics (AS&R) industry, particularly concerning the SAE Levels of Driving Automation:

1. SAE J3016 – Levels of Driving Automation

The SAE J3016 standard, established by SAE International, delineates six levels of driving automation, ranging from Level 0 (no automation) to Level 5 (full automation). This taxonomy is widely adopted in the automotive industry to classify the extent of automation in vehicles. The standard provides clear definitions for each level, specifying the roles of the driver and the automated system in various driving scenarios.[SAE International+1](#)[SAE International+1](#)

Source: SAE International. "Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles." SAE J3016_202104. [SAE International](#).
[UNECE Wiki+2](#)[SAE International+2](#)[Wikipedia – Die freie Enzyklopädie+2](#)

2. Role of AI in Autonomous Vehicles

AI is integral to the development of autonomous vehicles, enabling capabilities such as perception, decision-making, and control. AI algorithms process data from various sensors (e.g., cameras, LiDAR, radar) to interpret the vehicle's environment, make driving decisions, and execute control actions. The complexity and sophistication of AI systems increase with higher levels of vehicle autonomy.

Source: 98th Percentile. "Role of AI in Autonomous Vehicles." [98th Percentile Blog](#).
[98thPercentile](#)

3. Integration of AI in Robotics

The integration of AI into robotics enhances the adaptability and functionality of robotic systems. AI technologies, such as machine learning and computer vision, enable robots to perceive their environment, make informed decisions, and perform complex tasks autonomously. This integration is pivotal in advancing the capabilities of autonomous systems across various industries.

Source: Netguru. "The Impact of Robotics and Artificial Intelligence on Industries." [Netguru Blog, Software Development Company | Netguru](#)

4. AI Algorithms for Autonomous Vehicles

Advanced AI algorithms are crucial for enhancing the perception and decision-making capabilities of autonomous vehicles. These algorithms process high-definition mapping data and real-time sensor inputs to facilitate accurate environment modeling and safe navigation. The development of such algorithms is essential for achieving higher levels of vehicle autonomy.

[Financial Times](#)+[8voxelmaps.com](#)+[8The Verge](#)+[8](#)

Source: Voxelmaps. "AI Algorithms for Autonomous Vehicles: How Advanced Data Solutions Enhance Perception and Decision-Making." [Voxelmaps News, voxelmaps.com](#)

5. Decision-Making in Autonomous Driving

Decision-making is a critical component of autonomous driving systems. Research in this area focuses on developing algorithms that enable vehicles to make safe and efficient decisions in complex and dynamic environments. Approaches include rule-based systems, machine learning

models, and hybrid methods that combine data-driven and model-based techniques.

[Medium+3arXiv+398thPercentile+3](#)

Source: National Center for Biotechnology Information (NCBI). "How Do Autonomous Vehicles Decide?" [PMC Article](#).[PMC](#)

These sources provide comprehensive insights into how AI technologies underpin the functionality and advancement of autonomous systems and robotics, particularly in the context of varying levels of autonomy as defined by SAE J3016.

I need an introduction for the attached paper. Less than 1 page in length. Briefly highlight key themes and trends from the AS&R industry, and why this industry is critical to US national security.

ChatGPT said:

Here is an introduction for your paper, highlighting key themes and trends in the Autonomous Systems & Robotics (AS&R) industry and its significance for U.S. national security:

The Autonomous Systems and Robotics (AS&R) industry stands at a pivotal crossroads, significantly shaping the future landscape of national security, economic competitiveness, and technological innovation. Autonomous systems, characterized by increasing levels of sophistication in artificial intelligence, robotics, and machine learning, are rapidly transitioning from theoretical constructs to critical operational assets. This industry encompasses a diverse array of platforms, including unmanned aerial vehicles, autonomous maritime systems, ground robotics, and sophisticated loitering munitions, each increasingly indispensable for modern defense operations.

Key trends within the AS&R sector underscore the urgent imperative for robust strategic direction and enhanced collaboration between government entities, academia, and private industry. Notably, innovation trends such as additive manufacturing, iterative software updates, human-machine teaming, and reinforcement learning have accelerated technological capabilities, but also highlighted vulnerabilities, particularly within supply chains reliant upon critical materials sourced from geopolitical adversaries. Additionally, workforce constraints and stringent regulatory environments continue to present significant barriers to rapid innovation and adoption.

The United States faces heightened strategic competition as near-peer adversaries, particularly China and Russia, make aggressive strides in developing their autonomous warfare capabilities. These advancements pose direct challenges to U.S. technological supremacy and operational preparedness. As the global race for autonomy escalates, it is imperative for the U.S. to adopt integrated policies and targeted investments that foster domestic innovation, ensure secure supply chains, and solidify technological partnerships with allies. The performance and agility of the AS&R industry will thus not only dictate economic trajectories but profoundly determine national security outcomes in the decades ahead.

GLOSSARY OF ACRONYMS

A3 –The Association for Advancing Automation

AI – Artificial Intelligence

ANSI – American National Standards Institute

AS&R – Autonomous Systems and Robotics

CSO – Cost Accounting Standards

CDAO – Chief Digital and AI Office

CCA – Collaborative Combat Aircraft

CIO – Chief Information Officer

CMMC – Cybersecurity Maturity Model Certification

CNC – Computer Numerical Control

CUI – Controlled Unclassified Information

CRADA – Cooperative Research and Development Agreements

CSDR – Cost and Software Data Reporting

CSO – Commercial Solutions Openings

DARPA – Defense Advanced Research Agency

DAU – Defense Acquisition University

DAWIA – Defense Acquisition Workforce Improvement Act

DCAA – Defense Contract Audit Agency

DCSA – Defense Counterintelligence and Security Agency

DCTC – Defense Civilian Training Corps

DFARS – Defense Federal Acquisition Regulation Supplement

DIB – Defense Industrial Base

DISS – Defense Information System for Security

DIU – Defense Innovation Unit

DoD – Department of Defense

DoS – Department of State

DPC – Defense Pricing and Contracting

DPA – Defense Production Act

EAR – Export Administration Regulations

FAR – Federal Acquisition Regulation

FCL – Facility Clearance

IBAS – Industrial Base Analysis and Sustainment

ICSP – Interagency Committee on Standards Policy

HMT – Human Machine Teaming

IP - Intellectual Property

ISR – Intelligence, Surveillance, and Reconnaissance

ITAR – International Traffic in Arms Regulations

FFRDC – Federally Funded Research and Development Center

KIRIA – Korea Institute for Robot Industry Advancement

KIRO – Korea Institute of Robotics & Technology Convergence

MOSA – Modular Open Systems Approaches

NIST – National Institute of Standards and Technology

NSC – National Security Council

OSC – Office of Strategic Capital

OSTP – Office of Science and Technology Policy

OTA – Other Transaction Authority

PEO – Program Executive Office

PLA – People’s Liberation Army

PM – Program Manager

POM – Program Objective Memorandum

PRC – People’s Republic of China

R&D – Research and Development

RFP– Request for Proposal

RL – Reinforcement Learning

ROI – Return on Investment

SAE – Service Acquisition Executive

SBIR – Small Business Innovation Research

SECDEF –Secretary of Defense

UAS – Uncrewed Aerial System

UGV – Uncrewed Ground Vehicle

USV – Uncrewed Surface Vehicle

UUV – Uncrewed Underwater Vehicle

USD(A&S) – Office of the Under Secretary of Defense for Acquisition and Sustainment

USD(R&E) – Office of the Under Secretary of Defense for Research and Engineering

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All American Racers, Santa Ana, CA, April 2025

Anduril, Costa Mesa, CA, April 2025

Aptronik Inc., Austin, TX, April 2025

Aurora Flight Sciences, a Boeing Company, Manassas, VA, February 2025

Aurora Innovations, Pittsburgh, PA, February 2025

Boston Dynamics, Boston, MA, March 2025

Carnegie Mellon University Cloud Lab, Pittsburgh, PA, February 2025

Daedong Mobility, Daegu, ROK, April 2025

Daegu Gyeongbuk Institute of Science and Technology, Daegu, ROK, April 2025

DIVE Technologies, Boston, MA, March 2025

General Atomics Aeronautical Systems, Poway, CA, April 2025

Hanwha Aerospace R&D Pangyo House, Seongnam, ROK, April 2025

HD Hyundai Global R&D Center, Seongnam, ROK, April 2025

HD Hyundai Heavy Industries Robotics Manufacturing, Daegu, ROK, April 2025

HDT Global Battle Lab and Advanced Development Engineering (BLADE) Center, Fredricksburg, VA, January 2025

Human Engineering Research Laboratories, Pittsburgh, PA, February 2025

Hyundai Motor Robotics Lab/Central Research Center, Uiwang, ROK, April 2025

Korea Institute for Robot Industry Advancement (KIRIA), Daegu, ROK, April 2025

Korea Institute of Robotics & Technology Convergence, Pohang, ROK, April 2025

LIG Nex1, Daegu, ROK, April 2025

LIG Nex1 Pangyo House, Seongnam, ROK, April 2025

Machina Labs AI, Chatsworth, CA, March 2025

Mass Challenge, Boston, MA, March 2025

Nvidia Corporation, Santa Clara, CA, April 2025

Optimus System, Daegu, ROK, April 2025

Shield AI, San Diego, CA, April 2025

Textron Systems, Cockeysville, MD, March 2025

TechForge, Pittsburgh, PA, February 2025

The Engine, Boston, MA, March 2025