DEFENSE INNOVATION BOARD

A PATHWAY TO SCALING UNMANNED WEAPON SYSTEMS

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Executive Summary

Unmanned Weapon Systems (UxS) have become one of the defining features of modern conflict. While small aerial systems are the most high-profile of these examples, every domain of warfare is affected. Yet, the United States Department of Defense (DoD), once the world's leader in military applications of UxS, has lost ground to other nations in producing and utilizing these systems.

UxS cannot contribute to American security on PowerPoint slides or in small quantities typical of exquisite systems, only with sufficient production and the ability to field at scale will they matter. To effectively prepare the Joint Force for future conflicts, the DoD must collaborate closely with a variety of defense industrial partners to develop and produce the necessary UxS capabilities in relevant quantities. It must also establish military doctrine, organizational structures, and training programs that enable warfighters to deploy, operate, and sustain these platforms effectively under realistic conditions. Furthermore, the DoD should ensure that procured systems are continuously updated to remain effective in rapidly evolving operational environments.

Failure to act will leave warfighters unprepared and poorly equipped for future conflicts, endangering the lives of Americans and our allies. In a potential large-scale conflict, the widespread deployment of UxS — whether by the Joint Force or our adversaries — is an inevitability that demands immediate action. Waiting until we are confronted with footage of American service members falling victim to enemy first-person view (FPV) drones is not an option. We must act now with the urgency this challenge demands.

Critical Actions to Take:

1. Put relevant numbers of UxS in the hands of warfighters early and often — let them stress test and provide feedback throughout the technology development and acquisition process.

2. Pick UxS manufacturing winners and award them contractually.

3. Dramatically shorten DOTMLPF development timelines.

4. Develop more flexible funding mechanisms — make budget processes move at the speed of technology development.

The most important recommendation we can offer, however, is to ***act*** — act with the urgency that the changes in warfare and chaotic world security environment demand. We cannot afford the time to find perfect answers for each question. We also cannot afford to rely on the traditional procurement mechanisms to deliver in relevant timeframes. We must get unmanned systems in the hands of the warfighters in sufficient quantities to matter now.

Study Overview

The Defense Innovation Board (DIB) was tasked with identifying requirements for fielding UxS at scale. In addition to leveraging existing work on this topic, the DIB interviewed over 150 leaders in the UxS space, to include DoD leaders, Program Executive Offices, service members, founders, and other technical experts. This report outlines the key findings from these discussions, including an actionable roadmap for incoming leadership in Congress and the DoD.

For our purposes, we define "scale" to mean that enough systems are in the hands of warfighters, with sustainable supply during a conflict, to meaningfully contribute to military success at sustainable costs. We organized our recommendations in five categories. Each category comprises actionable recommendations with complementary, detailed appendices:

I) Demand Signal

II) Funding

III) DoD Structure & Processes

IV) Supply Chain

V) Acquisition & Manufacturing

Recommendations

I) Demand Signal

To begin the process of scaling UxS, DoD must identify the technologies that it wants to scale. As of now, one of the primary challenges UxS companies face is a lack of a clear demand signal from the DoD. Many organizations within DoD are currently experimenting with unmanned systems in small quantities, but outside of the Replicator initiative, it is not a clear what platforms DoD wants to move forward with in meaningful quantities. Adding to the confusion and delay is the DoD's elongated Planning, Programming, Budgeting & Execution (PPBE) and doctrine, organization, training, materiel, leadership and education, personnel, and facilities (DOTMLPF), and requirements development processes which prevent economies of scale and cost efficiency in small systems intended to be used en masse. To begin addressing these issues, the DIB recommends the following:

1. The Services should create a parallel requirements development process fit for rapidly changing, low-cost technologies (i.e. UxS).
    a. Accelerated DOTMLPF reviews for force design changes involving unmanned systems, and subsequent Force Integration Feasibility Assessments, should be used to communicate topline UxS numbers to help industry partners understand DoD direction in the UxS space.
2. DoD and the Services should publish an unclassified operational and tactical vision for UxS in the force, akin to assigned weapon systems in a unit's Modification Table of Organization and Equipment (MTOE).
    a. The "how" of UxS should rightfully remain a protected class of information, but topline budgets and more concrete procurement targets will provide necessary vector for private capital and UxS manufacturers.
3. The Services should place certain categories of UxS within the appropriate classes of supply (i.e. as no different than mortar rounds, artillery shells, and other Class V).
    a. While essential to proper UxS integration into the force, this step will also clearly signal to industry that DoD understands UxS role not only as capable ISR platforms, but as precise mass that is meant to be consumed in large quantities.
    b. Those systems must then be purchased and stockpiled at the required scale to meet mission needs.

II) Funding

To make a "demand signal" effective and elicit the desired response from manufacturers and capital allocators, DoD must have funding ready to commit. As with other rapidly evolving technologies, the state of the art with UxS changes far faster than the traditional governmental budget processes. We believe that funding flexibility is an essential element of scaling UxS. DoD and Congress must agree on a flexible funding mechanism with transparency back to Congress that allows DoD to move quickly in following the evolution of the technology and the evolving thinking on what system characteristics

DoD needs. Further, industry investors and/or stakeholders need to know that funding opportunities are consistent and present the possibility to be long-term and not singular orders. As with other areas where DoD must leverage private capital in order to scale, the threat of government shutdowns, and restrictions related to continuing resolutions and DoD processes that slow its ability to commit funding are a major impediment.

1. Work with Congress to agree on a funding mechanism that enables Program Manager to act with the speed and flexibility needed to get UxS systems fielded as soon as possible and then upgraded as appropriate.
2. Aggressively identify producers with winning UxS and UxS manufacturing processes, and award them with longer-term funding lines.
3. Identify and prioritize investment in companies that meet UxS-critical criteria.
    a. Digitalization of manufacturing processes.
    b. On/ally-shoring of critical mineral and manufacturing supply chain processes.
    c. Adoption of modern additive manufacturing techniques capable of scaling.
    d. Integration with to-be-determined common software and hardware frameworks.
    e. Adherence to Modular Open Systems Approach (MOSA)
4. When making key investment decisions, account for speed of delivery and creation of investor value.
    a. A large portion of this space is funded by private capital which will cease to engage if DoD fails to be a reliable return on investment for effective products that meet DoD needs. DoD's is not beholden to the creation of investor value, but like the dictates of terrain on a mission, market forces are a key consideration in this space.
5. Attach clearly defined contractual awards for standout performers at UxS field demonstrations.
    a. Must have clearly stated funding outcome, including source, duration, and procurement expectations, to as well as mechanisms for winners that incentivize companies to compete while ensuring investment can be returned throughout the Research, Development, Test and Evaluation (RDT&E) lifecycle.
    b. Complimentarily, funds are reinvested from legacy or adjacent programs, *instead of* losing them altogether as this creates the perverse incentive to perpetuate defunct tech.

III) DoD Structure & Processes

With its current structure and processes, DoD is not capable of scaling UxS production in a relevant timeframe. While encouraging progress has been made through the Replicator initiative and direct and personal involvement from the Deputy Secretary, scaling remains a key challenge. DoD has demonstrated the ability to meet urgent needs in the past with new organizations (e.g. Joint Improvised-Threat Defeat Organization) and with interagency efforts (e.g. Operation Warp Speed). There are several workable formulations, but whichever option is used requires there to be a clear line of authority and the responsibility to act with urgency. To better equip the DoD to address these issues, the DIB recommends the following:

1. Establish a Joint small UxS Management Office (J-sUMO) to concentrate efforts UxS acquisition efforts across the DoD.

a. The J-sUMO should be funded at the OSD level and involve each of the Services and Combatant Commands. Its founding function should be to minimize duplicative efforts across the DoD and concentrate innovation and acquisition efforts.

b. Require the use of cross-functional teams comprised of multi-echelon members of end-users, sustainers, scientists, and industry with targeted problem statements to address.

2. The DoD should drastically shorten technology timelines for UxS.

    a. Design, experimentation, requirements building, and other processes should not be siloed and sequential. Wherever possible, they should heavily overlap.

    b. Low-Rate Initial Production (LRIP) timelines should be cut in half. Senior leaders should be clearly brief on potential risks from truncated timelines and be empowered to make decisions based on said risk profiles.

3. OSD and the Services should develop an OSD-level joint Weapons System Certification (WECERT) to replace the current system of siloed, service-specific WECERT.

IV) Supply Chains

Modern technologies, including UxS, rely heavily on critical minerals, such as lithium, cobalt, and nickel, where China dominates the supply chain from extraction to end-use manufacturing. This dominance has enabled China to produce key components, like high-quality batteries and small brushless motors, at scales and costs that are difficult for U.S. manufacturers to match without similar government intervention. The vulnerability of U.S. manufacturers to supply chain disruptions, sanctions, and resource shortages — exemplified by sanctions levied on many major drone manufacturers by China in December 2024 — highlights the urgent need for action. To begin addressing these issues, the DIB recommends the following:

1. The DoD should identify specific component parts of UxS where it sees critical national security supply chain risks and require supply chain illumination *only* in these categories.

    a. Given UxS supply chains are almost entirely commercial, they are by nature difficult to track with any permanence. The identified components should be the most vital and vulnerable so as to avoid raising prices on UxS and discouraging new entrants into the space.

    b. Ensure Congress and DoD are in lockstep with industry when levying sanctions or regulations that will impact UxS supply chains.

    c. Navy Columbia class supply chain risk management best practices offer an effective roadmap for UxS, noting that the narrow scope is a significant reason for success.

2. The DoD should partner with Original Equipment Manufacturers to identify and scale cooperation on common, domestically produced components of UxS assemblies.

    a. Incentivizing cooperation and providing access to higher volume purchases will drive down overall prices and bolster an already fragmented and fragile market.

V) Acquisition & Manufacturing

We agree with those who argue that robust defense industrial capacity is a deterrent in and of itself. In order to produce and acquire UxS at scale, DoD must work closely with industry partners from the outset and recognize that Industry will only move at the speed of contract requirements. Speed and scale of delivery, as well as software adaptability, should be the central considerations in choosing and contracting for systems. Additive and modern manufacturing, and a robust network of suppliers, can

help with both speed of delivery and resilience of the supply base. Additionally, adopting concurrent testing and development processes, rather than sequential approaches, can significantly shorten timelines. Finally, any UxS systems acquired by the DoD must be designed for continuous updates to adapt to the rapidly evolving software landscape. To achieve UxS manufacturing and acquisition at scale, the DIB recommends the following:

1. The DoD (through the previously recommended J-sUMO office) must adopt and require common software and hardware standards and frameworks to push re-use and modularity at enterprise scale.
    a. These standards should allow for drone assemblies to be used on dissimilar systems from various manufacturers.
2. Expand investment of OSD Research and Engineering (R&E) efforts to utilize open-system government architectures and existing manufacturing infrastructure to create scalable UxS platforms not wholly reliant on large and consistent sales originating solely from defense manufacturers.
    a. Such efforts are essential to creating manufacturing surge capacity. Historically, munitions surge capacity is the first thing to be impacted by budget shortfalls. UxS' close parallel with commercial industry presents significant opportunity for housing this production capacity outside of the typical defense-specific spaces.
3. Eliminate "requirements"-based UxS Requests for Proposals (RFPs); shift to problems-based proposals to maximize creativity and innovation of solutions that exploit the entirety of industrial base and funding sources.

Scaling UxS is not a novel challenge involving unknown and untested technologies; rather, it is a challenge of bureaucratic flexibility and the willingness to take decisive action. Failure to do so makes us more likely to have a next war, and more likely to lose it. This challenge is not insurmountable, and the US has not lost the fight for UxS dominance, but regaining its seat as the UxS pathfinder requires the will, commitment, process improvement, and allocation of appropriate funding to ensure that service members are equipped with the tools they need to deter, fight, and win wars.

Appendix A – Clear Demand Signal

Despite the potential widespread use of Unmanned Weapon Systems (UxS) in future conflicts, and lessons from ongoing conflicts, demand signals from DoD have not matched the potential battlefield utility of UxS.[1] Vendors are often performing guesswork due to inadequate communication of DoD's operational vision and doctrine, leading to small-batch orders, inflated costs, suboptimal manufacturing, and substantial delays.[2] Most importantly, the DoD is not getting warfighters the systems they need in relevant quantities upon which they can provide feedback, train, and develop accompanying Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, and Facilities (DOTMLPF) components. Addressing these issues requires clearer communication of UxS roles[3], complementary funding lines, and improved planning to ensure both vendor sustainability and cost-effective procurement.

Put simply: the core challenge for domestic Unmanned Systems manufacturers scaling their operations with the Department of Defense (DoD) lies in the lack of a clear and consistent demand signal. This is exacerbated by the ambiguity surrounding the role of UxS in future combat scenarios. Despite significant efforts at the Office of the Secretary of Defense (OSD) level, such as the Replicator initiative, the communication of the DoD's operational and tactical vision for UxS to Congress and industry partners remains unclear, often due to security classification constraints.[4] As a result, industry partners and technologists are frequently left to operate based on assumptions and partial information, leading to inefficiencies. These inefficiencies arise because manufacturers must guess at future needs, leading to investments in technologies not officially required by DoD, thus disincentivizing cutting-edge innovation. This gap in communication and vision has created a broader divide between the DoD and industry, where technologists develop solutions based on their interpretations of conflicts and technology trends, rather than explicit DoD guidance.

This divide is manifest in the struggles faced by manufacturers, who receive small orders fraught with inefficiencies such as inflated prices and delayed deliveries. Vendors are left managing the suboptimal, small batch order planning that dominates the space, resulting in unoptimized manufacturing practices. One vendor we engaged who supplied roughly 1,000 Group 3 UAS in a year without a single order above 100 units, exemplified the constant struggles with subcomponent vendors.[5] This not only inflates costs for both DoD and industry but also hampers timely delivery.

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[1] For lessons learned from the Russo-Ukranian war regarding emerging technologies; Kunertova, D., & Herzog, S. (2024). Emerging and disruptive technologies transform, but do not lift, the fog of war – Evidence from Russia's war on Ukraine. ETH Zurich. Retrieved from ETH Zurich Repository and Hillström, E. (2024). Drönarutveckling och innovation i rysk-ukrainska kriget. DiVA Portal. Retrieved from DiVA Portal.

[2] DIB interview with anonymous UxS industry expert (October 4, 2024).

[3] Perhaps one of the most difficult aspects of scaling is the vast number of unmanned systems that are developed for specific mission roles, see Congressional Research Service. (2022). Unmanned Aircraft Systems: Roles, Missions, and Future Concepts (CRS Report No. R47188). Retrieved from https://crsreports.congress.gov/product/pdf/R/R47188

[4] DIB UxS industry roundtable (November 14, 2024).

[5] DIB UxS industry roundtable (November 14, 2024).

Appendix B – Funding

Although significant work is underway across the Services and at the Office of the Secretary of Defense, there remains a limited number of available funding lines. Furthermore, the budgets of said lines are not suitable to support new entrants in the DoD market at relevant levels, let alone achieve the desire cost curves and economies of scale.[67] At its core, resolving this issue requires more answers on the place of UxS within the Joint Force, and how they will—or will not—replace and/or augment traditional platforms in the battlespace. If the answer to those questions is to increase UxS investment to achieve real scale, sufficient funding must follow.

These funding challenges are further compounded by wide-ranging mission sets and the unique demands of different conflict zones, resulting in a sprawling set of required systems. In particular, these funding issues are underscored by the geographic, operational, and tactical challenges of the Indo-Pacific, where unique demands necessitate distinct capabilities with increased costs.[8] At the macro level, this means more money allocated for UxS. Given DoD's growing relationship with nontraditional vendors, and its increased ability to acquire commercial platforms, however, there are a multitude of considerations in lieu of topline budget increases. These largely reside at the nexus of private capital and defense. Specifically, the DoD *and* Congress must more effectively incentivize capital allocators to invest in UxS.

Unlike many other emerging technologies on the battlefield, UxS is relatively mature. The component parts and finished assemblies—even when we have insufficient production capabilities—are widely understood and replicable items. Hardware evolution has slowed, large amounts of capable companies have entered the space, and a race to the bottom has begun on prices.[9] To be sure, this a result that the DoD wants; indeed, to use UxS as many envision, it is a necessary one. Nevertheless, it will also result in more reluctance from capital allocators and must be accounted for.[10]

As it currently stands, the DoD is not taking the necessary actions to mitigate this reluctance. Some of those shortcomings are as follows:

- The DoD is making a large number of smaller bets instead of fewer, more concentrated ones.
- Funding considerations for aerial systems do not always track with their ground, underwater, and surface counterparts.
- The DoD has not sufficiently prioritized the Modular Open Systems Approach (MOSA) for picking winners in the UxS space.

Ultimately, while the DoD's chief concern is not the profitability of companies in the private sector, it is a real consideration for keeping necessary capital allocation engaged in the space. Absent a comprehensive funding strategy and decisive action to fund winning UxS platforms, the DoD risks losing companies at the hardware and software cutting edge. Combined with stagnant toplines, inflexible funding categories, and endless continuing resolutions, it is paramount that DoD allocates UxS funding with speed, precision, and mass.

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[6] DIB industry roundtable (November 18, 2024).
[7] Kavanagh, J. (2024). Arming for the Air Littoral: The Defense Industrial Base and Future Air Warfare. Æther: A Journal of Strategic Airpower & Spacepower. Retrieved from JSTOR.
[8] DIB DoD roundtable (December 4, 2024).
[9] DIB interview with anonymous industry expert (December 9, 2024).
[10] Ibid.

Appendix C – DoD Structure & Processes

While reform of DoD structure and processes is an evergreen topic, the UxS space offers a unique subset of these issues. Across the DoD, there are countless efforts to develop, acquire, and field unmanned systems. Many of these efforts are laudable, and some even essential to modernizing the force, but the hype surrounding small UxS, and their inherent accessibility has resulted a sprawling ecosystem which is not efficient, user-friendly, nor lends itself to acquisition at scale.[11] Even in the case of the Replicator initiative, an effort with significant senior leader and Congressional support, acquisition numbers will only approach low thousands for specific platforms. To create an ecosystem which sustains companies capable of producing at necessary scale, DoD must place predictable and large orders which drive the more modern manufacturing practices elaborated elsewhere in this report, and that financially reward companies that are producing cutting edge and effective products. Given budgetary realities, a sprawling and disconnected UxS ecosystem is not conducive to this.

A selection of varied UxS efforts within DoD are highlighted here:

- Replicator – Announced in August 2023, the first iteration of the Replicator initiative was established in order to deliver all-domain attritable autonomous systems (ADA2) to warfighters at scale. As a flagship effort in the DoD's push towards precise mass, Replicator has worked to develop an accelerated process that identifies capabilities with significant operational impact and ensures they are placed on systems that are put in the hands of warfighters. It has worked across the OSD/Service/Combatant Command spectrum, and integrated non-traditional defense companies and more traditional defense sources.
- Blue UAS – In an effort to enable more rapid acquisition of existing UxS platforms, and to help the Services sort through an expansive commercial marketplace, DIU's Blue UAS List exists as a registry of commercially available UAS platforms readily available for purchase by the force.

Service- and Combatant Command (COCOM)-level efforts are particularly worthy of examination, as they often reveal the everyday impediments to warfighters receiving the training they need and the necessary kit to do so, and the shared challenges across DoD components:

- As part of the Army's Transformation in Contact initiative, the Multi-Purpose Company (MPC) and its Robotic Autonomous Systems Platoon (formerly Lethal Unmanned Systems Platoon) has worked to stress test existing UxS platforms, understand how they might best be integrated into the Army structure, and test attached fire control processes and battle management systems. As part of this process, it has been a key component in modernizing Army's approach to integrating unmanned systems.
- The Navy has simultaneously established a "Robotics Warfare Specialist" general rating to provide a career path for sailors to operate unmanned systems.
- The Air Force recalibrated the Special Operations Weather Teams (SOWTs) to Special Reconnaissance (SR) in 2019. As part of this initiative, the SR capability has been expanded to integrate airpower, leveraging squad-level drones (Groups 1 and 2) to facilitate both lethal and non-lethal effects.

Despite the importance of these efforts, they are being hampered by outdated rules, regulations, and laws, in addition to nascent knowledge of UxS platforms and slow cultural adaption. For example, while Federal Aviation Agency (FAA) regulations have a role to play in managing airspace more broadly, a

[11] DIB interview with DoD expert (October 30, 2024).

significant portion of the struggle to train properly is happening at the ground-force/base commander level.[12] The Joint Readiness Training Center and others understandably prioritize soldier safety but have yet to adapt to an emerging technology.

As a prime examples of this, MPC has not been allowed to put multiple UxS systems in the air simultaneously, has limited hours on available platforms, and is simply not allowed to train on attritable systems.[13] Similarly, SR Airmen must contend with limited airspace during training exercises, which can decrease operational capability. Beyond the existing challenges, it is essential that military occupational specialties (MOS) prioritize UxS as a primary duty, rather than an additional responsibility, to ensure effective and safe utilization of these systems and allow operators to dedicate the necessary time and expertise to master the complex skills required for UxS operations.[14] The only case we found where sufficient test flying access was granted involved an industry stakeholder with personal contacts at a privately owned airfield that obtained FAA permissions—and others in Ukraine. While commendable, this approach is not scalable or a best practice. It underscores the significant challenge the DoD faces with UxS and future conflicts.

Beyond safety-related limitations, there are numerous other shortcomings common with the uptake of new and relatively untested UxS technologies. For example, the UxS packages being purchased by the Army lack sufficient replacements for the most commonly worn-out components, units are restricted from printing or ordering one-off substitutes, and the brigade-to-company feedback mechanisms only happen informally. Such issues will be commonplace across the DoD, and DoD components should not address them in silos.

Streamlining the multitude of internal DoD processes and procedures—and collectively addressing challenges in UxS manufacturing, acquisition, adoption, and training—is an essential step across the lifecycle of UxS platforms. The recommended Joint sUxS Management Office (J-sUMO) can be the central node for proliferating best practices and lessons learned across the Joint Force, centralizing development and acquisition programs, and ensuring adherence to common UxS architectures. Lastly, overall reform of the many ways DoD interacts with nontraditional defense vendors is also essential—especially regarding over or misclassification of tech and access to resources. While this study has laid out specific recommendations for the UxS space, a more thorough analysis and recommendation package can be found in the DIB's concurrent report Scaling Nontraditional Defense Innovation.

[12] DIB interview with Service stakeholders (October 8, 2024).
[13] DIB interview with Service stakeholders (October 8, 2024).
[14] Roberts, E., & Beck, A. (2017, September). Management and training programs of military drone small unmanned aircraft systems. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 61, No. 1, pp. 1131-1135). Sage CA: Los Angeles, CA: SAGE Publications. https://doi.org/10.1177/1541931213601767

Appendix D – Supply Chains

Supply chain vulnerabilities, analogous to those highlighted by COVID 19 shortages, remain one of the most pressing challenges the United States faces today. Defense platforms are especially vulnerable, given their likelihood of being targeted by adversarial sanctions. Even within the defense space, UxS systems stand out due to their unique reliance on adversarial nations throughout the manufacturing lifecycle, from resource extraction to assembly (excluding software). The DoD and Congress are both acutely aware of these vulnerabilities, and have taken steps to highlight them to industry and create real change in this space:

- **NDAA 2025, Sec. 849** – Directs the Secretary of Defense to "develop and implement policies, procedures, and tools to incentivize each contractor of the Department of Defense to assess and monitor the entire supply chain of goods and services provided to the Department by such contractor to identify potential vulnerabilities and noncompliance risks with respect to such goods and services."[15]
- **Securing Defense-Critical Supply Chains** – In response to Executive Order 14017[16], the DoD released the Securing Defense-Critical Supply Chains action plan intended to foster healthy, resilient, and widespread supply chains across the defense industrial base. Additionally, the plan provided updates on DoD's Review of Critical Minerals. The plan focused on four key areas: kinetic capabilities, energy storage and batteries, castings and forgings, and microelectronics.
- **Supply Chain Security Strategy** – As part of its 2021-2026 Strategic Plan, the Defense Logistics Agency released its Supply Chain Security Strategy[17] aiming to address these challenges "across the enterprise." The strategy selected four strategic actions to accomplish this goal: institutionalize supply chain security, maintain integrity and access to key data, partner with reputable vendors, and strengthen resiliency.[18]

These are essential efforts for DoD supply chain resilience, but they are likely to miss certain segments or take significant time to affect UxS industry. Supply chains in the unmanned space are almost entirely commercial. They are not controlled under the International Traffic in Arms Regulations (ITAR) nor the Export Administration Regulations (EAR), they are broadly available, and they are used in a multitude of other commercial products—what can be used in a drone may just as readily be used to run a refrigerator. It is exceptionally difficult for the DoD to sway these in any meaningful way.

DoD has, understandably, focused on the concept of supply chain illumination as a method to identify vulnerabilities and begin the long process of mitigation. In dual-use spaces however, particularly where commercial interests are the primary driver, supply chain illumination with any permanence is an exceptionally difficult task, and one that will drive up costs for any involved technologies. This will drive away potential entrants, discourage companies already in the space, and hike up prices on platforms that we intend to be low cost.

S.4638 - 118th Congress (2023-2024): National Defense Authorization Act for Fiscal Year 2025. (2024, July 8). https://www.congress.gov/bill/118th-congress/senate-bill/4638

[16] The White House. (2022). Securing defense-critical supply chains: An action plan developed in response to President Biden's Executive Order 14017. Retrieved from defense.gov

[17] Defense Logistics Agency. (2021). DLA Strategic Plan 2021-2026. Retrieved from DAU.edu

[18] For supply chain resilience lesson learned from SEA29, see Hust, C. R., & Kavall, A. P. (2021). *Systems Engineering Analysis Capstone Report.* Defense Technical Information Center. Retrieved from DTIC

While significant effort is underway to create adequate supply outside of China, the process is slow, and existing companies remain hugely vulnerable to supply chain disruptions and direct sanctions[19]. U.S.-based firm Skydio, for instance, was recently sanctioned by the PRC over their sales of UAS to the Taiwanese National Fire Agency. The resulting battery shortages have forced them to ration cells per unit, and to prioritize specific DoD customers over commercial entities.[20] This moment is a canary in the coal mine for what is possible when we have ceded complete control of resources, supply chains, and manufacturing ability.

Critical Minerals and UxS - As the United States pushes closer to energy independence, our resource priorities have shifted from fossil fuel-based concerns to mineral shortages and vulnerabilities.[21] From semiconductors to batteries, modern technologies require largescale access to lithium, cobalt, nickel, graphite, and more.[22] As highlighted by the House Select Committee on the CCP, the PRC dominates the playing field with these key resources, to include the entire supply chain from mining and processing to metallurgy and end-use manufacturing.[23] A 2022 U.S. Geological Survey examined 50 critical minerals, finding the U.S. entirely reliant on imports for 12 of 50, and more than 50% import-reliant on an additional 29, with the vast majority of these imports coming from China.[24] This is not solely due to the existence of said critical minerals in the ground, but lagging processing capabilities within the United States. In a close parallel to U.S. UxS manufacturing struggles, the existence of low-cost suppliers—particularly in an environmentally destructive extractive industry—has incentivized the U.S. to simply import. Domestic capabilities have diminished in kind.[25]

While this issue is widespread across the economy, UxS are liable to be acutely impacted. As previously highlighted, they have been early targets for strategic sanctions by the CCP. Small, medium, and large UxS all rely heavily on many of these critical minerals, and on manufacturing facilities largely based in China.[26] Silicone, for instance, is essential to create semiconductors while lithium is essential to produce high-performance lightweight batteries.[27] Even at the most fundamental level, these technologies are overwhelmingly based on resources and processes originating in China.

Across the U.S. federal government, there have been a growing focus on the critical minerals issue. For instance:

- The House Select Committee on the Strategic Competition between the United States and the CCP announced a Critical Minerals Policy Working Group focused on countering CCP control of mineral supply chains.
- The 2025 NDAA requires the Director of National Intelligence to develop a strategy to "improve sharing between the Federal Government and private entities of information and intelligence to mitigate the threat...to critical minerals inputs."[28]

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[19] Parthemore, C. (2011). Elements of Security: Mitigating Risks from Critical Mineral Supply Chains. Center for a New American Security. Retrieved from CNAS.
[20] Bry, A. (2024, October 30). China's sanctions on Skydio. Skydio. https://www.skydio.com/blog/chinas-sanctions-on-skydio
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[23] Critical Minerals Policy Working Group Final Report. Select Committee on the CCP. (2024, December 11). https://selectcommitteeontheccp.house.gov/media/policy-recommendations/critical-minerals-policy-working-group-final-report
[24] U.S. Geological Survey releases 2022 list of critical minerals: U.S. geological survey. U.S. Geological Survey Releases 2022 List of Critical Minerals | U.S. Geological Survey. (2022, February 22). https://www.usgs.gov/news/national-news-release/us-geological-survey-releases-2022-list-critical-minerals
[25] DIB interview with anonymous manufacturing expert (November 13, 2024).
[26] DIB interview with anonymous UxS industry expert (November 1, 2024).
[27] Schadlow, N., Herman, A., & Helwig, B. (2021). Powering Innovations: A Strategic Approach to America's Advanced Battery Technology. Hudson Institute. Retrieved from Hudson Institute.
[28] S.4638 - 118th Congress (2023-2024): National Defense Authorization Act for Fiscal Year 2025. (2024, July 8). https://www.congress.gov/bill/118th-congress/senate-bill/4638

- The DoD maintains the National Defense Stockpile with materials considered essential for national defense and civilian life.[29]

Despite this widespread focus, and the DoD's significant interest in this space, it has limited ability to influence the critical mineral sector. While it uses large quantities of rare earths and critical minerals in weapons systems, and is the most significant market in defense acquisitions, it is a relatively minor player compared to commercial and consumer markets. Indeed, the DoD estimates itself to be less than 0.1% of global demand.[30] As such, it must work closely with Congressional and industry partners to ensure that existing and potential shortages are clearly understood, and that DoD invests intelligently in reestablishing domestic rare earth supply chains where most necessary.

[29] Emergency access to strategic and Critical Materials. Congressional Research Service. (2023, November 14). https://crsreports.congress.gov/product/pdf/R/R47833

[30] Critical materials: Action needed to implement requirements that reduce supply chain risks. U.S. Government Accountability Office. (2024, September 12). https://www.gao.gov/products/gao-24-107176#:~:text=DOD%20uses%20large%20quantities%20of,0.1%20percent%20of%20global%20demand.

Appendix E – Acquisition & Manufacturing

The DoD must continue to work towards and encourage the onshoring and ally-shoring of key manufacturing capabilities, and work to dramatically decrease acquisition timelines for unmanned systems. Critical minerals, supply chain security, funding, and demand signal will all be for naught if we fail to modernize and reform these sectors[31].

On the whole, U.S. manufacturing lags behind China in a number of key measurements. The United States produces 16.3% of global manufacturing value added as opposed to China's 30.9%; only 12% of American factories have any form of robotic automation; approximately 1 in 3 factories have specialized software capabilities; the U.S. ranks 10th in the world in robot adoption density.[32] While these metrics range far beyond the defense sector, they are nonetheless indicative of similar issues within the defense industrial base. As a labor-intensive and demand-limited market, UxS manufacturing lags even further.

Most critically, high quality batteries and small brushless motors are largely assembled within China. While other countries, such as Japan and Croatia, have the technical capability to produce said systems, the quantities produced, and prices involved oftentimes represent unworkable quantities and cost curves. Simply put, China has forced modernization on manufacturers, artificially lowered prices by massive government subsidization of resources (e.g. steel) and has manufactured countless products without concern for demand.[33] This has pushed out non-state-backed companies, led to complete domination of specific markets, and severely hampered American manufacturer's ability to compete in the absence of matching government intervention.

While DoD's ability to influence overall manufacturing is limited, it has taken steps to modernize manufacturing practices and the workforce. For instance:

- America's Cutting Edge (ACE) is a joint DoD-Department of Energy initiative that is funded through DoD's Industrial Base Investments Office's Industrial Base Analysis and Sustainment (IBAS) Program. It is a partnership with Texas A&M University and Marshall University to stand up machine tool training centers to prepare a next generation of manufacturers.[34]
- The Office of Industrial Policy (IndPol) awarded Oak Ridge National Laboratory additional follow-on funds to continue machine tools technology development as a component of ACE.[35]
- The Office of the Secretary of Defense Manufacturing Technology (OSD ManTech) Program Office released its Additive Manufacturing Strategy in January 2021. The strategy seeks to ensure that "that DOD will realize the most benefits from AM technology by structuring our AM activities, aligning funding opportunities, and improving AM implementation efforts - all with the objective of enhancing our Warfighters' mission readiness."[36]

Of particular note in the DIB's research were OUSD Research and Engineering efforts to create standardized DoD UAS platforms based on open-systems government architecture, with freely available schematics for U.S. industry partners to produce. By using a Government Reference

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[31] A review of DoD's UxS acquisition efforts over the past 15 years can be found here, U.S. Government Accountability Office. (1997). Unmanned Aerial Vehicles: DOD's Acquisition Efforts (GAO Report No. T-NSIAD-97-138). Retrieved from https://www.gao.gov/products/t-nsiad-97-138

[32] U.S. Manufacturing Economy. National Institute of Standards and Technology. (2024, November 15)

[33] Shida, T. (2024, July 22). Chinese steel keeps flooding global market, pushing down prices. Nikkei Asia. https://asia.nikkei.com/Business/Materials/Chinese-steel-keeps-flooding-global-market-pushing-down-prices

[34] About ACE. ACE – America's Cutting Edge. (n.d.). https://www.americascuttingedge.org/about-ace/

[35] DASD(IndPol) visits Oak Ridge National Lab for an up-front look at Ibas impacts. OUSD A&S - Industrial Base Policy. (2021, September 21). https://www.businessdefense.gov/news/2021/dasdindpol-visits-oak-ridge-national-lab-for-an-up-front-look-at-ibas-impacts.html

[36] Martin, V. (2024, May 14). DOD Additive Manufacturing Strategy. DoD Research & Engineering, OUSD(R&E). https://www.cto.mil/dod-additive-manufacturing-strategy/

Architecture, the efforts are intended to achieve maximum scale of production at reduced costs, and to utilize existing manufacturing infrastructure less vulnerable to the whims of DoD budgets. While we recognize that DoD requires a wide range of UxS platforms, something this idea does not address, this approach represented a novel and meaningful approach to a specific problem set in the UxS space.

Similar to its work with supply chain resilience, DoD's ability to influence overall American manufacturing is limited. Nevertheless, it can take an active role in encouraging the uptake of modern manufacturing and financially rewarding industry partners which embrace modern manufacturing practices which lend themselves to scaling.

Lastly, and most importantly, DoD development of common hardware and software frameworks can provide clearer left and right guideposts on the integration of UxS systems into the Joint Force framework, and the manufacturing realities necessary to meet said frameworks. Properly constructed, this will help unify a fragmented UxS manufacturing base and begin to meet the scaling challenges we currently face.