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FINAL REPORT

Air Dominance in Strategic Competition:
Expanding Uncrewed Systems

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Field Studies Hosts and Guest Speakers

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Executive Summary

The aviation industry provides the bedrock of military power and has for over a hundred years. In the 21st century, technological advances in international weapons systems challenge the survivability of traditionally crewed aircraft. China's meteoric rise in military power and intent to rebalance the rules-based international order for its benefit necessitates an elevated U.S. emphasis on improving its aircraft capabilities and quantities. The capabilities of currently fielded Chinese and Russian surface-to-air and air-to-air weapons systems necessitate a recognition that crewed U.S. systems will be at significant risk in a peer-to-peer engagement and losses of platforms will be high. The U.S. must look to uncrewed aircraft systems to both increase the number of aircraft in the U.S. arsenal and reduce risk to crewed platforms.

The U.S. must overcome five critical barriers to accelerate the advancement and adoption of uncrewed aircraft technology. First, we must begin to reverse the post-Cold War industry consolidation of the major aerospace defense firms. Second, the U.S. must solve its supply chain shortfalls and ensure a robust inflow of raw materials and intermediate parts from dependable sources. Third, the U.S. government must address its outdated 20th century regulatory environment, specifically Federal Aviation Administration (FAA) civil aviation regulations, and the Missile Technology Control Regime (MTCR). Fourth, shortfalls in talented human capital throughout private industry, research and development labs, and the Department of Defense retard growth and require holistic action. Finally, the U.S. government's acquisition process remains protected and laborious, making the rapid fielding of critical new technology nearly impossible. Addressing these five barriers today will enable the U.S. to integrate uncrewed systems into the future fight at full speed.

This paper makes several recommendations to set the conditions for accelerating the fielding of uncrewed aircraft systems: 1. Leverage small U.S. businesses and international partnerships to increase innovation and competition in the uncrewed aircraft systems market; 2. Identify critical uncrewed aircraft components and ensure supply chain resiliency through diversity of suppliers and domestic re-shoring or allied friend-shoring of specific subcomponents; 3. Engage with Congress to: A. Fully fund, resource, and require the FAA to safely expand aviation regulations to fully incorporate uncrewed civilian flight and, B. Reinterpret the MTCR to allow for increased uncrewed technology sharing with partners and allies; 4. Bolster industry and government incentives for Science, Technology, Engineering and Math (STEM) education and government service; 5. Improve long-term acquisition execution through the use of multiyear contracts, Rapid Acquisition Authorities, and Middle Tier Architecture for key uncrewed aircraft programs. Harnessing initiative across these five lines of effort will set the conditions for the United States to maintain credible deterrence, uphold the rules-based international order, and dominate the air in strategic competition – today and into the future.

Introduction

"Let he who would have peace…prepare for war."
– Vegetius, 390 A.D.

In the 21st century, the U.S. finds itself facing the re-emergence of global strategic competition. The Russian invasion of Ukraine in 2022 and an increase in Chinese aggression in the Indian and Pacific Oceans demonstrate the need for the U.S. to prepare for peer military conflict. Whether in a military confrontation in the Taiwan Strait, or a land war in Europe, command of the air is critical to victory. The capabilities of UAS – long loiter times, smaller radar cross sections, no human life support equipment or human physiological limitations, and personnel operating more than one aircraft at a time – will be critical. The U.S. needs to increase its focus on developing and producing this strategic technology. **To expand the capability and capacity of uncrewed systems in air power and maintain the lead in the strategic competition, the U.S. must: reverse defense industry consolidation, secure reinforced industry-specific supply chains, overcome archaic regulatory limitations, attract effective human capital, and cultivate velocity in its defense acquisition processes**.

This paper examines the complexities of today's strategic environment, how uncrewed aircraft are critical to U.S. success in this environment, the characteristics of the current aircraft industry and its uncrewed subset, and five key factors that should be the focus of U.S. government efforts to streamline the fielding of uncrewed aircraft into the U.S. arsenal. Each factor contains the background data, required changes, and specific recommendations for the Department of Defense, Department of State, Department of Education, and Congress as applicable. Additionally, Appendix A contains a summary of the recommendations, Appendix B analyzes considerations for a U.S. defense of Taiwan against a Chinese invasion, and Appendix C provides a Porter's Five Forces analysis of the uncrewed aircraft industry.

The Strategic Environment

"War's character - its conduct - constantly evolves under the influence of technology, moral forces, culture, and military culture, which change across time and place."
– Lt. Col. Frank Hoffman, USMC (Ret.), 2017

The U.S. finds itself immersed in a changing global environment. The rules-based international order, which elevated global prosperity and prevented large-scale conflict for more than seventy years, is challenged by rising Chinese and resurgent Russian attempts to mold international relationships to their advantage. As these nations exert power, the U.S. and its allies are increasingly called upon to counter Chinese and Russian influence through diplomatic, economic, and military means. The U.S. has and will continue to meet these challenges through the modernization of its strategies, innovation efforts, and military capabilities. President Biden made it clear that this is a decisive decade, and the U.S. must adapt to prevail.[1]

Russia's invasion of Ukraine in early 2022 highlighted the changing nature of modern warfare. Russia, with far superior technology and manpower, was unable to secure an anticipated quick victory over determined Ukrainian resistance. As the world watched, Russian aircraft, ships, and tanks were defeated by weapons systems costing a fraction of their targets' procurement costs through the incorporation of new technologies used in innovative ways. Russia's inability to locate and destroy Ukraine's long-range surface-to-air missile systems, coupled with the extensive proliferation of tactical anti-aircraft weaponry, raised costs for the Russian Air Force beyond the level that its national leaders were willing to bear – effectively grounding its expensive manned air fleet and rendering it unable to support its ground forces or effectively strike strategic Ukrainian targets. In contrast, the growing use of small, low-cost, uncrewed platforms proved highly effective in supporting Ukrainian ground forces, enabling precise location, and targeting of Russian command and control, logistics, and infrastructure by long-range cannon, and rocket artillery. As the conflict dragged on, severe

Western sanctions created significant shortfalls in Russia's global supply chains, leading to degradation in capabilities across their fielded forces. The United States and its allies took note of these lessons and embarked on adaptation initiatives to ensure the right capabilities are available for the future fight.

Shifting Winds in U.S. Strategy and the Aircraft Industry

The Biden Administration's 2022 National Security Strategy (NSS), drafted in the aftermath of the invasion of Ukraine, identifies the realities of the current geopolitical landscape. "Russia has shown us that a declining power will strike sooner rather than later."[2] Pressed by perceived existential threats, and absent a perceived credible deterrent, Russia chose the path of conflict to preserve its national security interests. Russia's struggles in Ukraine also had other impacts on the NSS, both in degrading the U.S.'s assessment of Russian capabilities and in highlighting weaknesses in current military technology.

As a result of its ascendance, China emerged as the U.S.' pacing challenge, and American modernization initiatives are focused on this competition. China "is the only competitor with both the intent to reshape the international order and, increasingly, the economic, diplomatic, military and technological power to advance that objective."[3] Today, the likely areas for potential conflict revolve around the future of Taiwan and sovereignty disputes in the South China Sea. China's military capabilities increasingly threaten the U.S.' ability to project crewed aircraft into contested areas, catalyzing acceleration in fielding uncrewed platforms.

A Technological Awakening

The NSS identifies three mutually reinforcing lines of effort, one of which is to "modernize and strengthen our military so it is equipped for the era of strategic competition with

major powers."[4] Recognizing American industry's leadership in research and development (R&D), the NSS identifies the need to leverage private innovation and investment to reinforce national security while identifying Artificial Intelligence (AI) as one of several advanced technologies with strategic significance. As UAS move towards autonomy, the U.S. aircraft industry is important to three NSS priorities: military modernization, adoption of AI, and industrial depth.

The U.S.'s 2022 National Defense Strategy (NDS) maintains the U.S.'s core strategy of deterrence to achieve NSS objectives. To maintain deterrence credibly, the NDS calls for an emphasis on (R&D) for advanced capabilities. The Department of Defense (DoD) intends to strengthen its focus on AI by pursuing a fast-follower approach that takes advantage of R&D investments made by the private sector.[5] This approach also intends to leverage dual-use technologies and small businesses to incentivize and support disruptive innovation outside of the traditional industrial base. It also means the DoD is reliant on the speed and efficacy of the civilian sector to develop and field critical deterrent capability. Accelerating innovation and expanding the defense industrial base (DIB) is critical to executing the NDS and protecting the U.S.-led rules-based international order.

The Importance of the UAS Industry in the Strategic Environment

In the realm of strategic competition, the growth of the aircraft industry hinges upon UAS, as they offer versatile mission capabilities integral to the concept of combined arms warfare. UAS have assumed a critical role in contemporary warfare, particularly following the events of September 11, 2001. These advanced aerial vehicles have been deployed worldwide to gather intelligence, conduct surveillance, and carry out reconnaissance (ISR) and strike operations, significantly contributing to identifying and neutralizing terrorist threats through

targeted strikes. The changing dynamics of international relations, particularly the shift towards strategic competition, have led to a significant evolution in UAS application. The U.S., along with China and Russia, now relies heavily on UAS in a new paradigm of warfare that spans multiple domains and regions worldwide.[6]

As UAS become more critical in combined arms operations, new strategies and approaches are being explored to maximize their effectiveness. Through autonomy, the future holds immense potential for UAS to contribute significantly to both competition and warfare, shaping global security and military operations across different domains and regions. They can work in synergy with manned platforms and will eventually operate on their own.

The aircraft industry and air power are key components to achieving the NDS' goal of credible deterrence. Providing credible deterrence, in turn, requires understanding the threats and possible scenarios that could evolve between strategic adversaries so that they may be countered. For the time being, China's ability to project significant power is limited to its near abroad, namely the East and South China Seas. Chinese efforts to fortify this region create an effective Anti-Access Area Denial architecture capable of contesting U.S. presence in the area. The U.S. and its allies are faced with the dilemma of needing to neutralize advanced air defense systems capable of shooting down its crewed platforms while facing China’s ability to mass overwhelming air platforms in proximity to its shores. Fielding capable UAS will help solve these issues and set the foundation for a credible deterrence strategy.

The implications of interactions between the increased tempo of strategic rivalry combined with the advent of advanced technologies such as AI cannot be understated. Brian Schimpf, the co-founder of Anduril, summarizes the landscape:

> “With the resurgence of great power competition has come the resurgence of defense technology. Conflict with a near-peer competitor would look nothing like our recent

> warfighting experiences against nonstate actors. It could be fought over vast distances, involve technology we are unprepared to deal with and occur at a scale the United States has not had to contend with in decades. Suddenly, our glittering collection of large, exquisite systems, built to engineering standards decades behind consumer technology, feels outmoded."[7]

This outcome has significant implications for the aircraft industry in terms of what platforms can and should be pursued.

A 2022 RAND study identifies that a high-intensity, direct conflict with China is possible, likely through the escalation of a low-intensity conflict.[8] Here, a 2023 Center for Strategic and International Studies wargaming report focuses on the familiar scenario of an invasion of Taiwan from mainland China. Included were 24 wargaming scenarios where the consistent theme was that "the United States and Japan lose dozens of ships, hundreds of aircraft, and thousands of servicemembers"[9] while the U.S. and its allies did not always successfully defend the island. In this environment, the ability to mass a high volume of air-delivered fires and maintain resilience in the face of heavy aircraft losses played a key role. These results challenged the U.S.'s few-but-exquisite air platform acquisition strategies in favor of larger numbers of smaller, less sophisticated, and frankly expendable, aircraft.

Furthermore, the FY2024 Defense Budget provides the DoD, Congress, and the aircraft industrial base with the demand signal for increased and accelerated investments in the evolution of UAS applications. "To help build the Air Forces needed for the 21st century, [the proposal] funds the procurement of a mix of highly capable crewed aircraft while continuing to modernize fielded fighter, bomber, mobility, and training aircraft. The 2024 Budget also accelerates the development and procurement of uncrewed combat aircraft and the relevant autonomy to augment crewed aircraft. Investing in this mix of aircraft provides an opportunity to increase the resiliency and flexibility of the fleet to meet future threats while reducing operating costs."[10]

In summary, the changing strategic environment puts the aircraft industry at a crossroads. Support of NSS and NDS goals relies on credible deterrence, reinforced by the advanced UAS capabilities which the aircraft industry can provide. However, the definition of what constitutes credible deterrence may be changing faster than the industry can adapt under the current paradigm. The U.S. cannot conduct “business as usual" to overcome the challenges ahead.

Analysis: The Aircraft Industry

The aircraft industry has changed substantially since the Wright brothers’ first flight on December 17, 1903. The continuous evolution of airframes that could travel higher, farther, and faster with rapidly increasing capabilities transformed the world in the first century of flight. Today’s aircraft industry is dominated by powerful firms in a few industrial nations with supply chains and customers spanning the globe. Although there is competition between the major producers, this typically occurs with a small number of companies and trends toward a duopoly. For example, in the commercial airline market, Boeing and Airbus dominate the large airliner segment of the industry while Embraer and Bombardier (owned by Airbus) provide most of the regional airliner market. The U.S. military aircraft market, especially in crewed platforms, exhibits similar characteristics.

The U.S. military crewed combat fixed-wing market is highly concentrated in the traditional prime aerospace defense contractors: Lockheed Martin, Boeing, and Northrop Grumman. Likewise, the crewed combat rotorcraft industry is concentrated in companies such as Sikorsky (owned by Lockheed Martin), Boeing, and Bell. These subsectors of the aircraft industry continue to grow in complexity, have long acquisition timelines, face stiff government regulation, and experience myriad funding challenges. The resulting high barriers to entry result

in challenges to spur effective competition and drive innovation. The emergence of an uncrewed aircraft market provides an opportunity to change this paradigm.

Analysis: The Uncrewed Aircraft Industry

The Federal Aviation Administration (FAA) defines an uncrewed aircraft system as an uncrewed aircraft and the equipment necessary for the safe and efficient operation of that aircraft. An uncrewed aircraft is a component of a UAS. It is defined by statute as an aircraft that is operated without the possibility of direct human intervention from within or on the aircraft (Public Law 112-95, Section 331(8)).[11] The ability to conduct intelligence, surveillance, and reconnaissance, move troops and cargo around the battlefield, drop ordnance, execute aerial refueling operations, and contest other aerial vehicles are all examples of capabilities included in the current and future uncrewed aircraft industry. Advancements in technology will steadily move this industry from one heavily dominated by remotely (human-)operated systems to more AI-driven autonomous actions.

The emergence of uncrewed aircraft technology provides an opportunity for smaller companies to break into the aircraft industry, more so with the development of software and non-exquisite products. Shield AI, founded in 2015, is a new aerospace company focused on developing autonomous piloting software capable of operating its new V-BAT and existing aircraft like the F-16. Kratos, founded in 1994, is developing the XQ-58 Valkyrie drone in support of the DoD's Collaborative Combat Aircraft (CCA) initiative. Finally, both Skydio and Anduril are developing a broad spectrum of dual-use drone systems. These companies are the tip of the iceberg for small-business innovation in the uncrewed aircraft industry and the U.S. government is attempting to harness this innovation to maintain its technological dominance over its competitors in the second century of aviation. The DoD's Defense Innovation Unit, Air

Force's AFWERX, Navy's Innovation Center, Marine Innovation Unit, and Army's Rapid Capabilities and Critical Technologies Office all exist to help streamline the process of working with small businesses to harness their innovative activities, including in the uncrewed aircraft domain. A more detailed analysis of the uncrewed aircraft industry using Porter's 5 Forces model is offered in **Appendix B**.

Factor: Industry Consolidation and Organizational Culture

"The best way to enhance freedom abroad...
Is to demonstrate here that our system is worthy of emulation."
–President Jimmy Carter, 1978

Before the end of the Cold War, the DIB consisted of 51 firms. Today, there are only five: Lockheed Martin, Raytheon Technologies, General Dynamics, Northrop Grumman, and Boeing.[12] Consolidation continues today and is expected to continue due to market pressures that favor integrations and the entry of private equity firms performing roll-ups.[13] Specific to aircraft and related systems, the news is even grimmer. "Over the last three decades, the number of suppliers in major weapons system categories has declined substantially: tactical missile suppliers have declined from 13 to 3, fixed-wing aircraft suppliers declined from 8 to 3, and satellite suppliers have halved from 8 to 4."[14] While the DIB was consolidating in the late 1990s, the DoD began to introduce UAS as the technological frontier allowed. However, despite the possibility for disruptive innovation of UAS technology, the number of firms that produce UAS for the DoD is now consolidated to only five firms that in 2021 held a 75.5% market share.[15]

Consolidation in the UAS industry is driven by several factors, including rising R&D costs, increasing regulatory and certification requirements, and intense competition for contracts from government and commercial customers. In the U.S. defense market, some of the largest

players in UAS are also the dominant manufacturers in the wider aerospace and defense industry (the Primes). Non-U.S. manufacturers, predominantly in China, have taken over the market for civil and commercial UAS platforms, leaving only a few small-scale civil UAS manufacturers operating within the United States. These domestic manufacturers have not yet acquired the manufacturing capacity, customer base, or technological prowess to fully compete with their foreign rivals.[16]

While the causes of consolidation are a rational outflow from the structure of the industry and its political/economic ecosystem, negative economic outcomes from increasingly powerful entities approaching monopoly/duopoly status have significant national security implications, as revealed in the National Defense Industrial Association (NDIA) Vital Signs 2023 report:

> "Unfortunately, the [DIB] resiliency required to sustain the U.S. in great power conflict was sacrificed as part of the 1990s peace dividend. The powerhouses of industrial readiness – stable and predictable budgets, an experienced and specialized workforce; diversified and modern infrastructure; manufacturing innovation; and sufficient, including idle, capacity – have all atrophied under the combined transition to a services-based economy with a premium on just-in-time commercial supply chains."[17]

In addition to monopolistic concerns around price and capability, industry consolidation leaves DoD increasingly reliant on a handful of U.S. companies for critical defense *capacity*. [18] A RAND Corporation study recently confirmed this, noting the UAS industry is vulnerable to supply constraints at production rates beyond current levels.[19] This is attributed to various factors, including uncertainties related to financial outlook and demand, limited availability of firms that manufacture large UAS, and dependence on foreign sources (e.g. China) for specific components – sources that may not be permissible by DoD security standards, or unavailable at increased levels of international competition or hostility.[20] "In Vital Signs 2023, 42% of the NDIA member companies reported being the sole eligible provider in the U.S. for a defense-related product."[21]

This concentrated ecosystem has impacted the political culture of the DIB, involving a complex interplay between industry stakeholders, government elected officials, and other interest groups. To foster a successful partnership between the U.S. defense industry and the DoD, the federal government needs to prioritize the overhaul of policies, regulations, and authorities that are currently impeding the industrial base, and commit to resisting further industry consolidation through substantial, consistent, and predictable financial investments that can help bolster the DIB's strategic endurance and resilience.

Organizational Culture

In addition to the consolidation of the UAS market, the organizational culture in both the DoD (including its subordinate Services) and in Congress has hindered the advancement of these systems. When the MQ-1 Predator was introduced into the USAF in 1994, Defense policy, in concert with mutually aligned Congressional intention, required it to be unarmed and crewed by a minimum of four operators. The technology existed at the time to arm the platform with weapons and have an automated launch and recovery system reducing the crew to two. However, the organizational culture favored the preservation of billets, end strength, jobs, pilot relevancy, distrust of automation, and other factors unrelated to – or rather in opposition to – pure defense output and efficiency. It took seven years (and a war) following the Predator's debut to become armed, and twenty-six years until its successor, the MQ-9 Reaper, finally demonstrated the automated takeoff and landing capability which was originally available at the program's inception. The bias to preserve manpower and relevancy has been so pervasive that an Army general recently quipped, perhaps indicating a tipping point had been reached in that less pilot-led Service, that our 'unmanned' units have more manpower than our manned.[22]

Organizational culture limiting the advancement of UAS within the DoD often comes in the form of budget allocation, where the Department has reluctance to optimally fund uncrewed systems in favor of crewed systems in zero-sum PPBE decision-making. For example, the USAF has operated the crewed U-2 for sixty-six years. Platforms with capabilities largely overlapping the U-2's, such as the uncrewed RQ-4 released in 2001, fought against the U-2 for upgrades and sustainment dollars, with unequal representation in organizational culture and leadership. Although the UAS alternative had capabilities that far outpaced the manned system and could operate with (almost) no risk to a human pilot, organizational preferences significantly hindered UAS advancement and will lead to its retirement before the U-2.

While granting heavy flying objects autonomy, and potentially arming them on their own release authority, should certainly be considered *very* carefully, an undue bias against autonomy carries its own risks in the face of strategic competition. While the U.S. has not banned autonomous lethal UAS, it has placed its development and fielding under a complex regulatory framework. DoD Directive 3000.09, Autonomy in Weapon Systems, updated within months of this writing, details extensive limitations and processes that will undoubtedly delay the fielding of capable autonomous armed systems. For a program to even begin development, a proposal must be approved by the Under Secretary of Defense for Policy, the Under Secretary of Defense for Research and Engineering, and the Vice Chairman of the Joint Chiefs of Staff -- and fielding requires even more extensive approvals.[23] Precise policy way-aheads on this complex issue exceed the scope of this paper, and indeed the infosphere has become increasingly populated with warnings, urgings, and proposals about the best way to proceed. We note there is no precedent for a powerful weapon voluntarily not being developed by all parties who could feasibly do so; and even if there were mutual willingness, it would be nigh impossible to confirm

all-party compliance. Given that, and the fact that China, Russia, and other adversarial actors are pushing forward with weaponizable AI at full speed (to include non-kinetic AI-powered weapons aimed at ideological conversion of civilian populations including ours that we currently have no answer for), the safest course of action appears to be winning this arms race, then negotiating, if necessary, appropriate international arms controls from a position of strength. [24]

Rebalancing the Scales

The DoD needs both the resilience and competition that a diverse market offers. "When markets are competitive, DoD reaps the benefits through improved cost, schedule, and performance for the products and services needed to support national defense."[25] The consolidation of the DIB coupled with organizational culture that favors the status quo, continues to retard advancements in UAS development and implementation. To avoid falling behind, the DoD should take feasible steps that increase both competition and resilience.

Corporate concentration is not at all limited to the defense sector, and there may again come a day when the United States is due another pervasive round of government-forced breakups through anti-trust powers. Currently, the political will for that more extreme outcome does not appear forthcoming anytime soon. Below that threshold there are moderate steps the DoD can undertake to bring increased competition and capacity into the field, using large allied/partner nation defense firms, and bolstering mid-size domestic challengers.

Recommendation: *The DoD should expand on existing efforts like the Small Business Innovation and Research (SBIR) and Small Business Technology Transfer (STTR) programs to all levels of the acquisitions process.* This will necessitate larger amounts of stand-up time and spin-up funding to allow small/medium-sized firms to participate in a very capital-intensive process that would otherwise favor prime vendors.

Recommendation: *The DoD should be more amenable to procuring defense products from values-aligned international defense firms (e.g., Australian, European, South Korean, etc.), specifically not in partnership with U.S. Primes, who not only have strong, capable products for use in our military but whose presence would inject much needed competitive pressure to concentrated U.S. firms.* Side benefits to partnership and allied force integration are obvious second order effects. This movement would encounter political resistance from Congress, seeking to preserve funding streams for U.S. companies, but that resistance would not be insurmountable in all cases. It would also require strong Executive leadership, including politically appointed and uniformed defense leaders, to affirmatively select non-U.S. firms or even to allow them to compete fairly.

Recommendation: *Given the high rate of change in this field, in the near term the DoD should inject criteria into decision making aimed at preferencing new platforms over service life extensions and upgrades.* Shortening platform lifespan and increasing the frequency of platform changes would be a significant boon to competition. This would require decreasing the overall purchase number of current or future models (e.g., MQ-9, TRV-150C, CCAs) while fielding requests for proposals for advanced systems at more frequent intervals – ideally where the existing system is barred from competing, regardless of updated form. A five-to-seven-year interval is about a 'generation' in the high-tech, Moore's law-driven UAS field and a historical precedent exists for this faster military model turnover in living memory. The timeline for this recommendation would be to integrate an advanced model every five years versus sustaining an asset for decades.

Recommendation: *Since fully autonomous, AI-driven piloting and operational decision-making (including kinetic decision-making) appear to be the decisive approaching future, DoD*

should streamline policy requirements in DoD Directive 3000.09 and other related sources to increase speed and apply additional funding to R&D (and prototyping, testing, rapid fielding, etc.) sufficient to maintain the AI arms-race lead. Organizational culture, often the longest pole in the tent, will evolve as tech-centric (generally, millennial-forward) cohorts matriculate into the highest ranks in the coming years, and as more leaders with UAS and other automated platforms experience likewise proliferate. Progressive formal education among higher-level military and civilian leaders, exhibited herein, will contribute to the permeation of innovative thinking.

Factor: The Supply Chain

"And before you finish eating breakfast in the morning,
You've depended on half the people in the world."
–Martin Luther King, Jr., 1963

The U.S. aerospace industry supply chain is a complex international network linking businesses, individuals, and organizations, all of which produce and deliver final products and services from suppliers to consumers. As excess capacity, inventory, and redundancy carry significant costs, the dominant survivable business case has seen logistics chains thinned to their leanest position under ideal conditions. A confluence of negative circumstances – the intensifying strategic competition between the United States and China, the international COVID-19 pandemic, and the war in Ukraine between two significant global suppliers – exposes the weaknesses in the system, requiring a lengthy and expensive reconstitution period now underway. Considering UAS production, both growing strengths and lingering weaknesses can be observed in its supply chain. Positive outlooks accrue from the relative ease of low-end UAS construction, burgeoning innovation in advanced manufacturing, and favorable international relationships with advanced tool suppliers. However, persisting weaknesses continue to slow advanced UAS manufacture stemming from a dependence on adverse suppliers of rare earth

material, reliance on foreign advanced semiconductors, and a weakened domestic manufacturing base. U.S. policymakers can increase supply chain resiliency by creating an environment that supports careful stewardship of strategic resources and fosters domestic production while increasing cooperation with partners and allies.

Supply Chain Opportunities

Through dedicated engineering and the application of widely available and often lower-cost components, low-end UAS have become relatively easy and inexpensive to produce. As the UAS industry continues to mature, the typical cost/efficiency learning curve helps reduce costs for more capable systems. As a key input to lower-end models, the use of aluminum alleviates strain on supply chains as the material exists in much higher quantities and at a much lower cost than the titanium or composites used in high-end models.

The supply of titanium and its alloys is especially vulnerable due to the war in Ukraine and the resulting economic sanctions imposed on Russia, which was producing about 20% of global titanium production before the war.[26] The aerospace industry uses approximately 90% of the world's titanium, so substituting its use in UAS construction creates an opportunity to diversify the supply chain.[27] The third option for aircraft construction is carbon fiber composites which are technologically demanding and expensive. Under the price pressures for titanium and fiber, industry is experimenting with the use of advanced polymers such as GFRP, BFRP, or NFRP, (plastics reinforced with glass, basalt, or natural fibers) for UAS construction; these appear good candidates for additional government funded or subsidized research and testing.[28]

Recommendation: *Congress should expand the research and development tax credit for the aerospace industry to incentivize innovation in materials.*

UAS production, like that of most modern machines, is heavily reliant on access to semiconductors. Advanced chips with smaller transistors run faster and use less power, thus extending battery life or decreasing engine loads. While access to advanced chips is a vulnerability for the most sophisticated UAS production, low and mid-grade remotely piloted UAS can use semiconductor supply chains based on legacy fabrication techniques. Examples include the Atmel AVR microcontroller or the MSP430 microcontroller from Texas Instruments, which are power-efficient despite using legacy 180nm technology.[29] Current U.S. investment in domestic semiconductor production through the CHIPS and Science Act, and our continuing support for Taiwan's autonomy, appear appropriately poised to reduce current supply pressures long term.[30] **Recommendation:** *The DoD must carefully monitor the semiconductor supply chain and be prepared to recommend the use of the Defense Production Act to divert supply to critical programs if shortfalls are detected or anticipated.*

Supply Chain Challenges

While simple UAS may be somewhat shielded from production risk, advanced UAS supply chains are particularly reliant on access to rare earth elements and advanced semiconductors – both of which exist in large part outside our national boundaries. Further contributing to production risk, globalization has eroded U.S. domestic manufacturing capacity in exchange for clustered overseas production.

Ensuring a reliable influx of natural resources is essential to keeping UAS production alive. After almost 30 years of relative geopolitical stability since the fall of the USSR, recent events have elevated concern about adverse or unstable nations leveraging their control of rare earth minerals. In addition to titanium for aerostructures, the UAS industry relies on neodymium for high-performance magnets and motors.[31] Batteries require steady supplies of lithium, cobalt,

and nickel.[32] As early as 2009, The Chinese Communist Party (CCP) proved it was willing to leverage control of key elements when it restricted rare earth magnets to Japan over a maritime dispute regarding the Senkaku Islands.[33] In December of 2021, the CCP approved the merger of three state-owned rare earth suppliers to consolidate control of a sector the government sees as a key factor in global strategy.[34] Restrictions may also be self-imposed; large amounts of titanium are now locked behind allied sanctions of Russia. Trends are positive – rare-earth mines in California, Texas, and Alaska have recently opened.[35] Domestic production coupled with international cooperation has resulted in China's share of rare earth production falling from 80% in 2017 to 60% in 2021.[36] **Recommendation:** *To safeguard supply, U.S. policymakers should liberally permit and potentially subsidize, domestic extraction and refining of critical minerals.*[37]

The trend of offshoring manufacturing to countries with low labor costs has led to the loss of more than 60,000 U.S. factories and 5 million skilled jobs since 1990.[38] This loss of U.S. production capacity is the result of global macroeconomic forces that clustered production where comparative advantage was greatest. One underappreciated result has been a significant reduction in casting and forging capacity in the U.S., which impacts the ability of U.S. companies to produce UAS and other aerospace components domestically or to expand production if wartime surge required it. China has more than four times the casting and forging capacity of the U.S., and the U.S. has only a single supplier of specific high-tech castings and forgings.[39] While this is economically efficient in a rules-based system, the rise of great power competition has turned this consolidation into a security liability. To counter the tidal forces of economics, government action is needed to diversify and protect supply chains. President Biden's Executive Order 14017 targets supply chains and seeks to build domestic production capacity by while engaging with partners and allies in key areas of weakness.[40]

Recommendation: *Congress should increase funding for the Manufacturing USA and Manufacturing Capability Expansion and Investment Prioritization (MCEIP) programs to spur domestic production while seeking free trade agreements with partners and allies to leverage values-aligned international comparative advantages.*

Factor: The Regulatory Environment

"The cost of prevention should not exceed the cost of harm, divided by its likelihood of occurrence."
–Judge Learned Hand, *U.S. v. Carrol Towing Company*, 1947

While the U.S. is on the cusp of entering the next era of commercial and military aviation through proliferating UAS and expanding autonomy in aircraft, it remains bound by bureaucracy and regulations barely capable of administering previous generations of aircraft technology. Domestic UAS operating regulations, overseen by the FAA, and tightly managed export controls, enforced by the Department of State, lag well-behind UAS technology development and artificially restrict American industry from achieving innovation dominance. Managing cutting-edge advances in uncrewed flight with administrative instruments and policies cast in the last century puts the U.S. at a distinct disadvantage, as its strategic competitors, and even its partners, are on pace to displace the U.S. as the world's leader in uncrewed aviation – or even aviation writ large. China is much farther along than the U.S. in establishing uncrewed flight rules and leads in incorporating large passenger and freight carrying UAS, while Europe advances in crewed/uncrewed integration and UAS operations beyond visual range.[41] DoD strategy relies on a vibrant commercial industry to develop defense capabilities and its acknowledgment that it will be a "fast follower" of commercially developed technology illuminates the UAS regulatory environment's stark national security implications.[42]

Domestic Impediments

The FAA has done little to facilitate a clear and easy path for R&D to make UAS technology commercially scalable. The agency continues to resist intense lobbying, lengthy cross-examination, and even laws enacted by Congress requiring it to modernize its UAS licensing and approval for operation.[43] While nobly intentioned and reflective of an incredible safety record, this inertia restricts the U.S. from innovating into the future of aviation and surrenders its competitiveness in the field – not to an ally, but to our pacing threat, China.

The current regulatory environment severely restricts innovation in the industry by creating barriers to entry and drastically extends R&D timelines where development regularly outpaces approval. Commercial UAS under 55 pounds currently operate under FAA Part 107, which restricts flight below 400 feet and within visual line of sight operations.[44] Any operation or vehicle outside these parameters is subject to incongruous Part 91 rules designed for crewed aircraft and requires a lengthy waiver process for inapplicable items that often takes years for approval.[45] The FAA has recently shown nascent efforts to modernize UAS operations to expand data collection and R&D through its BEYOND program, granting blanket waivers for UAS beyond visual line of sight operations, but the program is currently limited to nine sites, located in the most remote land in the country (far from technology clusters), and does not address the altitude or weight restrictions of Part 107.[46] Consequently, large UAS developers continue to be mired in lengthy approval processes to test and innovate on their own property and in adjacent airspace, shoehorning uncrewed system R&D into regulatory architecture designed for crewed systems and limited by archaic requirements for visual observers.[47]

Domestic UAS firms are lagging, held back not by the limits of their creativity and engineering but by government bureaucracy. Resultingly, the DoD cannot harvest the full

innovation potential of the nation's UAS industry to develop the weapon systems necessary for current and future dominance. Meanwhile, our primary strategic competitor, China, recognizes the requirement for regulations to keep pace with technology and capitalizes on streamlined UAS policies and a detailed plan for UAS integration into the national airspace. This open approach helped China unseat the U.S. as the leader in the commercial (dual use) UAS industry.[48] Though many elements of the Chinese state-run system may ultimately prove disadvantageous, its more balanced approach to the risk/reward of flight innovation appears superior. Either way, it's clear China is leveraging its UAS regulatory framework into a military advantage by fielding new capabilities faster than the United States.

Congress recently recognized the need for a catalyst in UAS regulatory reform in the Advanced Air Mobility Coordination and Leadership Act (AAMCLA), charging an independent working group to provide recommendations and a national strategy for incorporating UAS into the national airspace system.[49] The working group has 18 months to survey stakeholders across UAS employment activities, review the current regulatory architecture for limitations, and submit an accelerated path for UAS incorporation. Meanwhile, the FAA's plan for incorporating UAS into the national airspace remains "on the horizon," delayed by safety concerns and complex efforts to develop solutions requiring additional research and personnel resources.[50]

Recommendation: *Congress must seize the opportunity in the 2023 five-year FAA reauthorization to elevate the leadership of the FAA's Office of UAS Integration to an Associate Administrator. Congress should also expand the office's authorities to modernize regulatory frameworks,[51] and fully resource it annually through appropriations to fulfill the AAMCLA's working group recommendations.* **Recommendation:** *In conjunction, the FAA should expand its Part 107 weight limitation to 1,000 pounds or more to facilitate the R&D of larger UAS*

without cumbersome Part 91 waivers. **Recommendation:** *Additionally, the FAA should at least double the amount of BEYOND sites, focusing on ranges and locations convenient to UAS industry clustering.* **Recommendation:** *Finally, within the next two years, the FAA should develop standards for UAS safety and traffic deconfliction equipment to spur the creation of systems capable of integrating safely into crewed airspace above 400 feet*.[52]

Balancing Transportation Risk

Expanding domestic UAS accessibility is not without risk. Objections to modernizing domestic UAS regulations anchor on the FAA's gilded standard of safety. Proliferating autonomous or remotely piloted aircraft may create a hazard to crewed aircraft airborne and citizens below. While this is a valid concern, the FAA remains the gatekeeper of operator licensing for crewed and uncrewed aircraft. By upholding its internationally recognized safety standard when issuing operator licenses and holding operators/entities accountable for unsafe practices, the FAA can continue to provide for a very safe aeronautical environment while responsibly expanding the operations of UAS in the national airspace system. Perhaps there is a point at which we can be *too* safe, at the cost of innovation and incorporation. Whether or not Congress should relieve the FAA of some risk threshold is an open question. There is precedent in ground transportation for the American public's willingness to support favorable tradeoffs.

Opening Export Controls

Outdated export controls enforced by the U.S. government on its UAS industry also stand as hurdles in expanding autonomy in domestic and allied aircraft. These controls, designed around antiquated technology, fail to keep pace with UAS innovation and limit competition, ultimately impacting national security and stifling aircraft autonomy development.

The U.S. primary restriction on UAS exports comes from its participation in the Missile Technology Control Regime (MTCR). The MTCR is a voluntary agreement among 35 nations designed to limit the proliferation and delivery of weapons of mass destruction.[53] In the agreement, missiles or other vehicles (now including UAS) capable of delivering payloads of 500 kilograms or more over ranges of 300 kilometers are subject to a strong presumption of denial for export.[54] UAS were added to the MTCR in 1992 when the aircraft, both in form and function, were effectively remotely piloted one-way missiles.[55] Large aircraft-substitute UAS, such as the RQ-4 Global Hawk, are now subject to the same strict export limitations as ballistic missiles. Despite UAS' development into highly advanced multi-mission recoverable aircraft, their export controls remain trapped in 1992 – even as the aircraft they substitute for are not.

Under U.S. law, UAS exports are subject to scrutiny under Arms Export Control Act (AECA) and the International Traffic in Arms Regulations (ITAR). The AECA is the underlying law that authorizes the Executive Branch to control the export of defense articles and services via the Department of State, while ITAR implements the law and provides specific guidance on controlled items.[56] The AECA and ITAR prescribe similar considerations to MTCR when resolving export decisions (WMD proliferation, regional stability, etc.), but neither delineates a strong presumption of denial for exporting UAS. We assert these regulations are sufficient.

Unnecessarily restricting UAS exports by adhering to antiquated MTCR classifications has national security implications for the U.S. and our allies, most of whom are MTCR co-signers. First, exporting domestic defense products allows nations to influence the world order by setting the terms of their use. In the void created by overly restrictive American UAS export controls, China became the leader in the market with a 'no questions asked' approach to sales and now advances its designs on the world order.[57] Second, restricting the sale of UAS to U.S.

partners limits interoperability and cooperation. Nations otherwise approved to purchase fighter aircraft but denied American UAS technology are increasingly turning to China. Purchasing Chinese UAS precipitates integration incompatibility with U.S. systems and limits opportunities for cooperation due to Chinese intelligence collection concerns.[58] Finally, limiting UAS exports impedes domestic access to international revenue streams and available markets. With limited sales and customers, American UAS firms do not fully experience the incentives to innovate and develop new systems from the volume and variety of international demand. As a result, the DoD's capacity to field dominant capabilities is reduced, as our Pacing Threat fills the skies with increasingly capable platforms in our absence.

Critics of expanding UAS exports cite the dangers of arms proliferation and an increased risk of sensitive UAS technology capture as primary concerns. While there is plenty of room between our current position and a race to the bottom, these rationales do not hold when there is a very willing and far less scrupulous supplier filling all comers with capabilities that, for lack of our own participation, have begun to outpace our own. With UAS exports conducted responsibly and in accordance with the AECA and ITAR, the U.S. can set the terms of responsible UAS use and continue to export to countries and regions aligned with U.S. values.

Recommendation: *The Administration should immediately publicly reaffirm the MTCR's principles and encourage other nations to join in its updated interpretation while retaining relevant UAS export considerations in the agreement.* With expanded export opportunities, the Department of State should responsibly proliferate UAS exports to allies and partners, thus blunting Chinese influence and benefits from available markets and advancing aircraft autonomy innovation for U.S. firms and defense.

Factor: Human Capital

"What's right about America is that although we have a mess of problems…
We have great capacity – intellect, and resources – to do something about them."

–Henry Ford, 1932

Whether across the military, the aircraft industry, or America writ large, if we intend to deter future conflict and win if required, the time to return focus and resources to generating, recruiting, and retaining dominant American human capital is upon us. Both the aircraft industry and the military suffer from reduced rates of innovation due to limitations in human capital. As a basic input to economic productivity, the U.S. education system output constrains the aircraft industry and military services. Over time, the U.S. has fallen behind in the quality and quantity of STEM education outcomes compared to other countries, leading to a shortfall in its skilled workforce. Both the aircraft industry and the military are now in direct competition for critical talent, which the nation needs in both places at once.

STEM Education

The National Science Board estimates that 23% of the entire U.S. workforce now requires a STEM education. [59] According to the Bureau of Labor Statistics, the U.S. will be short 3,800 aerospace engineers per year between 2021 and 2031.[60] Boeing anticipates hiring 10,000 employees this year in engineering and manufacturing alone.[61] The Science Board evaluated the state of U.S. mathematics and engineering in K-12 schools in 2022: The U.S. ranks 7th out of 37 in science and 25th out of 37 in mathematics among the world's leading countries.[62] In 2017, foreign-born individuals received 60% of American engineering doctorates and nearly a third departed for their home nation after graduation.[63] Even when industry or the military successfully hires STEM personnel, demand for their services leads to poor retention.[64] Lockheed Martin, Bell Textron, Boeing, and Airbus are facing similar issues, per their annual

reports. As the aircraft industry becomes more software-driven, companies like Amazon and Google are now competing in the same pool. The average pay for a software engineer at Amazon is $191,000; Shield AI is $178,000; while Airbus and Boeing average (only) $130,000.[65] Military salaries trail farther, exacerbating shortages in our most technical fields.

The aircraft industry should continue to expand its outreach and facilitate education with the promise of employment upon completion. “We must focus on policies that develop our workforce, create partnerships between industry and academia and invest in education, training, and retraining programs that will prepare workers for the jobs of the future,” said Tom Gentile, President and CEO of Wichita-based Spirit AeroSystems and Chairperson of the Aerospace Industries Association.[66] One example of a successful partnership between industry, government, and the local community is the National Institute of Aviation Research (NIAR) based at Wichita State University (WSU). The NIAR WERX program offers full-time employment with NIAR while studying at WSU Tech Aviation Maintenance Technology Program and earning credits toward a bachelor's degree. Programs like this can be combined with others focused on growing underrepresented STEM populations.

Additionally, the aerospace engineering community is under-represented in several key demographics. Females comprise 48% of the workforce but only one-third of the STEM workforce.[67] In 2019, African Americans, Hispanics, American Indians, and Alaska Natives comprised 30% of the workforce, but only 23% of the STEM workforce.[68] Filtering STEM education results by household income is just as stark.[69] While most companies have internships and other early hiring programs, they are highly competitive and typically pull from the top income quintile of the US population.

To create a broader base of Americans qualified in STEM fields, we must reach the part of the population that is under-represented. **Recommendation:** *Industry should expand educate-and-hire programs and expand their reach into underrepresented communities. Industry should increase mentorship opportunities and outreach in K-12 to introduce STEM education and career field options earlier.* **Recommendation:** *DoD should partner with the Department of Education with funding, training, and employment support to expand STEM outreach into the American education system, especially focusing on under-represented communities.*

Recruiting – The New Front Lines

The military also faces human capital shortfalls, especially as the technological competency required to operate complex systems (like UAS) is driving the need for a higher baseline of education. The Secretary of the Army, Christine Wormuth, recently said, "We are in a war for talent, and it will take all of our people – troops from all components, families, Army civilians, and soldiers for life – to fight and win this war."[70] The difficulty of recruiting is a strategic issue and promises to remain one of the biggest challenges for the future all-volunteer force – if in fact, it can remain all-volunteer into the future.

Beyond the aircraft field, if the current widespread recruiting slump persists in size and duration, already nearing alarming rates of degradation, the military services must prepare to ask the President and Congress to propose more aggressive options, such as mandatory public service for young Americans. This initiative could manifest itself in many forms, tailored to the citizens' skills and desires, but also to the needs of the nation. The required service could be in the military, rebuilding infrastructure, teaching underserviced communities, or designing uncrewed systems in the aircraft industry – answering demand across many sectors.

Government-funded training could be included, especially targeting underserved STEM fields. If mandatory options are infeasible or not yet required, bridging solutions that combine military service with guaranteed, attractive follow-on jobs in related industries will incentivize service and fill critical industry gaps.

Just as the DoD must compete aggressively against the private sector for military talent, it must also revitalize recruiting efforts for the civilian defense corps, the nearly one-million federal government civilians who fill critical jobs throughout all Services and the DoD. Beyond a small cohort of those who have experience with government service, most Americans have little understanding of the opportunities available to serve as a defense civilian. The DoD and each service should begin to aggressively advertise and recruit defense civilians with the same energy applied toward prospective military members. The private-sector model is outpacing the outdated federal system, creating gaps to hire and deliver civilian talent to DoD and supporting the warfighter in uniform. **Recommendation:** *DoD increase funding for the SMART program to enable 25 students to enter the program in 2024. With a 91% completion of service from over three-thousand students this program is a huge win for the DoD.*

A discussion of U.S. human capital requirements in the military and supporting industries must also consider the current state of our 'adult generating pipeline' – the entire structure that 'graduates' some four million young Americans into adulthood each year. The availability rate of the U.S. civilian population to meet the minimal qualifications of military service has steadily declined throughout the modern period. This is a combination, to a lesser extent, of an increasing demand for specialized intellect, physical and moral fitness, but more so of a decline in the supply of scholastically and physically qualified members of the U.S. population. Only 23% of American youth are eligible to serve in uniform right now, and even fewer are qualified

to work the F-35 assembly line or code out the first AI pilot.[71] The national-level changes to our education and socio-economic systems necessary to regenerate a US-grown modern workforce exceed the scope of this paper, but we note that the Department of Defense should continue, and elevate, its ongoing attempts to lobby Congress, the Executive, and the American People to redress this critical need. **Recommendation:** *DoD continues to highlight the holistic health of the American population as a matter of National Security, supporting other Departments, and law/policy where appropriate, aimed at increasing comprehensive fitness for national service*.

Factor: Acquisitions Process

"The bureaucracy is expanding to meet the needs of the expanding bureaucracy."
–Oscar Wilde, 1892

Today's DoD acquisition professional struggles to design, develop and deploy innovative, complex aircraft systems with the needed velocity to dominate the strategic environment. Department program management offices (PMOs) struggle with contracting, policy, and administrative challenges that impede the speed of development and fielding of military UAS.

Multi-Year Contracts

Lessons learned from the Lockheed Martin F-35 and Bell V-280 PMOs show promise in reducing schedule delays and costs through multi-year contracts. These contracts offer the manufacturers predictability to streamline production and investment while offering the government discounts and price stability and speeding delivery to the warfighter. The DoD does not fully capitalize on these contractual agreements because Congress and the Services often oppose contracts that tie up budget dollars for several years, reducing present-day flexibility.

DoD began acquiring F-35s in 2007, starting with an annual procurement of 14 units in 2008 at a cost of over $200 million per unit. Today, the annual procurement rate has increased to

100 units, and the per-unit price has decreased to less than $100 million for a more sophisticated model.[72] The DoD realized in 2017 that multi-year contracts and economic order quantities would reduce costs, schedule delays, and speed up acquisitions.[73] Because both Congress and the Air Force were in such agreement about the future of the F-35, both parties were willing to risk tying up future budgets. In 2019, the F-35 PMO awarded a block buy, similar to a multi-year procurement, that reduced per-unit costs by 9% and allowed Lockheed Martin to buy more materials and components at less cost and hire more efficiently.[74] The block buy also allowed the contractor to procure long lead items that traditionally slowed production.

The Army's Future Vertical Lift program experienced similar problems to the F-35 program during design and development and repeated some of its early 'mistakes.' Initially, the Army awarded a limited contract to Bell and Sikorsky for prototypes. Both teams ramped up engineers, software developers, and other skilled labor to build the prototypes. After completing the prototypes, the Army paused to select the best design and resolve the losing protest. The significant pause forced both teams to lay off most of their workforce. Bell won the protest and is now projecting to deliver the first new prototype in 2025 – a year later than the Army's original projection.[75] Taking a multi-year contracting approach, the Army could have provided sufficient funding to bridge the pause, and thereby accelerate initial production.

Recommendation: *Congress should expand authorities for multi-year contracting and mandate their increased use at the Service level through the PPBE process.*

Requirement and Budget Stability

Though the military Services have taken overt steps in recent years to streamline their acquisitions process, they remain significantly indecisive in requirement adjustment and creep and continue to show hesitancy to stick to budget plans over any but the shortest of time

horizons.[76] At the platform level, setting realistic requirements – and more importantly, resisting the urge to change them in the face of new information, new leadership, or new technical options – is essential for avoiding unnecessary delays. Through the PPBE process, PMOs must plan their budget carefully two to three years before they execute funding. This requirement is challenging enough in the fast-paced world of highly technical UAS procurement but is significantly exacerbated by intra-Service budget churn as leaders continually reprogram dollars for an ever-changing set of priorities of the day. These reprioritizations may have urgent validity, such as a large, unexpected response to the invasion of Ukraine, but the incessant fluctuations, most of which stem from more optional alterations, inevitably translate into elongated schedules and increased costs.[77] Procurement and PPBE experts in the Services must first educate themselves on the benefits (in time and money) to decision stability, and then educate Senior Leaders to drive a cultural shift towards decisiveness and tenacity.

Recommendation: *DoD should continue its current effort to update the PPBE process, reduce internal requirement and budgetary reprogramming churn, and increase program manager authority and autonomy to execute stable programs at speed.*

The importance of timely annual enacted budgets cannot be overstated, as numerous experts have emphasized in the past. The failure to achieve this objective results in billions of dollars being sub-optimized and significant delays in project completion. Given that Continuing Resolutions (CR) have become the established norm, the Department should collaborate with Congress at the staff and line-item level, leveraging industry political influence, to secure legal measures, interpretations, or cultural acceptance that allow budgetary and authoritative flexibility within the procurement process. These efforts are crucial for sustaining operational efficiency when budgets spend nearly as long unenacted as enacted. As an example, the Secretary of the

Air Force sent a proposal to Congress in FY23 to start new programs without a completed fiscal budget.[78] Initially, there was hesitation on the part of the Service Departments to ask for relief from the pain of CRs out of fear that the pain was necessary to prevent and shorten them. This hopeful view has been proven wrong; CRs are here to stay; and we should lean into the full suite of accommodations, bolstered in argument by the current exigency of competition and war, to thrive in them. **Recommendation:** *The DoD should work with Congress for necessary authorities to increase program execution stability and efficiency under Continuing Resolutions.*

"Rapid" Authorities

Where Congress has allowed for a variety of contract vehicles to speed delivery, such as Rapid Acquisition Authority (RAA), Middle Tier of Acquisition (MTA), and Other Transaction Authority (OTA), DoD has been slow to fully embrace their potential. A limited number of trained acquisition professionals are already using them, but most program managers are still relying on traditional contract vehicles that often take ten to twenty years to fully field. **Recommendation:** *While the Department should promote training and use of these rapid acquisition authorities, Congress should resist creating additional oversight mechanisms that reduce the flexibility of these tools. In parallel, the Department must immediately develop and publish DoD policy that moves away from contracting vehicles that do not support the fast-paced, highly technical UAS field, such as Firm Fixed Price (FFP) contracts using the Lowest Price Technically Acceptable (LPTA) bid.* These contract types force UAS firms to race to the bottom, cutting quality, innovation, and speed.

Coordinated Approach

As the UAS market becomes more mature, the DoD has an opportunity to avoid vendor-lock pitfalls of the past. We should expect that industry leaders will gravitate towards individual contracts, assertions of data rights, and the use of proprietary components. This slicing of clients and lock-in of ownership erodes the relative power of the DoD buyer and produces monopolistic outcomes of higher costs and slower rates of innovation and production. While much of this was DoD-caused or validated, the Department is taking early steps to ameliorate it.

As a step forward, a Modular Open-Systems Approach (MOSA) is now a requirement under Title 10, and both Department and Industry practitioners address the issue openly.[79] Much opportunity remains for closer collaboration between buyers across Program Offices, Services, and even across Departments – to merge requirements and contract in larger quantities. In addition to reducing costs and improving schedules, improved fleet standardization and corresponding simplification of sustainment and supply chains would be a significant bonus. This effort is nascent; complex coordination is hard; and we don't purport to have a silver bullet.

Recommendation: *UAS project offices work with contracting commands to embed clear MOSA requirements into UAS contracting while seeking opportunities to combine requirements for increased bargaining power and standardization efficiencies.*

Accelerated Testing

Today's complex aircraft systems invite much longer testing periods to ensure the advanced technology is safe, integrated, and working as intended. Lives are at stake and testing agencies rightly take their jobs very seriously – with an incredible recent record.[80] Largely excluded from the ground-centric expedited fielding of certain GWOT platforms (e.g. the MRAP), the aircraft testing enterprise has enjoyed more peaceful schedules over the modern

period, and all parties have allowed evaporating risk tolerance to completely dominate competing requirements for speed – severely lengthening program delivery schedules across the board. As competition heats up in today's global environment, this tradeoff must become more balanced. **Recommendation:** *Led by Department level directives and oversight, the acquisition and test communities must streamline UAS testing. Government testing agencies must partner with the UAS industry to conduct testing together, build trust, and encourage the concept of test quickly, test often, and fail fast. In a similar fashion to the FAA recommendations above, DoD must affirmatively lower the risk thresholds test agencies are chartered to reduce and assume responsibility for the imperfections and accidents that become more likely to occur.*

Conclusion: Air Dominance in Strategic Competition

Expansion of uncrewed capability and capacity in air power is required to maintain the lead in strategic competition. In the 2022 NSS, President Biden noted that the United States "will seize this decisive decade to advance America's vital interests, position the United States to outmaneuver our geopolitical competitors, tackle shared challenges, and set our world firmly on a path toward a brighter and more hopeful tomorrow."[81] The aircraft industry, particularly its uncrewed aircraft subset, is a critical component of U.S. military modernization to meet future challenges across the globe. Setting the conditions to accelerate the development and fielding of increasingly advanced uncrewed aircraft is vital to maintaining U.S. military advantage. With that objective in mind, the U.S. must reverse defense industry consolidation, secure reinforced supply chains, overcome archaic regulatory limitations, attract effective human capital, and cultivate velocity in its acquisition process. Prioritizing these factors in the shadow of potential conflict will enable the U.S. to outpace its competitors, project dominant airpower, and protect the U.S.-led, rules-based international order.

Appendix A: Consolidated Recommendations

Executive Office

a. The Administration should immediately publicly reaffirm the MTCR's principles and encourage other nations to join in its updated interpretation while retaining relevant UAS export considerations in the agreement.

Congress

b. Congress should expand the research and development tax credit for the aerospace industry to incentivize innovation in materials.
c. To safeguard supply, U.S. policymakers should liberally permit, and potentially subsidize, domestic extraction and refining of critical minerals.
d. Congress should increase funding for the Manufacturing USA and Manufacturing Capability Expansion and Investment Prioritization (MCEIP) programs to spur domestic production while seeking free trade agreements with partners and allies to leverage values-aligned international comparative advantages.
e. Congress must seize the opportunity in the 2023 five-year FAA reauthorization to elevate the leadership of the FAA's Office of UAS Integration to an Associate Administrator, expand the office's authorities to modernize regulatory frameworks, and fully resource it annually through appropriations to fulfill the AAMCLA's working group recommendations.
f. Congress should expand authorities for multi-year contracting and mandate their increased use at the Service level through the PPBE process.

Department of Defense

g. The DoD should expand efforts like the Small Business Innovation and Research and Small Business Technology Transfer programs to all levels of the acquisitions process.
h. The DoD should increase procurement of defense products from values-aligned international defense firms (e.g., Australian, European, South Korean, etc.), specifically not in partnership with U.S. Primes, who not only have strong, capable products for use in our military but whose presence would inject much needed competitive pressure to concentrated U.S. firms.
i. The DoD should inject criteria into decision making aimed at preferencing new platforms over service life extensions and upgrades.
j. The DoD should streamline policy requirements in DoD Directive 3000.09 and other related sources to increase speed and apply additional funding to R&D (and prototyping, testing, rapid fielding, etc.) sufficient to maintain the AI arms-race lead.
k. The DoD must carefully monitor the semiconductor supply chain and be prepared to recommend the use of the Defense Production Act to divert supply to critical programs if shortfalls are detected or anticipated.
l. The DoD should partner with the Department of Education with funding, training, and employment support to expand STEM outreach into the American education system, especially focusing on under-represented communities.

m. The DoD should increase funding for the SMART program to enable 25 students to enter the program in 2024. With a 91% completion of service from over three-thousand students this program is a huge win for the DoD.

n. *The DoD should continue to highlight the holistic health of the American population as a matter of National Security, supporting other Departments, and law/policy where appropriate, aimed at increasing comprehensive fitness for national service.*

o. The DoD should continue its current effort to update the PPBE process, reduce internal requirement and budgetary reprogramming churn, and increase program manager authority and autonomy to execute stable programs at speed.

p. The DoD should work with Congress for necessary authorities to increase program execution stability and efficiency under Continuing Resolutions.

q. UAS project offices work with contracting commands to embed clear MOSA requirements into UAS contracting while seeking opportunities to combine requirements for increased bargaining power and standardization efficiencies.

r. Led by Department level directives and oversight, the acquisition and test communities must streamline UAS testing. Government testing agencies must partner with the UAS industry to conduct testing together, build trust, and encourage the concept of test quickly, test often, and fail fast. Similar to the FAA recommendations above, DoD must affirmatively lower the risk thresholds test agencies are chartered to reduce and assume responsibility for the imperfections and accidents that become more likely to occur.

s. While the Department should promote training and use of these rapid acquisition authorities, Congress should resist creating additional oversight mechanisms that reduce the flexibility of these tools. In parallel, the Department must immediately develop and publish DoD policy that moves away from contracting vehicles that do not support the fast-paced, highly technical UAS field, such as Firm Fixed Price (FFP) contracts using the Lowest Price Technically Acceptable (LPTA) bid.

Federal Aviation Administration

t. The FAA should expand its Part 107 weight limitation to 1,000 pounds or more to facilitate the R&D of larger UAS without cumbersome Part 91 waivers.

u. The FAA should at least double the amount of BEYOND sites, focusing on ranges and locations convenient to UAS industry clustering.

v. *Within the next two years, the FAA should develop standards for UAS safety and traffic deconfliction equipment to spur the creation of systems capable of integrating safely into crewed airspace above 400 feet.*

Industry

w. Industry should expand educate-and-hire programs and expand their reach into underrepresented communities. Industry should increase mentorship opportunities and outreach in K-12 to introduce STEM education and career field options earlier.

Appendix B: Capstone Addendum – Adding Quills to Taiwan's Porcupine Defense

Note: This addendum responds to scenario question #1: *China-Taiwan: Short- and long-term implications; levers U.S. and others have to address them.*

At the 20th Congress of the Chinese Communist Party (CCP), General Secretary Xi Jinping remarked that the CCP had the "option to take all necessary measures" to achieve unification with Taiwan.[82] If Taiwan desires to maintain autonomy, it must deter Chinese invasion. Taiwan's economy is less than one-twentieth that of China's economy, with barely one-one-hundredth of the population.[83] As Taiwan cannot hope to reach military parity with China, Uncrewed Aerial Systems (UAS) offer an affordable means to increase deterrence, achieve increased capability in mass, and yield greater persistence than manned aircraft. Policy changes to the Missile Technology Control Regime (MTCR) could help facilitate increased access to American-produced UAS for Taiwan's defense.

UAS Proliferation Impact

The People's Liberation Army Air Force (PLAAF) has over 3,000 aircraft, including a growing number of fifth-generation fighters.[84] Conversely, Taiwan's Air Force has less than 700 aircraft, with combat capabilities limited to fourth-generation Indigenous Defense Fighters (IDFs) and F-16s.[85] Operating a fourth-generation fighter like the F-16D costs $13,339 per flight hour, but an MQ-9 Reaper is much cheaper at $864 per flight hour.[86] While not nearly as capable as an F-16, the Reaper has a longer loiter time and comes at a much lower per-unit cost.[87] Furthermore, UAS offer considerably more protection for the highest value asset in air defense: trained and qualified aircrew. As reported by the RAND Corporation, Taiwan's Air Force is held at risk on the ground by Chinese missiles and rockets and is outmatched in the air.[88] Short Takeoff and Vertical Landing (STOVL) UAS partially undermine this Chinese strength.

Overall, a large mass of persistent UAS surveillance creates a network of sensors that could detect and track enemy contacts and provide cueing for land-based, mobile missile defenses. Such capability could result in significant risk to an invasion force while mitigating counter-targeting. The U.S. Chief of Naval Operations recently stated that UAS offer solutions to Chinese military and paramilitary threats in the area.[89] Deterring China will require both quality and quantity in capability across all domains. Because of their low cost, UAS offer the best option to increase quantity in the air domain. Proliferating autonomy in UAS technology will also allow fewer trained and qualified aircrew to employ a greater number of assets. Despite these advantages, U.S. sales of highly capable UAS to Taiwan remain minimal.[90]

Artificial Limits on Effective Deterrence

A barrier to the sale of UAS is the Missile Technology Control Regime (MTCR), a voluntary agreement between 35 countries designed to prevent the proliferation of weapons of mass destruction (WMD) delivery vehicles.[91] Exports of large UAS such as the Reaper are presumptively denied or strictly limited in accordance with outdated MTCR guidelines generated when UAS were effectively remotely piloted missiles. Notably, China is not a signatory and emerged as the arms dealer of choice for UAS while MTCR members heavily restrict UAS exports as part of the agreement.[92] China is certainly unwilling to arm Taiwan, so the U.S. is a logical alternative. The U.S. should utilize its autonomy and latitude granted in the MTCR to expand exports of large UAS actively and responsibly to Taiwan, magnifying quantity in Taiwan's aerial defense and complicating the Chinese invasion calculus.[93] In addition to helping bolster Taiwan's deterrence efforts, international sales of American UAS could offset and even reduce Chinese participation in the UAS market.

Some might argue that the sale of American UAS to Taiwan would be seen as escalatory by the CCP and sour relations with Washington. However, the U.S. already sells F-16 fighters to Taiwan, which have more capability than uncrewed systems. Additionally, UAS offer alternate paths to prevent the escalation of events to a crisis. For example, had the American MQ-9 brought down by Russian aircraft in the Black Sea in March of 2023 been a crewed platform, the ramifications would have undoubtedly escalated from an isolated event into a crisis.[94]

In Conclusion

American-made UAS provide an actionable lever that the U.S. can use to increase Taiwan's ability to deter aggression from the CCP. UAS are cheaper and less risky to operate than manned aircraft, have longer persistence, and can endure attrition through reserve quantity. Technology outpaced the relevancy of UAS in the MTCR. The U.S. should modernize its UAS export policy for the 21st century and capitalize on an opportunity to provide Taiwan with abundant and affordable capabilities to deter China. These sales would also displace Chinese systems from the global arms marketplace, yielding benefits for American UAS manufacturers and the DIB.[95] The sale of UAS to Taiwan would satisfy the U.S. strategic imperatives of developing the capabilities of partners and allies, building enduring advantage, and creating deterrence through denial.[96]

Appendix C: Industry Analysis – Porter's 5 Forces

The aircraft industry includes a wide variety of systems and platforms ranging from simple store-bought drones through complex military fighter aircraft developed and produced at the national level. When conducting this industry analysis, the analysis focused on the comparison between top-end exquisite military aircraft and the emergence of high-performance uncrewed aircraft. The UAS industry is characterized as follows:

a. **Barriers to entry:** When developing top-end exquisite military aircraft the barriers to entry are high. This causes nations to fund these aircraft nationally with very few companies able to resource development on their own budgets. It also means that aircraft are designed and resourced through international collaboration such as in the case of the Eurofighter and to a lesser extent the F-35. However, with less exquisite, easily mass-produced, and lower-end systems such as uncrewed aircraft the opportunity for new competition is much broader. The lower costs and less sophisticated technology, along with the reduced risk to human life means that more companies can submit innovative ideas to meet military needs.
b. **Power of suppliers:** The current aircraft industry model relies on numerous suppliers across the globe to produce aircraft. This comes in the way of raw materials such as titanium and aluminum over to major components such as engines and fuselages. There is a delicate balance that large prime manufacturers must maintain with timelines for delivering aircraft and availability of the parts to make their product. Suppliers of these parts and systems have the power to influence the cost of the final product and timelines. Supply chains are easily influenced, not only through supplier costs and timelines, but through external factors such as natural disasters, pandemics, and geo-political influences. When dealing with exquisite aircraft, the power of suppliers is greater than that of mass-produced uncrewed systems.

c. **Power of customers:** The U.S. government holds significant power when dealing with exquisite systems. It is effectively the only buyer, and should a company want to export a military product it must have its approval. With the emerging uncrewed market this dynamic can shift should the technology carry dual-use application.
d. **Existing competition:** The defense primes in the U.S. have an advantage in that they have already competed in the market, have the capital investment to produce new systems, and already produce uncrewed systems. Examples in the uncrewed market include the Reaper, Predator, and Shadow. The future of uncrewed/autonomous systems may come in the form of the Next Generation Air Dominance (NGAD) platform with possible development coming from the likes of Boeing and Lockheed Martin.[97] As smaller companies enter the market with their products the primes may take steps to acquire them or work collaboratively on projects. An example is Shield AI, which is developing software for autonomous flight.
e. **Threat of substitutes:** The obvious substitute to uncrewed/autonomous systems are manned aircraft. Uncrewed systems will face continued headwinds in technological development and cultural adaptation, but should present increasing challenge to the status quo over time.

In summary, the aircraft industry is highly concentrated within a few powerful primes coupled to a monopsony buyer. With high barriers to entry both in terms of technology and regulation, it is not expected that disruption will occur through new market entrants or substitute products. As such, it is more likely that the industry will change and innovate internally and gradually rather than through external market forces.

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