May 2023

Rising Demand and Proliferating Supply of Military UAS

Exploring Demand from New UAS Importers and Options for U.S. Security Cooperation and Industrial Base Policy

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Contents

Table of Tables

Table of Figures

Executive Summary

Uninhabited aerial systems (UAS) have a long history of use, but they were once a capability primarily found in cutting-edge militaries that often kept at least their armed variants a closely guarded capability. Prompted in part by lower barriers to entry—shown in the burgeoning commercial UAS market—and advances in information communication technology, this exclusive period is no more. The Center for the Study of the Drone (CSD) reported that the number of countries with operational drone capabilities rose from 60 in 2010 to 102 or more in April of 2020. This increase can be partially attributed to a marked rise in countries importing military UAS and loitering munitions. As measured by the Stockholm International Peace Institute (SIPRI), total UAS and loitering munition transfers rose from 736 units in 2001–2010 to 1,612 units in 2011–2020, armed UAS and loitering munitions being the main drivers of this growth.

To understand the trends and implications of this proliferation, this report asks three questions: (1) What countries are driving the increase in demand? (2) How has the supply of military UAS changed? (3) How is the U.S. defense industrial base positioned to support U.S. foreign policy goals in this new environment? The report addresses these questions with quantitative analyses of global UAS and loitering munition transfers and contract spending by the U.S. government on UAS, enabled by a groundbreaking labeling effort. This analysis is supported by a closer look at examples of demand and supply. The first two examples are the two interstate wars equipped during this period of growing UAS proliferation: the 2020 Nagorno-Karabakh war and the ongoing Russian invasion of Ukraine. The third example examines the structure of the U.S. industrial base for UAS and the international agreements and export policies that shape transfers.

Across these analyses, the paper reaches four broad conclusions. First, **UAS and loitering munitions offer a wide range of capabilities to a growing range of states.** States prioritizing military spending, like Azerbaijan, may seek ways to project power, while frontline states—states nearby a potentially hostile great power—like Ukraine, pursue affordable ways to challenge a foe that employs advanced weaponry in great numbers.[1] UAS and loitering munitions offered potential benefits that were well established before the 2020 Nagorno-Karabakh war, including intelligence, surveillance, and reconnaissance (ISR) capabilities; supporting counterterrorism and counterinsurgency operations; and lowering risk when projecting power beyond one's borders.[2] In one or both of these conflicts, UAS and loitering munitions demonstrated further strengths: affordable command-and-control and ISR integration, budget airpower in support of combined arms, the potential to rapidly build a domestic industry supporting the production of UAS, and support for larger information warfare efforts.

Second, **Ukraine is a leading experimenter in frontline state usage of UAS and loitering munitions and the future frontline demand for these systems is uncertain.** Frontline states often prioritize military spending, but they have a separate set of considerations shaped by a powerful neighbor. After Russia's annexation of Crimea, Ukraine undertook an effort to build up domestic production and importation of commercial and military UAS as well as loitering munitions. Data from the Stockholm International Peace Research Institute (SIPRI) shows that in terms of

[1] The distinction is not one of absolute spending; with the exception of 2011–2014, Ukraine has had consistently larger military expenditures. Instead, frontline states are distinguished by needing to account for a highly capable adversary.

[2] Non-state actors are also a potential source of demand, which may prompt interest in counter-UAS systems, but their demand has more limited industrial base implication and trade and is beyond the scope of this paper.

estimated production cost, 12.5 percent of Ukraine's total imports were UAS and loitering munitions—well above Azerbaijan's 3 percent. This was a bold step by Ukraine, as while UAS and loitering munitions have advantages for frontline states, they also pose greater risk: the sophisticated air defenses and electronic warfare capabilities held by great powers mean that UAS and loitering munition capabilities will be actively contested. Unless they possess stealth abilities, even highly capable systems may face a short lifespan. U.S. support for Ukraine has included lower-cost UAS such as the Puma and loitering munitions such as the Switchblade and the recently declassified Phoenix Ghost, but not higher-capability UAS such as the U.S. Army's Gray Eagle. Russian countermeasures have played an important role in the conflict but have not prevented Ukraine's UAS and loitering munition assets from contributing to the combined arms war effort.

In the past two decades, most of the top 25 countries that are prominent traders of UAS and loitering munitions have not been frontline states, with exceptions such as importers like Ukraine and the Philippines along with Poland's role as an exporter of loitering munitions. This is beginning to change, as shown by the Republic of Korea's import of maritime surveillance UAS in 2018 and new agreements between the United States and both Taiwan and Australia. However, with Chinese counter-UAS capabilities likely even more capable than those deployed by Russia, the dynamics for these nations and exporters seeking to equip them will likely be shaped by the war in Ukraine and are still uncertain.

Third, **countries now have a range of alternatives for acquiring UAS and loitering munitions.** The trade is shaped not just by demand but also by supplier foreign policy considerations, national-level restrictions, and multilateral regimes. Regardless of demand, new importers faced potential limits at the start of the century on their ability to acquire UAS and loitering munitions. Israel was the predominant global seller but largely limited its transfers to unarmed UAVs and loitering munitions, and the United States rarely made exceptions to the presumption of denial for more capable UAS that fell under Missile Technology Control Regime restrictions. The entry of China as an exporter of armed drones has been a major driver of the growth in UAS and loitering munition deliveries as measured by estimated production cost, with the Middle East being a standout recipient. In addition, the United Arab Emirates, Turkey, and Poland entered the scene as exporters. While representing a smaller portion of global output, Turkey's TB2s filled a prominent comparatively low-cost armed UAS role for both Azerbaijan and Ukraine. For new importers, including Azerbaijan, UAS and loitering munitions have represented only 1 to 3 percent of the estimated production cost of their imports over the past two decades, in keeping with the idea that the systems play a supporting role rather than being a top priority of most nations. This growth in the number of suppliers is partially present in the U.S. defense industrial base. While most spending goes to a mix of the "Big Five" prime defense contractors and UAS specialist General Atomics, the number of participating vendors on UAS projects rose in the past decade, even as there has been some consolidation in the top 10 vendors.

Fourth, **the United States has increased its exports of UAS but primarily to wealthy, trusted allies— a marked difference from exports of other weapons platforms.** Thanks in part to successors to current systems currently being developed in the classified sphere, unclassified U.S. government spending on UAS systems was $3.02 billion in fiscal year 2021, down from a recent high of $5.34 billion in fiscal year 2019. This spending is overwhelmingly military and generally for products, but as far as defense spending is concerned, it includes a higher proportion of research and development (R&D) spending than most other weapon systems. This unclassified spending can employ restrictive contracting for commercially available items or use other transaction authority (OTA) spending, which supplements contract spending using a mechanism with greater flexibility. However, commercial and OTA spending only accounted for $191 million in fiscal year 2021, with the past four years being a period of higher spending but not yet reaching the heights of over a decade ago.

The Missile Technology Control Regime (MTCR) has played an important role in discouraging the transfer of larger and long-ranged UAS. The last decade has also seen the Arms Trade Treaty entering into force and the United States developing a joint understanding of the proper use of UAS, both efforts that increase the attention paid to importers of UAS and to how they are used. U.S. exports of high production cost systems rose during this period, but in keeping with the 2015 UAS export guidance these consisted predominantly of approved transfers to U.S. allies that raised few risks. This trend has continued after the United States revised its understanding of the MTCR, removing the presumption of denial for its highly capable systems.

List of Abbreviations

AGL – Above Ground Level
DOD – Department of Defense
EAR – Export Administration Regulations
FMS – Foreign Military Sales
FPDS – Federal Procurement Data System
FY – Fiscal Year
ISR – Intelligence, Surveillance, and Reconnaissance
ITAR – International Traffic in Arms Regulations
MSL – Mean Sea Level
MTCR – Missile Technology Control Regime
SIPRI – Stockholm International Peace Research Institute
TIV – Trend Indicator Value (used by SIPRI as a measure of estimated procurement cost)
OTA – Other Transaction Authority
UAS – Uninhabited Aerial System(s)

CHAPTER 1

Introduction

The military use of powered uninhabited aerial systems (UAS) has evolved since their inception in the twentieth century. From the 1930s through the 1950s, the primary strategic case for UAS was for non-kinetic missions, including serving as practice targets and decoys.[3] The case for including reconnaissance capabilities evolved beginning in the late 1950s and first saw extensive use in combat during the Vietnam War, where the Lightning Bug UAS conducted 3,425 intelligence, surveillance, and reconnaissance (ISR) operations.[4] Innovation in the use of UAS was certainly not limited to the United States. Israel pioneered many of the Cold War–era UAS developments and remains a leading UAS exporter today; for example, in the 1983 Operation Peace for Galilee, it leveraged signal-emitting UAS to trick Syrian radar operators into expending missiles on decoys. [5] For the United States, UAS became increasingly integrated into the use of precision guided munitions, proving critical for tactical level intelligence collection, battlefield damage assessment, and target validation during the Gulf War.[6] After the dissolution of the Soviet Union in 1991, the strategic case for U.S. employment of UAS evolved again to address smaller asymmetric challenges. Humanitarian intervention in the former Yugoslavia combined with a constrained budget prompted the development of the long-endurance Predator UAS.[7]

The strategic case evolved once again after the September 11, 2001, terrorist attacks to include both ISR and strike capabilities in support of counterterrorism and counterinsurgency operations; it was later in that year that the first UAS with an AGM-11 was deployed.[8] During Operation Enduring Freedom and Operation Iraqi Freedom, the United States maintained air superiority and faced minimal opposition in air defenses, which meant that less stealthy UAS were useful and used.[9]

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[3] Abigail R. Hall and Christopher J. Coyne, "The Political Economy of Drones," *Defence and Peace Economics* 25, no. 5 (September 3, 2014): 445–460, https://doi.org/10.1080/10242694.2013.833369.
[4] John David Blom, *Unmanned Aerial Systems: A Historical Perspective* (Fort Leavenworth, KS: Combat Studies Institute Press, 2010). There were unsuccessful armed UAS attempts in combat during World War II. Hall and Coyne, "The Political Economy of Drones."
[5] Pieter D. Wezeman, Alexandra Kuimova, and Jordan Smith, "Arms Transfers to Conflict Zones: The Case of Nagorno-Karabakh," SIPRI, April 30, 2021, https://www.sipri.org/commentary/topical-backgrounder/2021/arms-transfers-conflict-zones-case-nagorno-karabakh.
[6] Jack Miller, "Strategic Significance of Drone Operations for Warfare," *International Relations*, August 19, 2013, 13.
[7] Hall and Coyne, "The Political Economy of Drones."
[8] The Gnat, renamed the Predator, was first used over Yugoslavia, but saw much wider use in response to the post-9/11 strategic reality. Mark Bowden, "How the Predator Drone Changed the Character of War," *Smithsonian Magazine*, November 2013, https://www.smithsonianmag.com/history/how-the-predator-drone-changed-the-character-of-war-3794671/; Frank Strickland, "The Early Evolution of the Predator Drone," *Studies in Intelligence* 57, no. 1 (2013): 6.
[9] Matthew Fuhrmann and Michael C. Horowitz, "Droning On: Explaining the Proliferation of Unmanned Aerial Vehicles," *International Organization* 71, no. 2 (2017): 397–418, https://doi.org/10.1017/S0020818317000121; Rose Butchart et al., *Reaching*

UAS provide some advantages over inhabited aircraft that may lead a country to opt to acquire uninhabited vehicles. The U.S. military details in its Unmanned Systems Integrated Roadmap FY2013-2038 that UAS are "preferred alternatives . . . for missions characterized as dull, dirty, or dangerous."[10] One such advantage, of course, is that it removes the risk to operators' lives; this in turn also enables operations that domestic audiences might not otherwise support. Another consideration is that UAS have lower personnel and operating costs per hour of operation compared to inhabited aircraft.[11] UAS also remove human limitations that burden human-piloted aircraft, such as flight endurance caps, human-centric safety requirements, and multidirectional maneuverability limitations of the human body.[12]

The Obama administration's June 2015 National Military Strategy shifted the nation's strategic focus back to great power competition focusing on China, necessitating a new strategic concept for UAS. [13] A mix of rapid technological developments and classified approaches makes summarizing that concept difficult. As the 2017 Unmanned Systems Integrated Roadmap noted, "over the last decade, the advancement of unmanned systems technology has exploded, and the extrapolated growth curve hints that by the time of the publication of this document, some unidentified emerging technology or issue will likely emerge to disrupt any path that a traditional strategy might lay out."[14]That document did not outline a specific technology direction for UAS but put forward overall themes of "interoperability, autonomy, network security, and human-machine collaboration."[15] Some analysts have forecast that UAS will be pivotal in future great power conflict, often invoking specific technological developments like swarming maneuvers.[16]

That said, the question of the use of UAS in conflict is not merely limited to great powers and innovators like Israel Even the use of unarmed UAS for ISR purposes may lower the threshold for entry into combat and the United Nations Office for Disarmament Affairs published a report raising five implications of armed UAS: (1) "altering incentives in the use of force"; (2) "tempting States to interpret legal frameworks to permit fuller exploitation of the expanded capabilities of armed UAVs"; (3) "use of armed drones by covert armed forces in ways that do not permit sufficient transparency or accountability"; (4) "increasing use by non-State armed groups or even individuals"; and (5) "automation and compressing the 'time to strike' process."[17] The Center for the Study of the Drone (CSD) reports that

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Farther, Risking Less: Remotely Crewed Systems' ISR Applications for Great Power Competition (Washington, DC: Center for Strategic and International Studies, September 2021), https://www.csis.org/analysis/reaching-farther-risking-less.

[10] United States Department of Defense, *Unmanned Systems Integrated Roadmap: Fiscal Years 2013-2038* (Washington, DC: U.S. Department of Defense, 2013), 20, https://digital.library.unt.edu/ark:/67531/metadc949794/.

[11] Edward G. Keating, John Kerman, and David Arthur, *Usage Patterns and Costs of Unmanned Aerial Systems* (Washington, DC: Congressional Business Office, June 1, 2021), 16, https://www.cbo.gov/system/files/2021-06/57090-UAS.pdf.

[12] Fuhrmann and Horowitz, "Droning On."

[13] Ronald O'Rourke, *Renewed Great Power Competition: Implications for Defense—Issues for Congress* (Washington, DC: Congressional Research Service, May 29, 2020; updated March 10, 2022), 48.

[14] Office of the Assistant Secretary of Defense for Acquisition Washington United States, "Unmanned Systems Integrated Roadmap: 2017-2042" (U.S. Department of Defense, August 1, 2018), https://apps.dtic.mil/sti/pdfs/AD1059546.pdf.

[15] Ibid, 4.

[16] Bob Work, "Reagan Defense Forum: The Third Offset Strategy," interview by Thom Shanker, *Reagan Defense Forum*, Ronald Reagan Presidential Foundation and Institute, November 7, 2015, https://www.defense.gov/News/Speeches/Speech/Article/628246/reagan-defense-forum-the-third-offset-strategy; Christian Trotti, "Swarming to Victory: Drones and the Future of Great Power Competition," *The National Interest*, May 16, 2022, https://nationalinterest.org/blog/techland-when-great-power-competition-meets-digital-world/swarming-victory-drones-and-future.

[17] "Study on Armed Unmanned Aerial Vehicles – UNODA," accessed January 3, 2023, https://www.un.org/disarmament/publications/more/drones-study/.

"at least 28 countries have deployed UAVs beyond their borders since the 1980s."[18]I Within or beyond their borders, "at least 10 countries—Azerbaijan, Israel, Iraq, Iran, Nigeria, Pakistan, Turkey, UAE, U.K., and U.S.—are believed to have used UAVs to conduct aerial strikes."[19]

The November 2020 Armenia-Azerbaijan war over the Nagorno-Karabakh region and the current conflict in Ukraine have seen extensive use of UAS, including loitering munitions.[20] They have provided a low-cost enabling role for specific kill chains and have also supported larger combined arms efforts. They have made important impacts, especially in the early stages of these conflicts. UAS have played a prominent role in information warfare, giving evidence of battlefield proficiency that can be used to rally supporters and demoralize adversaries. Ongoing evidence from Ukraine shows the utility of UAS and loitering munitions, along with Javelin missiles and satellite images and communications, as part of the evolving approaches to warfare. However, they have not made traditional weapons platforms like tanks obsolete.[21]

The operational utility of UAS has driven increased demand across the globe as shown in Stockholm International Peace Research Institute (SIPRI) data, with a nearly 60 percent increase in UAS delivered internationally and a 577 percent rise in loitering munition deliveries between the first and second decades of this century. While there are expensive high-end systems, affordable cost is a distinguishing feature of many UAS. The Teal Group estimates that the unclassified military UAS market will grow to $13.2 billion in FY 2032, a 41 percent increase over FY 2023 spending.[22] The industrial base is an increasingly global one, as different offerers—and different countries—specialize in different market niches. Teal finds "the US will account for 71.9% of the unclassified R&D spending on UAV technology over the next decade, and about 34% of the unclassified procurement through the forecast decade," notable in both cases but smaller than the equivalent shares of military equipment in general.[23] Understanding the global UAS industrial base, the international arms trade, and the relevant regulatory regimes for these systems is key to understanding how they will achieve operational effects in future conflicts.

KEY CONCEPTS

There are several different classes of uninhabited systems that are used for warfighting effects. Traditional missiles are long-range, high-speed munitions aimed to strike a target. UAS missions range from ISR to employing other mission packages (including electronic warfare) and carrying and launching their own munitions. UAS are often remotely piloted and, if they survive the mission, can be recovered when it is complete. A last class—loitering munitions—falls between these two with some aspects of both. Like UAS, they can fly to the target area and stay aloft until a decision is

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[18] Dan Gettinger, *The Drone Databook* (Center for the Study of the Drone at Bard College, 2019), XIII, https://dronecenter.bard.edu/projects/drone-proliferation/databook/. This number includes peacekeeping and coalition operations (e.g,. 21 countries deploying UAS to Afghanistan).

[19] Ibid., XIII. The CSD also noted that even when staying within national borders, UAS can be used to "quell domestic uprisings and suppress minority populations."

[20] There is no standard definition for loitering munitions, though they must be able to provide an organic kinetic effect. Defining loitering munitions is difficult because of advances in loitering systems and missiles, giving the systems increasing similar capabilities and characteristics. Many definitions rely on Justice Stewarts' "I know it when I see it" standard. With that said, loitering munitions often have the following capabilities: electro-optical cameras, capability to loiter over a target before striking, retrievability, and the ability to have a human on or off the loop.

[21] "No, Tanks Will Not Be Obsolete in the Wars of the Future," Task & Purpose, April 18, 2022, https://taskandpurpose.com/news/tanks-obsolete-wars-russia-ukraine/.

[22] Steven J. Zaloga, David Rockwell, and Tom Zoretich, *World Military Unmanned Aerial Systems: 2022/2023 Market Profile & Forecast* (Fairfax, VA: Teal Group, 2022), 1, https://shop.tealgroup.com/products/wmuav.

[23] Zaloga, Rockwell, and Zoretich, *World Military Unmanned Aerial Systems,* 2.

made to use them. Like missiles, however, they have kinetic warfighting effects and are not intended to be reusable after striking a target; many models may not even be recoverable if they fail to find a target. In short, attritability is assumed for missiles and loitering munitions. For UAS, attritability is not the default assumption in most cases but is a lower cost option than the loss of an inhabited system.

The focus of this report is the latter two types. To capture the difference in both employment concepts and capabilities, this analysis uses three broad categories, shown in Table 1. The first category, unarmed UAS, participates in long kill chain and encapsulates the largest portfolio of UAS. "Long kill chain" means that for kinetic action to take place, targeting data first must be relayed to another system that is used to achieve that kinetic effect, typically after being transmitted back to a command post. While more organization capacity is required to make an effect happen, unarmed UAS platforms can be simpler. This trade-off means that unarmed UAS are the most ubiquitous platform and are often deemed to be lower proliferation risks.

The secondary category, armed UAS, have a short kill chain and are systems that can achieve kinetic effects from weapon systems mounted on the airframe. This simplifies the complexity of a kill chain and means that operators can surveil and strike a target from a single platform. These systems, however, are often larger and carry hefty acquisition and sustainment price tags relative to other UAS. This higher price tag typically comes with the ability to perform multiple functions or traits such as greater endurance, in addition to the fact that most armed UAS can support long kill chains in addition to their direct attack capability. Loitering munitions have self-contained kill chains, which is to say these systems have a warhead integrated into the airframe and can conduct surveillance of a target before striking it. From a proliferation concern perspective, the difference between a self-contained kill chain UAS and a missile is at times negligible.

Table 1 – UAS and Loitering Munition Operating Concepts

Category	Concept	Operational Complexity	Common Uses	Examples
Unarmed UAS	Long kill chain	High	Artillery spotting, battlefield surveillance	DJI Drones, Global Hawk, PD-2
Armed UAS	Short kill chain and long kill chain	Moderate	As above, as well as tracking and destroying targets needing long-term monitoring	Reaper, TB2
Loitering Munition	Self-contained kill chain	Low	Suppression of enemy air defenses, precision strikes requiring target verification	Switchblade, Harop

Source: CSIS Defense-Industrial Initiatives Group data analysis.

ROADMAP

Starting with the examination of cases, Chapter 2 describes the use of UAS in the 2020 conflict between Armenia and Azerbaijan, primarily focusing on demand for UAS and loitering munitions. Chapter 3 examines both demand and supply by studying the role of UAS and loitering munitions in Ukraine's industrial base in the period between the 2014 annexation of Crimea and Russia's 2022 invasion, followed by a discussion of the challenges of supplying and replacing UAS for the wartime effort. Chapter 4 focuses on supply, examining U.S. acquisition of UAS. This chapter details who is doing the buying, the extent of use of commercial sources and nontraditional contracting approaches, the structure of industrial base, and U.S. exports. Chapter 5 then describes U.S. and multilateral rules regarding transfer of UAS before discussing the global trade in military UAS and loitering munitions, exploring both the growth in the range of suppliers and new sources of demands for UAS transfers. Finally, Chapter 6 discusses options and recommendations for the U.S. government and industry for UAS exports in this new environment.

CHAPTER 2

The Nagorno-Karabakh Conflict

The 44-day conflict in 2020 between Armenia and Azerbaijan over the disputed Nagorno-Karabakh region resulted in a decisive victory for the Azeri aggressors, who made heavy use of UAS and loitering munitions in addition to missiles and rocket artillery. This conflict is summarized here because of its strategic implications for how a wider range of countries might plan to acquire and employ UAS and loitering munitions and how this would drive demand for the global UAS industrial base.

Tensions between Armenia and Azerbaijan had been building throughout 2020 with roots in many decades of disagreement. Azerbaijan triggered the major air and ground war when it moved to reclaim the disputed region on September 27, 2020. The subsequent six weeks of fighting culminated in the deaths of over 6,000 combatants, and Azerbaijan successfully regained control of significant portions of the Nagorno-Karabakh region, which had been under Armenian control since 1994.

A high level of international media attention was given to the use of UAS on both sides of the Nagorno-Karabakh war, widely crediting their use for Azerbaijan's victory. Experts have argued that Azerbaijan's investment in obtaining technological superiority in multiple military domains enabled Baku to launch its offensive to regain the Nagorno-Karabakh region under Azeri control.[24] This section will look at the role that UAS played in the Nagorno-Karabakh war with specific attention to the arms buildup ahead of the conflict, what made UAS such an effective tool, and why their use was given so much attention by the media and internationally.

Role of UAS Overview

Long-simmering conflicts between the two nations meant that Azerbaijan and Armenia both made efforts to modernize their militaries ahead of the conflict breaking out. These modernization efforts included the fielding of more advanced air and missile systems. Armenia's missiles and rocket artillery are predominantly Russian, comprised of Soviet-era Tochka and Scud missiles, Iskander missiles purchased from Russia in 2016, and MLRS purchased from Russia and China. As seen in Table 2, Armenia possessed indigenous UAS, including X-55/Kh-55 and Krunk as well as Armenian HRESH loitering munitions.

Table 2 – UAS Purchases prior to the Start of Hostilities

Armenia	Azerbaijan
X-55/ KH-55 – Indigenous – UAS	TB2 – Imported – UAS
HRESH – Indigenous – Loitering	Harop – Imported – Loitering

[24] Wezeman, Kuimova, and Smith, "Arms Transfers to Conflict Zones."

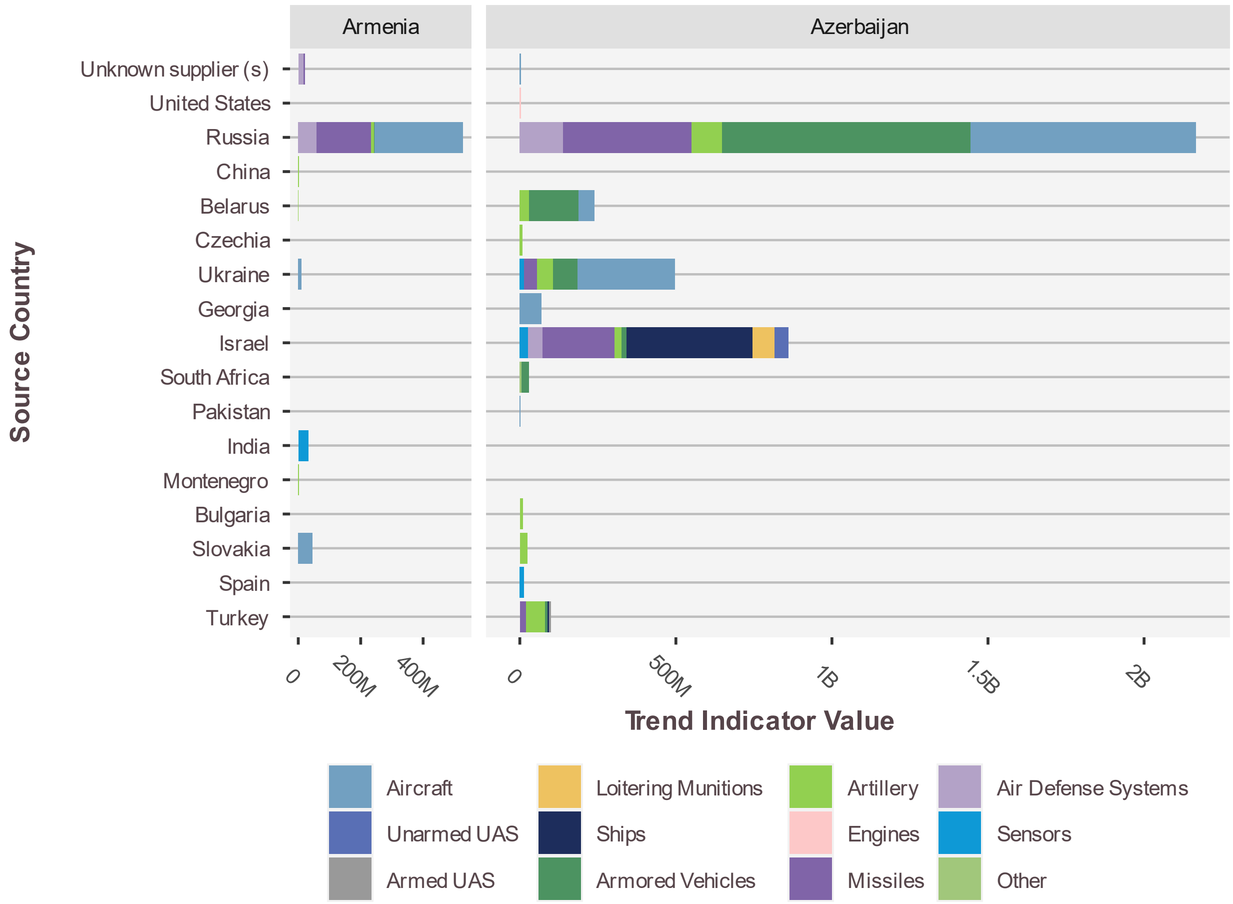
KRUNK – Indigenous – UAS	Orbiter 1K – Imported – Loitering
	Orbiter-3 – Imported – Loitering
	SkyStriker – Imported – Loitering
	Hermes-900 – Imported – UAS
	Hermes-450 – Imported – UAS
	Heron – Imported – UAS
	Aerostar – Imported – UAS
	Searcher – Imported – UAS
	An-2 – Imported, but locally modified – UAS

Source: Shaan Shaikh and Wes Rumbaugh, "The Air and Missile War in Nagorno-Karabakh: Lessons for the Future of Strike and Defense," CSIS, *Critical Questions*, December 8, 2020, https://www.csis.org/analysis/air-and-missile-war-nagorno-karabakh-lessons-future-strike-and-defense.

Azerbaijan, on the other hand, entered the conflict with a militarily superior arsenal of missiles, rockets, and UAS. In the period leading up to the 2020 conflict, Azerbaijan's largest arms suppliers were Russia, Israel, Belarus, and Turkey, as seen in Figure 1.[25] The x-axis in that and later figures uses SIPRI's trend indicator values (TIVs), which are based on the core production cost of a unit when known and are otherwise estimated by the range of capabilities and components of the system. In the two decades preceding the conflict, Azerbaijan invested significant revenue from its oil and gas sales into arms modernization and diversification. Notable among the Azeri arsenal are several UAS and loitering munitions, summarized in Table 2, that Azerbaijan used heavily during the conflict, including Israeli-made Harop, Orbiter, and SkyStriker munitions as well as the now infamous Bayraktar TB2 UAS purchased from Turkey. In the period between 2011 and 2020, SIPRI estimates the volume of Azerbaijan's arms imports to have been 8.2 times more than Armenia's.[26]

[25] "Arms Transfers Database: Trade Registers [Turkish Sales, 2011-2021]," Stockholm International Peace Research Institute, accessed February 8, 2023, https://armstrade.sipri.org/armstrade/page/trade_register.php. SIPRI assigns 6.25 million in TIV for aggregate value of the 5 TB2, which were transferred to Azerbaijan in 2020. This results in a thin sliver on graph in Figure 1, under 7 percent of the TIV of Turkey's total transfers during the period.
[26] Ibid.

Figure 1 – Foreign Arms Deliveries to Azerbaijan and Armenia, Trend Indicator Values by Platform Type, 1999–2021



Source: "SIPRI Arms Transfers Database ," SIPRI, June 12, 2022, https://www.sipri.org/databases/armstransfers; CSIS analysis.

WHY WERE UAS SO EFFECTIVE?

Media reporting of Azerbaijan's victory over Armenia in the 44-day conflict widely credits the use of UAS by Azeri forces for their success. Subsequent analysis by experts describes a more complex explanation for Azerbaijan's decisive victory. Rather than simply a larger, more advanced UAS arsenal, Azerbaijan's war efforts were buffeted by a strong ground force, external support from advanced military powers like Turkey, significantly higher levels of defense spending leading into the conflict, and Armenia's arguably poor air defense strategy.

According to SIPRI:

> In 2020 Armenia's military spending accounted for 4.9 per cent of its gross domestic product (GDP) and Azerbaijan's accounted for 5.4 per cent. In both cases, the national share of each country was considerably higher than the 2020 world military spending average of 2.4 per cent of global GDP. However, the military spending levels in absolute terms differed significantly between the two countries: in 2020, Armenia spent US$634 million and Azerbaijan spent $2238 million.[27]

[27] Ibid.

In addition to its robust cache of foreign UAS and loitering munitions, Azerbaijan also acquired arms such as self-propelled DANA howitzer artillery from Czechia and radar-jamming systems from Spain to support its battle efforts.[28] However, Azerbaijan's superior weapons arsenal did not result in an easy victory for Azeri ground forces, who lost at least 2,900 combatants and had thousands more wounded in the conflict. While Azerbaijan's effective UAS strategy arguably neutralized Armenia's initial high ground advantage, victory still required Azeri ground forces to defeat a determined enemy who proved capable in other areas despite relying on capable but legacy air defenses.[29]

Moreover, Azerbaijan received what many analysts seem to agree was crucial support, in addition to arms sales, from its Turkish allies. Turkey's role in the Nagorno-Karabakh conflict has been described as one of the "magic bullets" of Azerbaijan's victory—another "magic bullet" being the use of UAS.[30] Not only were Turkish Bayraktar TB2 UAS front and center for the duration of the conflict, but Turkey is reported to have sent a host of Syrian mercenaries to Azerbaijan, and senior Turkish military personnel reportedly lent substantial support to Azeri operational planning and command.[31] According to Can Kasapoglu, the director of the Security and Defense Research Program at the Center for Economics and Foreign Policy, Turkish support to Azerbaijan also included "a complete robotic warfare doctrine and concept operations," modeled after Ankara's own strategy. Turkey tested this strategy during the earlier Libyan and Syrian conflicts where Ankara's UAS prowess first made headlines.[32]

Thus, the success of UAS should be attributed not just to the imported equipment from multiple nations but also to the broader range of support Turkey provided. Azerbaijan used UAS highly effectively to exploit the gaps in Armenian air defense, which was particularly vulnerable to drone attack. Armenian air defense included the use of Strela-10 (SA-13), Osa (SA-8), Kub (SA-6), Krug (SA-4), S-300, and Tor missile systems, of which only the Tor system represented an effective counter to the Bayraktar TB2 and loitering munitions used by Azerbaijan.[33] According to analysis published by *Military Strategy Magazine*, "the effective range of the Strella-10s and Osas against the TB2 drone sized targets was shorter than the range of the missiles these carried; whereas the longer-ranged Kubs, Krugs and S-300s were optimized against targets bigger and faster than the drones, so to them the drones were invisible."[34] Moreover, Armenian air defense strategy failed to use the relevant assets Armenia possessed effectively—employing systems without providing cover, thus allowing Azerbaijan to identify and neutralize them as easy targets. Armenian mistakes like these allowed Azerbaijan, which did not command the air, to exploit the gap in Armenian air defense and gradually build air dominance to gain a decisive upper hand.[35]

The strength of Azerbaijan's investment in a diverse range of UAS seems to be derived from their key role in an extremely effective Azeri combined arms strategy. The success of Azerbaijan's ground forces leaned heavily on tactical

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[28] Ron Synovitz, "Technology, Tactics, And Turkish Advice Lead Azerbaijan to Victory in Nagorno-Karabakh," Radio Free Europe/Radio Liberty, November 13, 2020, https://www.rferl.org/a/technology-tactics-and-turkish-advice-lead-azerbaijan-to-victory-in-nagorno-karabakh/30949158.html.
[29] Eado Hecht, "Drones in the Nagorno-Karabakh War: Analyzing the Data," *Military Strategy Magazine* 4, vol. 7 (Winter 2022): 31–37, https://www.militarystrategymagazine.com/article/drones-in-the-nagorno-karabakh-war-analyzing-the-data/.
[30] Haldun Yalçınkaya, "Turkey's Overlooked Role in the Second Nagorno-Karabakh War," German Marshall Fund, January 21, 2021, https://www.gmfus.org/news/turkeys-overlooked-role-second-nagorno-karabakh-war.
[31] Nigar Göksel, "Turkey Recalibrates Its Hard Power," International Crisis Group, August 13, 2021, https://www.crisisgroup.org/europe-central-asia/western-europemediterranean/turkey/turkey-recalibrates-its-hard-power; Yalçınkaya, "Turkey's Overlooked Role in the Second Nagorno-Karabakh War."
[32] Synovitz, "Technology, Tactics, And Turkish Advice."
[33] Hecht, "Drones in the Nagorno-Karabakh War."
[34] Ibid.
[35] Ibid.

targeted strikes by UAS and loitering munitions against Armenian assets and ground units, effectively clearing the way for Azeri infantry to take control of Armenia-controlled areas.[36] The Turkish Bayraktar TB2 was especially effective in these combined arms operations. The TB2, equipped with 50lb MAM-L laser guided munitions, is purported to have destroyed "89 T-72 tanks, 29 armored vehicles, 131 artillery pieces, 61 rocket launchers, 543 trucks, 9 radar systems, and 15 Surface-to Air-Missile (SAM) systems."[37]

Although credit for Azerbaijan's combined arms strategy—which mirrors that of NATO doctrine—has been laid at Turkey's feet, Azerbaijan nonetheless demonstrated some inventive UAS-enabled operations to exploit gaps in Armenia's air defenses. In one such operation, Azerbaijan had converted several Soviet-era AN-2s to be remotely piloted and flew them within range of Armenia's air defense systems in order to trick Armenia into producing a radar signal that Azeri HAROPs could target. The ruse worked, and when Armenian air defense assets tracked the AN-2s the HAROP was able to target the radar signal and destroy the relevant air defense system.[38]

WHY WERE UAS GIVEN SO MUCH ATTENTION?

Perhaps more so for the Nagorno-Karabakh conflict than any war before it, the world was presented with a relatively new technology that was newly central to peer-to-peer conflict as well as extensive, if biased, documentation of its use: hours of UAS footage depicting the carnage and chaos reaped by relatively new technology. Though UAS use in a broader range of warfare—particularly of the incredibly destructive TB2—had been previously demonstrated in the recent Libyan and Syrian conflicts, the Nagorno-Karabakh conflict was arguably the first time that footage was circulated at such a large scale and proliferated worldwide by mainstream media platforms. Azerbaijan's Defense Ministry released hours of footage showing the extensive damage caused by their UAS, including the destruction of Armenian tanks, artillery, ground fortifications, and antiaircraft systems.[39] The novelty alone would have been sufficient to spark conversation in policymaking and military communities about the importance of UAS to warfighting strategy and the footage acted as an accelerant to this process. As a result, many analysts, pundits, and experts debated if the example of Azerbaijan's success suggested a major shift in the way states fought wars. Some experts questioned whether the proliferation of armed UAS would result in the obsolescence of the tank. According to analysis from *Atlantisch Perspectief*, "the perceived ease with which Armenian tanks were destroyed by drones prompted some observers to claim the end of the era of the tank and make other sweeping assertions on the future of warfare."[40]

The operational calculus for circulating the devasting footage was twofold for the Azeri and Turkish side of the conflict. First, Azerbaijan sought to bolster domestic support for the war. According to reporting by the *New Yorker*, Azerbaijan's president Ilham Aliyev "used the TB2 to target vehicles and troops, then displayed footage of the strikes on digital billboards in the capital city of Baku."[41] Second, Azerbaijan conducted a media campaign to suppress the morale of Armenia's combatants that continued throughout the conflict, including several compilations of UAS strikes against not only Armenian assets but specifically targeting Armenian troops. The message being communicated to Armenia's troops from Baku was clear: "You will not win this war."

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36 Joël Postma, "Drones over Nagorno-Karabakh: A Glimpse at the Future of War?," *Atlantisch Perspectief* 45, no. 2 (2021): 15–20.

37 Ibid.

38 Ibid.

39 Synovitz, "Technology, Tactics, And Turkish Advice."

40 Postma, "Drones over Nagorno-Karabakh."

41 Stephen Witt, "The Turkish Drone That Changed the Nature of Warfare," *New Yorker*, May 9, 2022, https://www.newyorker.com/magazine/2022/05/16/the-turkish-drone-that-changed-the-nature-of-warfare.

IMPLICATIONS

Azerbaijan is an example of an importer state for UAS that has relied on both traditional lead exporter Israel for unarmed UAS and loitering munitions and on new supplier Turkey for armed TB2s. The Armenia-Azerbaijan war demonstrates why a wider range of states may seek UAS and loitering munitions; furthermore, due to Azerbaijan's prominent success and information operations, it shows why future demand is likely to be strengthening. Even though the victory was made possible by widespread military investments as well as a range of Turkish support, Azerbaijan's employment of UAS and loitering munitions demonstrated that these systems could help make expensive capabilities—notably, combined armed operations and a range of air power tactics—affordable to a wider range of nations.

CHAPTER 3

Russia's Invasion of Ukraine

While Russia's February 2022 invasion of Ukraine shocked the world, it was in many ways the continuation of a series of developments that began with the Russian invasion of Crimea in 2014 (if not before) and continued with the conflict in Nagorno-Karabakh. Both Russia and Ukraine's defense industrial bases made significant strides after 2014, but neither was completely prepared for the events of 2022.

This section will examine the role of UAS in the defense industrial base of Ukraine in the years leading up to the February 2022 invasion before looking at how both sides have been able to sustain their armaments as the conflict has continued.

Defense Industrial Base Preparations

This section primarily focuses on Ukraine, because Russia did not build an advantage in numbers of UAS as it has in other domains, entering the conflict with only an estimated two to three dozen Orion UAS.[42] While Russia has range of other UAS systems, including the armed Forpost as well as both small and large unarmed UAS, the Orion systems are its premier armed UAS.[43] Other notable systems include the Orlan-10, which was distributed to artillery units and "is employed as an EW asset to intercept and jam 3G, 4G, and Global System for Mobile Communications (GSM) cellular communications, as well as to broadcast text messages."[44] Russia primarily relies on domestic manufacturing for its weapon systems. Its international acquisitions have been squeezed: most of its UAS imports previously came from Israel, a country which has committed to upholding international sanctions on Russia.[45] Russia has also imported UAS from Iran, with Tehran claiming that the transfer was limited to a small number of systems before the war started but Washington and Kyiv providing intelligence of more recent and large scale transfers.[46] A 2021 Conflict

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[42] Dan Sabbagh, "'War-Enabling, Not War-Winning': How Are Drones Affecting the Ukraine War?" *The Guardian*, May 15, 2022, https://www.theguardian.com/world/2022/may/15/war-enabling-not-war-winning-how-are-drones-affecting-the-ukraine-war.
[43] John Chipman, *The Military Balance 2022* (London, UK: The International Institute for Strategic Studies, 2022), 195, 201.
[44] Sunil JB Babu and Huw Williams, "Ukraine Conflict: Ukraine's Electronic Warfare Systems in Focus," *Janes*, March 4, 2022, https://www.janes.com/defence-news/news-detail/ukraine-conflict-ukraines-electronic-warfare-systems-in-focus; Samuel Cranny-Evans, "Russia Integrates Orlan-10 into 2S5 Formations for Increased Lethality," *Janes*, March 23, 2020, https://www.janes.com/defence-news/news-detail/russia-integrates-orlan-10-into-2s5-formations-for-increased-lethality.
[45] Lahav Harkov, "Blinken: We Appreciate Israel's Sanctions, Bennett Mediation with Russia," *Jerusalem Post*, March 27, 2022, https://www.jpost.com/israel-news/article-702433.
[46] Ellen Nakashima and Joby Warrick, "Iran Sends First Shipment of Drones to Russia for Use in Ukraine," *Washington Post*, August 30, 2022, https://www.washingtonpost.com/national-security/2022/08/29/iran-drones-russia-ukraine-war/; Reuters, "Iran Says It Supplied Drones to Russia before Ukraine War Began," *The Guardian*, November 5, 2022, https://www.theguardian.com/world/2022/nov/05/iran-says-it-supplied-drones-to-russia-before-ukraine-war-began; Joby Warrick,

Armament Research analysis of Russian UAS systems downed in Ukraine *before* the war found that many were obtained from Western companies or relied on Western parts.[47] Many if not all of these parts and systems were barred from export to Russia even before the latest round of sanctions, though some transfers occurred before more stringent controls were in place.[48] This, combined with resupply problems faced by both states, contributed to a situation where Russia not only lost capabilities at a faster-than-expected rate but had difficulty replacing them as they were lost.

UAS IN THE UKRAINIAN DEFENSE INDUSTRIAL BASE

Ukraine focused on developing its domestic industrial base after Russia's 2014 invasion of Crimea—and nonetheless faced challenges. When the 2014 conflict started, Ukraine found itself without "a single modern UAS."[49] Estimates place its February 2022 inventory at between 1,000-6,000 UAS, with the higher figure including more commercial systems.[50] While some of these systems are imports, Ukraine accomplished this in part by significantly building out its industrial base for UAS manufacturing.[51] This disproportionate focus on UAS manufacture in Ukraine has been attributed to it playing to Ukraine's "key strengths like computer programming and engineering, which do not require heavy industrial equipment, and because of low startup costs."[52] This has led to a number of UAS manufacturing plants springing up across Ukraine—including, in October 2021, the announcement of a plant outside Kyiv to build TB2s.[53] February 2022 saw the announcement of a coproduction agreement between Ukraine and Turkey; May 2022 saw the introduction of the T253, which some have reported as a Ukrainian-produced TB2 variant and which others have suggested indicates Ukraine received a shipment of at least an additional dozen TB2s from Turkey.[54]

Table 3 – Example Ukrainian UAS Manufacturers

Vendor	Role
Chuguev Aviation Repair Plant	Drone Production

Souad Mekhennet, and Ellen Nakashima, "Iran Will Help Russia Build Drones for Ukraine War, Western Officials Say," *Washington Post*, November 23, 2022, https://www.washingtonpost.com/national-security/2022/11/19/russia-iran-drones-secret-deal/.

[47]Conflict Armament Research, *Weapons of the War in Ukraine: A Three-Year Investigation of Weapons Supplies into Donetsk and Luhansk* (London, UK: Conflict Armament Research, November 2021), https://www.conflictarm.com/reports/weapons-of-the-war-in-ukraine/.

[48] Ibid.; James Byrne et al., *Silicon Lifeline: Western Electronics at the Heart of Russia's War Machine* (London, UK: RUSI, August 8, 2022), https://rusi.org/explore-our-research/publications/special-resources/silicon-lifeline-western-electronics-heart-russias-war-machine.

[49] John Wendle, "The Fighting Drones of Ukraine," *Smithsonian Magazine*, February 2018, https://www.smithsonianmag.com/air-space-magazine/ukraines-drones-180967708/.

[50] Wendle, "The Fighting Drones of Ukraine"; Stephen Shankland, "Ukraine Is Fighting Russia with Drones and Rewriting the Rules of War," *CNET*, April 19, 2022, https://www.cnet.com/news/ukraine-is-fighting-russia-with-drones-and-rewriting-the-rules-of-war/; Matt Burgess, "Small Drones Are Giving Ukraine an Unprecedented Edge," *Wired*, June 5, 2022, https://www.wired.co.uk/article/drones-russia-ukraine-war.

[51] Wendle, "The Fighting Drones of Ukraine."

[52] Ibid.

[53] Witt, "The Turkish Drone That Changed the Nature of Warfare."

[54] Burak Ege Bekdil, "Turkey and Ukraine to Coproduce TB2 Drones," *Defense News*, February 4, 2022, https://www.defensenews.com/global/europe/2022/02/04/turkey-and-ukraine-to-coproduce-tb2-drones/; Sabbagh, "'War-Enabling, Not War-Winning'"; David Hambling, "New Turkish Bayraktar Drones Still Seem to Be Reaching Ukraine," *Forbes*, May 10, 2022, https://www.forbes.com/sites/davidhambling/2022/05/10/new-turkish-bayraktar-drones-still-seem-to-be-reaching-ukraine/.

Matrix UAV	Drone Design and Production
UA Dynamics	Drone Design and Production
Ukrspecsystems	Drone Design and Production
Aerorozvidka NGO	Drone Design and Production
JSC Meridian n. S.P.Korolyov	Drone Production
Igor Sikorsky Kyiv Polytechnic Institute	Drone Design
Athlon Avia	Drone Design and Production
DeViRo	Drone Design and Production
Dronarnia	Drone Design and Production

Source: Manufacturer websites; secondary sources; and CSIS analysis.[55]

Table 3 above shows Ukrainian UAS manufacturers identified in a review of the literature.[56] Most of these companies list Kyiv as their corporate headquarters, though production is located in Kharkiv, Dnipro on the west bank of the Dnipro river, and Zaporozhye on the east bank. Russia's 2014 invasion already threatened Ukraine's traditional industrial heartland in the Donbas basin.[57] While Ukraine's UAS manufacturing capacity largely grew up after 2014,

[55] "Chuguyevskiy Aviation Repair Factory," accessed January 4, 2023, https://charz.com.ua/en/; John Wendle, "The Fighting Drones of Ukraine," *Smithsonian Magazine*, February 2018, https ://www.smithsonianmag.com/air-space-magazine/ukraines-drones-180967708; "UA Dynamics," accessed June 1, 2022, https://uadynamics.com/; "UKRSPECSYSTEMS," accessed January 4, 2023, https://ukrspecsystems.com/; "Aerorozvidka NGO [Aerial Reconnaissance]," Aerorozvidka, accessed January 4, 2023, https://aerorozvidka.xyz; "Home | Athlon Avia – Unmanned Solutions," April 23, 2020, https://athlonavia.com/en/home; "HOME," ВАТ "Меридіан" ім. С.П. Корольова, accessed January 4, 2023, https://merydian.kiev.ua/en; "Unmanned Vehicles Are Created in KPI | Igor Sikorsky Kyiv Polytechnic Institute," accessed January 4, 2023, https://kpi.ua/en/spectator; "Home | Athlon Avia – Unmanned Solutions," April 23, 2020, https://athlonavia.com/en/home; "Main | DeViRo," accessed January 4, 2023, https://deviro.ua/; "Дронарня | Dronarnia," accessed January 4, 2023, https://dronarnia.com.ua; Viktoria Kolomietz and Andrey Zinchenko, "The Effectiveness of the Use Unmanned Aerial Vehicles in the Process of Performing Aviation Work in Ukraine and the Factors of their Formation," Unpublished Work, May 22, 2022, https ://easychair.org/publications/preprint/wD28; Jon Guttman, "Punisher: Ukraine's Stealthy, Home-Built Drone," HistoryNet, June 27, 2022, https://www.historynet.com/ukraine-punisher-drone/.

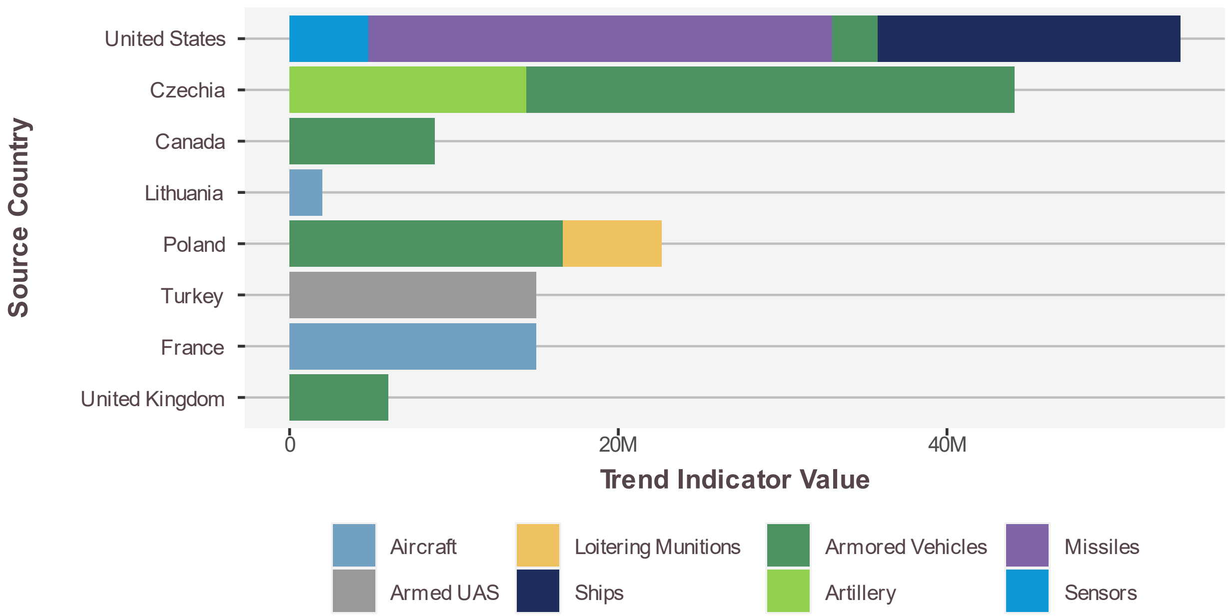
[56] The cited sources also identified additional companies, but the table only includes those that could be confirmed via multiple published documents or manufacturer websites.

[57] Lubomyr A. Hajda et al., "Ukraine," Britannica, updated September 15, 2022, https://www.britannica.com/place/Ukraine.

Russia's invasion nonetheless besieged some of these locations, especially Kharkiv and the east bank of the Dnipro. As these areas have come under attack, this has compounded some of the resupply issues discussed later in this section.

Besides its domestic manufacturing base, Ukraine has also augmented its UAS supply through imports. While much has been said of UAS deliveries to Ukraine during the conflict, Ukraine's prewar foreign arms deliveries were largely focused on other arms transfer sectors:

Figure 2 – Foreign Arms Deliveries to Ukraine, Trend Indicator Values by Platform Type, 2014–2021



Source: "SIPRI Arms Transfers Database ," SIPRI, June 12, 2022, https://www.sipri.org/databases/armstransfers; CSIS analysis.

As shown in Figure 2, UAS were an import priority, but a relatively late one; most came in the form of TB2s purchased from Turkey in 2019 and 2021 and Warmate loitering munitions purchased from Poland in 2018. As measured in estimated production cost, Ukraine was notably more focused on UAS than was Azerbaijan. Exports to Ukraine from the United States in the lead-up to the war were not UAS-focused and included HMMWV Up-Armored Humvees, Javelins, Firefinder weapons-locating systems, and Island patrol craft.

Even before the TB2s were arriving, Ukraine relied on UAS domestic production after the invasion of Crimea in part because the United States and other countries were reluctant to sell Ukraine high-quality motors and other components—leading the country to rely on China for parts and to assemble many UAS in-country at the facilities discussed above.[58]

[58] Wendle, "The Fighting Drones of Ukraine."

UAS in Russia's Push to Kyiv

Like the 44-day war in Nagorno-Karabakh, the early days of the conflict in Ukraine saw heavy use of UAS, especially TB2s.[59] Skeptics had doubted that UAS would prove as useful against more robust Russian defenses. However, perhaps due to poor Russian preparations, Ukraine was able to release video of specific examples of TB2s successfully attacking armored fighting vehicles, and they proved notably effective against surface-to-air missiles.[60] Table 4 shows some of the primary systems in use by Ukrainian forces.

Table 4 – Examples of UAS and Loitering Munitions Used by Ukraine

UAS	Altitude (m)	Range (km)	Payload	Source
Unarmed UAS				
PD-1	~3,000 MSL	95	USG-212 EO/IR gimbal or USG-211 EO gimbal (standard)	Domestic
PD-2	5,000 MSL	1,000	USG-212 EO/IR gimbal or USG-211 EO gimbal (standard); LiDAR optional	Domestic
Mavic 3	6,000 MSL	30	Omnidirectional binocular vision system, infrared sensor	Commercial
RQ-20 Puma	500 AGL	20	Gimbaled payload, IR camera / illuminator	Delivery (U.S.)
Armed UAS				
TB2	<5,500 MSL	<300	4 Laser Guided Smart Ammunition	Delivery (Turkey)
Punisher (relies on Spectre for targeting)	?	<50	UB-75HE – Unguided bomb High-explosive Caliber 75 MM	Domestic
Spectre (relies on Punisher for munition)	?	50	HD (720p), 2.0 Megapixel Camera	Commercial
Loitering Munitons				
Switchblade 300	<152 AGL >4,572 MSL	10	Northrop Grumman advanced munition	Delivery (U.S.)

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[59] Lauren Kahn, "How Ukraine Is Using Drones Against Russia," Council on Foreign Relations, March 2, 2022, https://www.cfr.org/in-brief/how-ukraine-using-drones-against-russia.

[60] Kahn, "How Ukraine Is Using Drones Against Russia"; Sebastien Roblin, "Russia's War in Ukraine," *Inside Unmanned Systems*, June 30, 2022, https://insideunmannedsystems.com/russias-war-in-ukraine/; Zachary Kallenborn, "Seven (Initial) Drone Warfare Lessons from Ukraine," Modern War Institute at West Point, May 12, 2022, https://mwi.usma.edu/seven-initial-drone-warfare-lessons-from-ukraine/.

Switchblade 600	<183 AGL >4,572 MSL	>40	Anti-armor warhead	Delivery (U.S.)

Note: Range refers to data link range, which is often closer than maximum theoretical range.
MSL refers to mean surface level, or the service ceiling altitude. AGL refers to above ground level, or how far above the launch point the system can operate.
Source: Self-reporting by manufacturer websites.[61]

The Russian invasion of Ukraine saw both parties using some of the same systems: both Russia and Ukraine used China's DJI Mavic system, for example. Ukraine's performance reflects that it is not just technology development but technology deployment that matters in a conflict. While Russia had experience using UAS in combat from the war in Syria, Ukraine ultimately proved to make more effective use of UAS in the early months—perhaps in part by better incorporating UAS-specific tactics, rather than treating the systems as inhabited system equivalents.[62] In fact, a group of just 30 Ukrainian UAS operators was able to destroy multiple armored vehicles and a supply depot, ultimately leaving "the first echelon of the Russian force . . . without heat, without oil, without bombs and without gas."[63] This particular group was from the volunteer special operations forces-like unit Aerorozvidka.[64] This demonstrates that while there was definitely excitement over the use of UAS in the early stages of the conflict—from uploaded strike videos to think tank analyses to stuffed toy versions of systems produced by Ukraine and songs dedicated to the Bayraktar TB2—UAS also served a deeply practical purpose.[65]

Resupply: Challenges and U.S. Military Aid

Ukraine was hit hard in the early days of the conflict: the Foreign Policy Research Institute put estimated Ukrainian losses in the first two months of the war at a minimum of "94 tanks and 171 armored/infantry fighting vehicles and

[61] "PD1UAS.Com | PD-1 VTOL Fixed-Wing UAV," accessed December 30, 2022, https://pd1uas.com/; "UKRSPECSYSTEMS - PD-2 UAS with 200+ Km Effective Range," accessed June 23, 2022, https://ukrspecsystems.com/pd-2-uas; "Mavic 3 - Specs - DJI," DJI Official, accessed December 29, 2022, https://www.dji.com/mavic-3/specs; "Puma™ LE UAS (UAV) - Group 2 UAS Capabilities in a Group 1 Footprint | Military Battlefield Drone," AeroVironment, Inc., accessed December 30, 2022, https://www.avinc.com/uas/puma-le; "Bayraktar TB2," Baykar, accessed August 8, 2022, http://www.baykartech.com/en/uav/bayraktar-tb2/; "UA Dynamics," accessed June 1, 2022, https://uadynamics.com/; "SPECTRE," TRNDlabs, accessed December 30, 2022, https://trndlabs.com/products/spectre; "Switchblade® 300 - Suicide Drone | Kamikaze Drone," AeroVironment, Inc., accessed December 30, 2022, https://www.avinc.com/tms/switchblade; "Switchblade® 600 Kamikaze Drones | Suicide Drone," AeroVironment, Inc., accessed June 23, 2022, https://www.avinc.com/tms/switchblade-600.
[62] Bryan Clark and Dan Patt, "Ukraine Embraces the 'Messy Middle' to Win the Drone War," Hudson Institute, May 13, 2022, https://www.hudson.org/research/17826-ukraine-embraces-the-messy-middle-to-win-the-drone-war.
[63] Julian Borger, "The Drone Operators Who Halted Russian Convoy Headed for Kyiv," *The Guardian*, March 28, 2022, https://www.theguardian.com/world/2022/mar/28/the-drone-operators-who-halted-the-russian-armoured-vehicles-heading-for-kyiv.
[64] Alia Shoaib, "Inside the Elite Ukrainian Drone Unit Founded by Volunteer IT Experts: 'We Are All Soldiers Now.,'" *Business Insider*, April 9, 2022, September 20, 2022, https://www.businessinsider.com/inside-the-elite-ukrainian-drone-unit-volunteer-it-experts-2022-4.
[65] "Байрактар" [Bayraktar], *іграшок "Копиця"* [*Toys Kopitsa]*, https://toys-kopitsa.com.ua/uk/vse-bude-ukrayina/bajraktar; "Turkish Drone Is so Effective, Ukrainian Troops Are Singing about It," CNN, April 7, 2022, YouTube video, 4:35, https://www.youtube.com/watch?v=S4qUsPCFV28.

personnel carriers," without specifying UAS.[66] In the early weeks of the war, Russian state media alleged that "Russian forces have destroyed . . . four TB2s."[67] In April 2022, *Foreign Policy*'s Jack Detch reported that "Russia claim[ed] to have shot down 583 Ukrainian drones during the two-month war but has not provided any independent verification for this claim."[68] The open-source intelligence group Oryx documented that Ukraine lost 30 UAS in the first four months of the war, although this is likely an undercount according to the Foreign Policy Research Institute.[69] This put both countries in a position where they needed to resupply.

U.S. military aid packages began reaching Ukraine seven days into the war—five days after the first package was authorized on February 26.[70] As covered in Table 5, military equipment aid during the war came primarily in the form of drawdowns, in which the United States sent preexisting stock. This expedited the delivery, as such systems can take months or years to acquire. Initial aid delivery may have been especially rapid because the first drawdowns came from stockpiles pre-positioned in Europe.[71] Later military aid, like the June 15 package, was predicted to take weeks to arrive—and while these packages have encountered delays, this is still a rapid transfer compared to the typically multiyear Foreign Military Sales (FMS) process.[72]

Table 5 – U.S. Drawdown and Acquisition Transfers to Ukraine

Drawdown	Date	Total Value	UAS and Loitering Munitions
17	**Aug 8, 2022**	$1B	
16	**Jul 22, 2022**	$270M	Phoenix Ghost (<580)
15	**Jul 8, 2022**	$400M	
14	**Jul 1, 2022**	$820M	
13	**Jun 23, 2022**	$450M	
12	**Jun 15, 2022**	$350M	
11	**Jun 1, 2022**	$700M	
10	**May 19, 2022**	$100M	
9	**May 6, 2022**	$150M	
8	**Apr 21, 2022**	$800M	Phoenix Ghost (121+)
7	**Apr 13, 2022**	$800M	Switchblade (?)

[66] Philip Wasielewski, "Appraising the War in Ukraine and Likely Outcomes," Foreign Policy Research Institute, April 8, 2022, 3, https://www.fpri.org/article/2022/04/appraising-the-war-in-ukraine-and-likely-outcomes/.
[67] Kahn, "How Ukraine Is Using Drones Against Russia."
[68] Jack Detsch, "Drones Have Come of Age in Russia-Ukraine War," *Foreign Policy*, April 27, 2022, https://foreignpolicy.com/2022/04/27/drones-russia-ukraine-war-donbas/.
[69] Stijn Mitzer and Jakub Janovsky, "Attack On Europe: Documenting Russian Equipment Losses During The 2022 Russian Invasion Of Ukraine," Oryx, accessed August 11, 2022, https://www.oryxspioenkop.com/2022/02/attack-on-europe-documenting-equipment.html; Philip Wasielewski, "Appraising the War in Ukraine and Likely Outcomes," Foreign Policy Research Institute, April 8, 2022, https://www.fpri.org/article/2022/04/appraising-the-war-in-ukraine-and-likely-outcomes/.
[70] David Sanger et al., "Arming Ukraine: 17,000 Anti-Tank Weapons in 6 Days and a Clandestine Cybercorps," *New York Times*, March 7, 2022, https://www.nytimes.com/2022/03/06/us/politics/us-ukraine-weapons.html.
[71] Ibid.
[72] W.J. Hennigan, W. J, "Ukraine Won't Get Key Weapons From $1 Billion Aid For Months," *Time*, June 15, 2022 accessed June 24, 2022, https://time.com/6188028/biden-ukraine-weapons-aid/.

6	**Apr 5, 2022**	$100M	
DOD procurement	**Apr 1, 2022**	$300M	Switchblade (?), Puma (121)
5	**Mar 16, 2022**	$800M	Tactical UAS (100)
4	**Mar 12, 2022**	$200M	
3	**Feb 25, 2022**	$350M	
2	**Dec 28, 2021**	$200M	
1	**Aug 27, 2021**	$60M	
		$7.85B	

Source: DOD press releases through August 8, 2022, available at https://www.defense.gov/News/Releases/.

The United States sent 15 military aid packages between August 2021 and July 15, 2022, moving to the announcement of additional military aid approximately every two weeks over spring and summer 2022. Only the DOD procurement actions—notably the April 1, 2022, package, which included Switchblade and Puma UAS—directly engage the industrial base. As of July 7, 2022, the Department of Defense acquisition actions totaled $42 million, an amount dwarfed by value of defense drawdowns.[73]

This ameliorated some of the resupply issues faced by Ukraine. As mentioned in the discussion above, much of Ukraine's domestic manufacturing capacity was located in areas hard-hit by the conflict, interrupting production—although Ukraine has repelled assaults on both Kyiv and Kharkiv.[74] Domestic support for the war—and perhaps UAS in particular—has also played an interesting role in Ukraine's defense industrial base, including direct donations of UAS systems, crowdfunding, and even a charity auction to support the purchase of PD-2s.[75]

Russia has not faced direct Ukrainian strikes on the areas housing its production facilities in the same way, but the "homespun" nature of some captured systems suggests that it is also facing resupply issues.[76] For Russia, this is due in part to sanctions by many of its usual trading partners for weapons components, which limit its ability to repair or manufacture tanks, among other heavy weapons systems.[77] Many Russian UAS systems are laden with components

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[73] CSIS analysis of FPDS data reported at "Data Bank: Ukraine Mission Support Report," SAM.gov, https://sam.gov/reports/awards/static.

[74] Emma Graham-Harrison, and Kateryna Semchuk, "Trial by Fire: Ukraine War Becomes Gruelling Artillery Duel," *The Guardian*, May 13, 2022, https://www.theguardian.com/world/2022/may/13/gas-masks-medics-ukraine-choking-troops-sloviansk.

[75] Chris Vallance, "Ukraine Sent Dozens of 'Dronations' to Build Army of Drones," BBC News, July 8, 2022, https://www.bbc.com/news/technology-62048403; "Ukraine Conflict: How Are Drones Being Used?" BBC News, August 22, 2022, https://www.bbc.com/news/world-62225830; Patrick Jackson, "Ukraine War: Eurovision Trophy Sold to Buy Drones For Ukraine," BBC News, May 30, 2022, https://www.bbc.com/news/world-europe-61628590.

[76] Sabbagh, "'War-Enabling, Not War-Winning.'"

[77] Mia Jankowicz, "Ukraine Claims That Russia Can't Build or Repair Tanks Any More Because Western Sanctions Deprived It of Components," *Business Insider*, accessed July 18, 2022, https://www.businessinsider.com/russia-unable-make-new-tanks-sanctions-ukraine-claim-2022-3; Doug Palmer, "Tech Sanctions Have Hit Russia Harder than Expected, Biden Official Says," *POLITICO*, March 30, 2022, https://www.politico.com/news/2022/03/30/u-s-boasts-99-percent-drop-in-controlled-technology-exports-to-russia-00021785.

from countries now sanctioning the state.[78] Based on Cold War and prewar behavior, Russia may be able to continue to acquire some parts in violation of sanctions, at much greater cost and inconvenience. The small quantities needed for UAS production make it more likely that Russia would be able to mitigate the impact of sanctions if they prioritized limited contraband for these systems, but wider effects are being seen as the lack of Western parts was noted to be slowing domestic manufacturing in Russia three months into the war.[79] Six months into the war, Ukrainian officials described Russian use of UAS systems bought from Iran.[80] Both countries used the commercial DJI Mavic system, but the company has now refused to sell to both.[81]

IMPLICATIONS

UAS have been a prominent part of this conflict but only Ukraine prioritized them going into the war. After the 2014 annexation of Crimea, Ukraine built up a fleet of UAS that relied on both domestic industry investments and international imports—for the deliveries themselves as well as to reinforce their attempts to build their industry. While Russia, which has a larger defense industrial base and greater annual spending, does have its own UAS fleets, sanctions on Russia made the development of UAS more difficult for them. Ukraine, by comparison, benefits from access to parts in addition to direct transfers of UAS loitering munitions from the United States. Given the public attention devoted to UAS in both the Ukraine and the Nagorno-Karabakh conflicts, these experiences may lead to increased demand for and emphasis on UAS in other nations. Industrialized nations may make investments to produce their own systems; but whether to gain access to more advanced systems, to jumpstart domestic production, or for reasons of cost, many countries will turn to arms import. That said, the experience of frontline states, whose foes will have robust counter-UAS capabilities, is still developing and are more nuanced and symmetrical than the advantages achieved by Azerbaijan. These differences can help explain why frontline states have not been central to the rising demand seen in the subsequent discussion of the arms trade.

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[78] Jeanne Whalen, "Russian Drones Shot Down Over Ukraine Were Full of Western Parts. Can the U.S. Cut Them Off?," *Washington Post*, February 11, 2022, https://www.washingtonpost.com/technology/2022/02/11/russian-military-drones-ukraine/.

[79] Whalen, "Russian Drones Shot Down Over Ukraine"; Paul Hannon, "Russia's Factories See Another Decline in Output, but Pace Slows," *Wall Street Journal*, May 4, 2022, https://www.wsj.com/livecoverage/russia-ukraine-latest-news-2022-05-04/card/russia-s-factories-see-another-decline-in-output-but-pace-slows-hDqPNVR6wYkEJsp1EJTY.

[80] Kateryna Stepanenko et al., "Russian Offensive Campaign Assessment, August 5," Institute for the Study of War, August 5, 2022, https://www.understandingwar.org/backgrounder/russian-offensive-campaign-assessment-august-5.

[81] Detsch, "Drones Have Come of Age in Russia-Ukraine War"; Sean Hollister, "DJI Drones, Ukraine, and Russia — What We Know about AeroScope," *The Verge*, March 23, 2022, https://www.theverge.com/22985101/dji-aeroscope-ukraine-russia-drone-tracking.

CHAPTER 4

U.S. Defense Industrial Base Trends

UAS have seen production and use by a growing number of companies, but the United States has a long-established domestic industry, which predated the wars in Iraq and Afghanistan and the counterterrorism and counterinsurgency operations that saw their widespread use. The rapid pace of commercial advances combined with growing use in recent conflicts and the potential for new technologies—from stealthier systems to highly attritable swarms—suggest the potential for continued transformation of the UAS industrial milieu.

This section explores the role of the United States as a supplier along with the industrial base it relies on. To understand the UAS defense industrial base, this report asks four questions: (1) Who in the DOD is spending on UAS? (2) To what extent is the DOD drawing on the commercial market? (3) What is the structure and distribution of the prime contractors providing UAS to the DOD? What is the role of FMS for the U.S. industrial base?

U.S. Contracting for UAS

The primary source for this information is the Federal Procurement Data System (FPDS), which includes all civil and defense government contract transactions, with a few notable carveouts mentioned below where relevant.[82] The FPDS tracks UAS spending with a code for "complete unmanned aircraft systems and subordinate air vehicles."[83] That tracking was expanded by the efforts of the study team as described below, and the analysis here is limited to UAS. Further, the FPDS only includes prime contractors (and classified contracts are not required to be reported), so next-generation systems such as the recently revealed Phoenix Ghost and speculated stealthy RQ-180 would not be included in the data. The Teal Group notes "the big issue for the US drone sector is the extent of secret 'black' drone programs."[84] They estimate the U.S. military UAS budget will be $10.6 billion in FY 2023 but only $5.4 billion, just 51 percent of that funding, will be unclassified. [85] While civilian agency data is included in this analysis, intelligence agencies do not report into the FPDS, although they have played a notable role in the development and use of UAS.[86]

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[82] This paper applies OMB federal outlay deflators to adjust for inflation.

[83] The product or service code is 1550 "Unmanned Aircraft," which includes "only complete unmanned aircraft systems and subordinate air vehicles." The entry notes that "converted or modified guided missiles" are excluded, but the codebook makes no mention of loitering munitions in this or other categories.

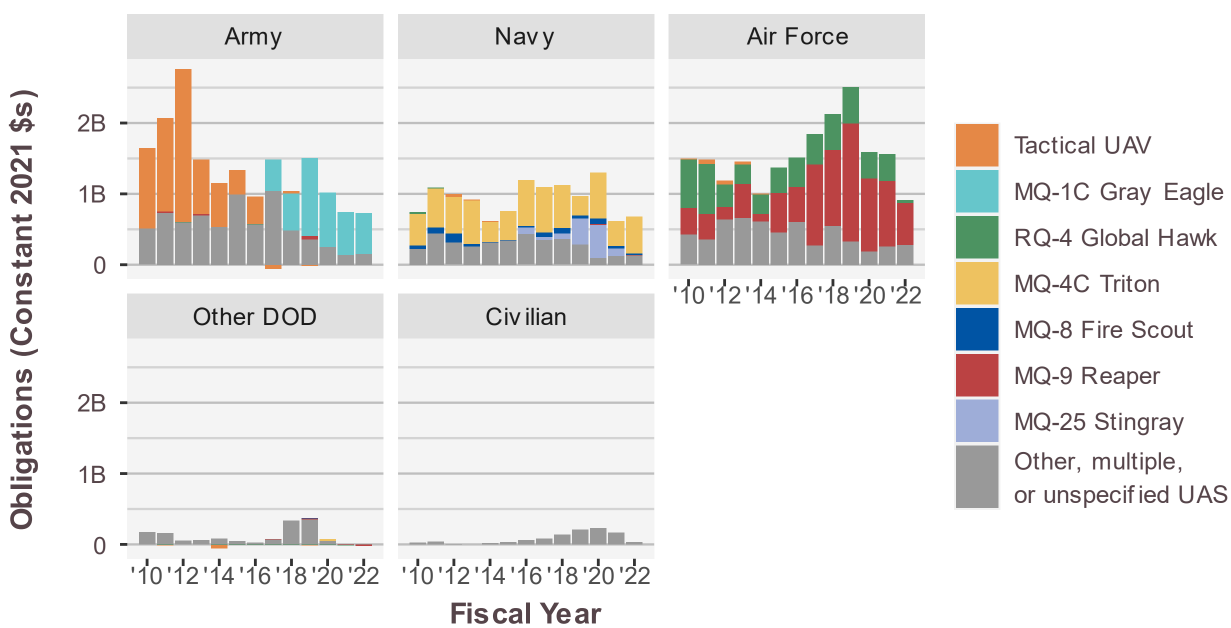
[84] Steven J. Zaloga, David Rockwell, and Tom Zoretich, *World Military Unmanned Aerial Systems: 2022/2023 Market Profile & Forecast*, 1.

[85] Zaloga, Rockwell, and Zoretich, *World Military Unmanned Aerial Systems*, 3.

[86] Strickland, "The Early Evolution of the Predator Drone."

To better capture the sector, CSIS has also searched through the major defense acquisition programs labeled within the FPDS to determine which of them qualify as UAS.[87] The study team further expanded the data set by searching through transaction descriptions from FY 2010 through FY 2021 associated with $10 million or more in then-year obligations to find which included UAS. This effort takes on a key challenge of analyzing UAS within the FPDS, which is that there is only the single aforementioned product or service code that covers uninhabited vehicles. The FPDS only tracks UAS as products and does not cover R&D—which is often grouped with aircraft research—or maintenance and repair and other services. Because loitering munitions are not explicitly covered as a product category and their programs are not large enough to be captured as a major defense acquisition program, they are only incidentally included in this data. Contracts that meet any of the three criteria of (1) using the product code for UAS, (2) being tied to a UAS major defense acquisition program, or (3) mentioning being for a UAS project in the description are all included in the data set, summarized in Figure 3.

Figure 3 – Federal Prime Contracts for UAS, FY 2010–FY 2021



Source: FPDS; CSIS analysis.

Totaling across all five DOD and civilian customers shown in Figure 3, unclassified spending on UAS had peaked at $5.3 billion in FY 2019 before falling to $4.1 billion in FY 2020 and then $3.0 billion in FY 2021. This total contract spending is in line with the Teal Group estimate that the unclassified budget for military UAS research, development,

[87] The DOD acquisition code field in FPDS is used to make these identifications. These codes capture the R&D through production of these systems as well as major upgrades. However, they are not designed to capture sustainment activity and so will miss out on operation and maintenance contracts. The projects included are as follows: QH-50, MQM-40/42 REDHEAD/ROADRUNNER, QM-107 GD MSL TGT SYS, UAV HUNTER (SHORT RANGE UAV), RPV (AQUILA), GLOBAL HAWK, MQ-8 Fire Scout, TACTICAL UAV, HAEUAV, QH-50 DASH, BQM-34 FIREBEE, BQM-74, BQM-74E SSAT, PREDATOR UAV, PIONEER UNMANNED AERIAL VEH, BAMS , MQ-9 Reaper, JTUAV, and MQ-1C Gray Eagle.

testing, and evaluation and procurement spending in FY 2023 is $5.4 billion.[88] Trends varied across the military departments, with the Army having the highest spending levels before the FY 2013 budget caps. Army spending has been driven by Tactical UAVs, which includes the RQ-7 Shadow and the MQ-1C Gray Eagle, a successor to MQ-1 Predator. The Air Force had seen steady increases in contract obligations since FY 2014 before leveling off at $1.5 billion a year, slightly higher than the spending level at the start of the reporting period in FY 2010. The Air Force is planning the retirement of both systems receiving the bulk of its spending, the RQ-4 Global Hawk and MQ-9 Reaper, with classification limiting public discussion and cost reporting of any follow-on plans.[89] The Navy has steadily spent on Broad Area Maritime Surveillance, which became the MQ-4C Triton, an upgraded RQ-4 Global Hawk. The dramatic drop in Navy spending, from a peak of $1.3 billion to only $0.6 billion, is driven in part by uneven annual obligations for the MQ-25 Stingray, which is still categorized as an R&D project with aerial refueling as a key mission. Meanwhile, civilian spending peaked at $222 million in FY 2020 before falling to $163 million in FY 2021, but despite that decline by more than a quarter, FY 2021 was still the third-highest year in the last decade for spending.

The majority of UAS contract obligations go to products (69 percent over the reporting period), as shown in Figure 4, and the decline in overall spending is largest in absolute terms in that category, falling by more than half from a recent peak of $3.44 billion in FY 2019 to $1.95 billion in FY 2020 and $1.55 billion in FY 2021—the latter two values each being new lows for this reporting period.

The proportion of UAS spending for R&D is remarkable. Across the reporting period, 11 percent of UAS obligations went to R&D, varying between 6 and 17 percent. For contrast, seven other defense system portfolios are included in Figure 4, which has a variable y-scale because remotely crewed systems are by far the smallest of the group.[90] While the UAS R&D rate is below that of space systems (55 percent); electronics, comms, and sensors (14 percent); and air and missile defense (25 percent), it still exceeds that of aircraft (7 percent), ships and submarines (2 percent), land vehicles (4 percent), and ordnance and missiles (4 percent).[91] UAS R&D spending did drop from $0.6 billion in FY 2020—the highest level since FY 2012—to only $0.18 billion in FY 2021, but both the high and low can be attributed to the uneven annual distribution of contracts for the MQ-25 Stingray.

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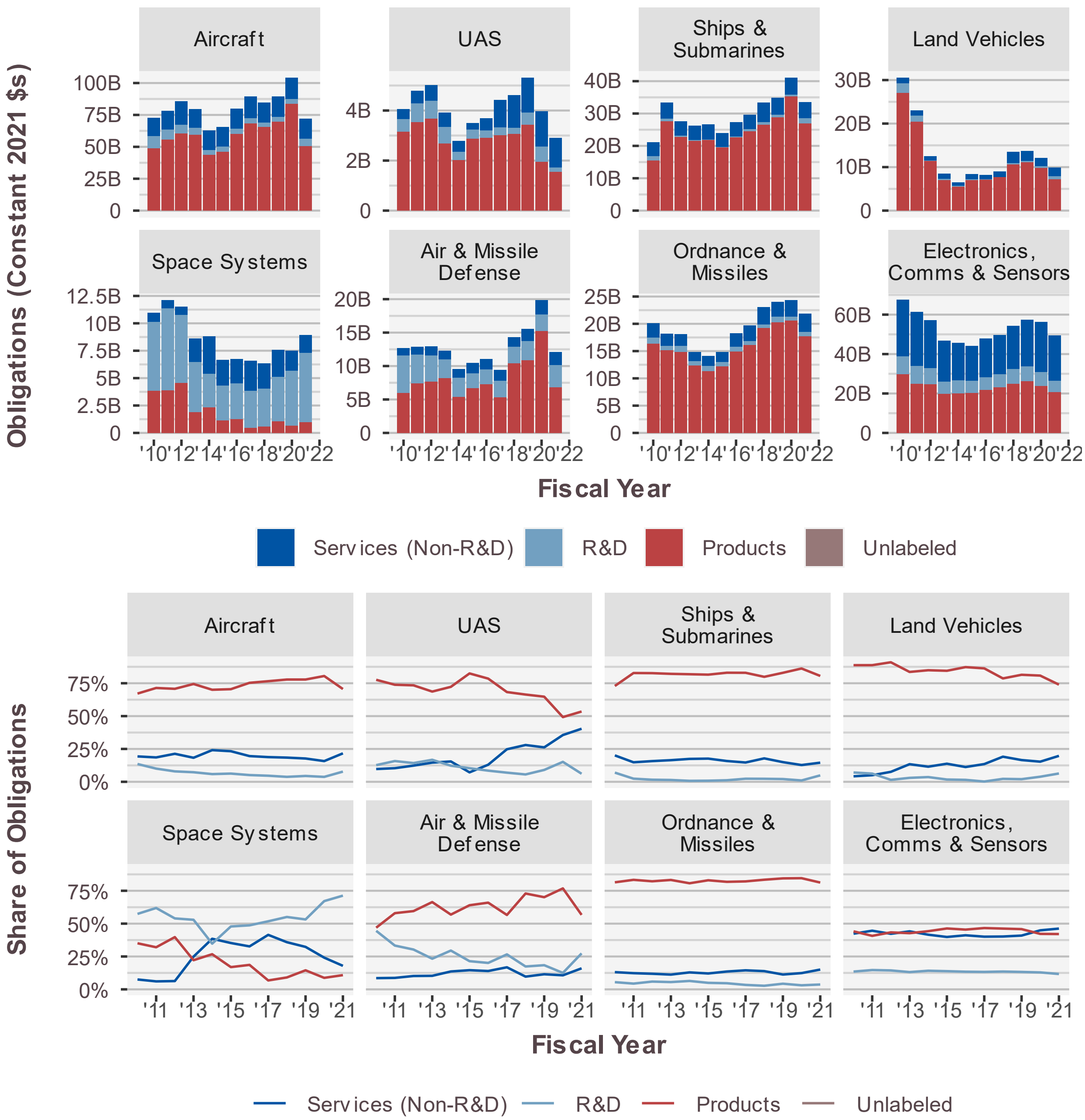
[88] Steven J. Zaloga, David Rockwell, and Tom Zoretich, *World Military Unmanned Aerial Systems: 2022/2023 Market Profile & Forecast*, 3. While this is complicated slightly by multiyear procurement, budget figures should reliably exceed contract spending. That said, the Teal Group estimate does not include operations and maintenance spending, which is an important part of contract spending.

[89] John Tirpak, "Secret Global Hawk Successor Due in 2027-2029," *Air Force Magazine*, July 22, 2021, https://www.airforcemag.com/secret-global-hawk-successor-due-in-2027-2029/.

[90] This graph does not include those platforms less tied to a particular defense system: other products, other services, other knowledge-based and R&D, and facilities and constructions.

[91] As was discussed above, there are no product or service codes dedicated to R&D for UAS. However, the comparatively high rate of R&D contract spending for this portfolio suggests that CSIS's layered labeling approach is overcoming that limitation.

Figure 4 – Defense System Platform Contract Obligations and Share of Obligations by Product, R&D, and Service, FY 2010–FY 2021



Note: Unlabeled not shown. Source: FPDS; CSIS analysis.

Turning to services, a review of some of the descriptions of major service UAS service contracts found some examples of UAS ISR as a service, but far more common is contractor logistic support that is focused on keeping these systems in an operational state. Twenty percent of UAS contracting spent on services, while likely a conservative estimate, is also greater than that of most vehicular categories—but largely comparable to that of the aircraft sector (19 percent), lagging slightly behind space systems (23 percent) and well behind electronics, comms, and sensors (42 percent). Notably, however, that last sector incorporates a range of information and communications technology services that includes business system support. While spending on UAS services declined from $1.41 billion in FY 2020 to $1.17

billion in FY 2021, that lower level of obligations was still higher than any year from FY 2010 to FY 2016, when annual spending averaged below $0.5 billion.

FEDERAL ACQUISITION, OTHER TRANSACTION AUTHORITY, AND THE COMMERCIAL UAS MARKET

The federal and defense acquisition system has a range of tools that are oriented to accessing commercial or emerging technology in addition to tools for developing technology within the traditional defense industrial base. The total value for of civil UAS is estimated by the Teal Group to be $7.2 billion in 2022, smaller than the value of military UAS but still a major source of innovation.[92] Commercial acquisition contracting authorities loosen some of the restrictions on acquisition with the intent of employing commercial market discipline and benefiting from technology investments not made for government purposes.

In commercial-adjacent sectors like the UAS industrial base, many technological advances are not government funded and are sold to a wider market. The traditional federal contracting system has tools for accessing products and services that are commercially available, which this paper refers as commercial contracting. [93] As seen in Figure 5, commercial contracting represents only a few hundred million of the billions spent on UAS each year. That amount has risen for the Army, Air Force, and civilian agencies. That said, any such use is still nascent or under-labeled, as the last four years have seen an average of 5 percent of federal contract dollars for UAS use a commercial approach, compared to higher average levels for aircraft (7 percent), space systems (9 percent), and ships and submarines (14 percent)—let alone the 26 percent of land vehicle obligations spent using commercial contracting approaches. This rate in recent years does exceed that for ordnance and missiles or air and missile defense (2.1 and 0.5 percent respectively), showing that rates do exceed that of exclusively defense-focused sectors.

Beyond contracts, multiple agencies in the federal government have been empowered to employ Other Transaction Authority (OTA) agreements for the purposes of acquiring emerging technology. This authority is limited to certain circumstances, such as the DOD's prerequisite that the provider either have significant participation from a nontraditional defense vendor or have invested their money in development via a cost-sharing arrangement. As shown in Figure 5in the blue bars, the Army has managed the majority of these OTAs for UAS, which is also true for reported OTAs overall. That said, in many cases this involves the Army managing funds from another service, and the heights of Army OTA spending for UAS occurred during the FY 2011–FY 2013 period where OTA reporting was less consistent. The only reported civilian user of OTAs is the Department of Homeland Security, but an important caveat is that centralized OTA reporting is still new and does not include the first agency to hold this authority, the National Aeronautics and Space Administration.

When looking at OTA and commercial contracting together, the Army remains the biggest spender. Army the spending over the last four years—including a peak at $143 million in FY 2019—brings spending back around peak levels in FY 2014, when the majority of funds went to Northrop Grumman with significant participation by nontraditional defense contractors. The increase for Air Force and civilian commercial contracting—to $58 million

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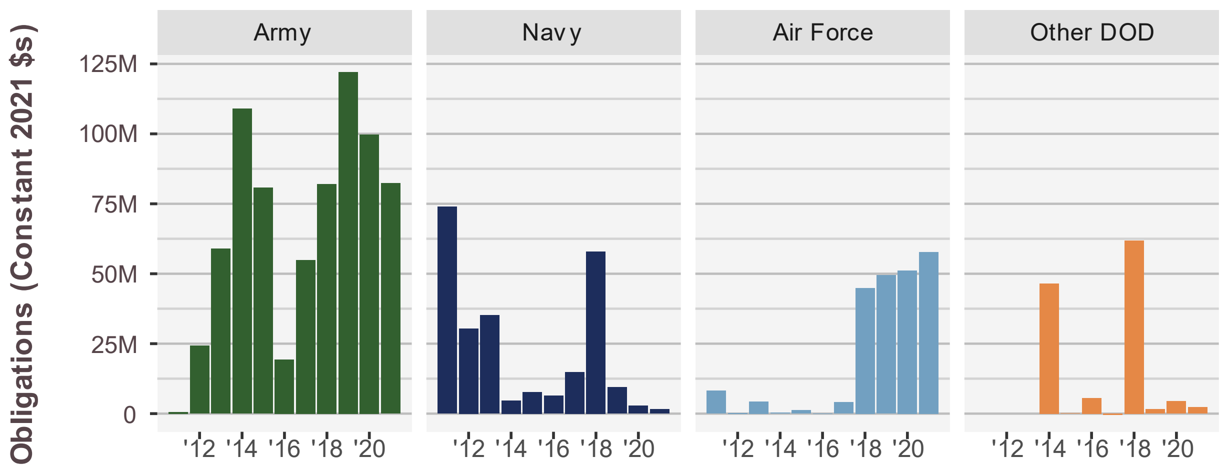
[92] Jeremiah Gertler and Tom Zoretich, *World Civil Unmanned Aerial Systems: Market Profile & Forecast 2022/2023* (Fairfax, VA: Teal Group, 2022), 1, https://shop.tealgroup.com/products/wcuav.

[93] For this paper, "commercial contracting" refers to federal contract procedures for items that are commercially available according to the definitions in the Federal Acquisition Regulations 2.101. The authorities available for commercial contracting are available in part 12 of the Federal Acquisition Regulations. In FPDS there are multiple relevant fields, and this paper treats as commercial any transactions using *Commercial Item Acquisition Procedures*; that qualify as commercial under the DOD-focused *Information Technology Commercial Item Category*; or that employ less demanding test procedures allowed by *Simplified Procedures for Certain Commercial Items.*

and $17 million respectively in FY 2021—has slowed since a huge jump in FY 2017 but does appear to be a robust and sustained engagement via commercial contracts. The Navy and the rest of the DOD have historically made more use of commercial contracting for UAS than in recent years, although with the Navy's $14 million in OTA spending in FY 2021 it slightly overtakes Army as the leading employer of OTA for UAS. Another part of this story is also a shift in attention: in recent years, uninhabited maritime systems have been a growing priority for the Navy with regard to OTA spending, and counter-UAS technology is a growing priority for the DOD writ large and for the Defense Innovation Unit (DIU) in particular.

Figure 5 – Federal Obligations for UAS Using Any Commercial Authorities or OTA, FY 2011–FY 2021



Source: FPDS; CSIS analysis.

The Defensive Innovation Unit (DIU) is worth further comment as an important user of OTAs as part of its Blue UAS program. This is part of the DIU's larger mission to bring in the best technology from parts of industry that do not customarily work with the DOD. The Blue UAS effort seeks to create an on-ramp for selling commercial UAS to the U.S. government. This process ensures that they are compliant with DOD policy, simplifying their subsequent use both by the DOD and by civilian agencies. One challenge facing the U.S. government is that while the commercial UAS market is still actively contested, the dominant consumer UAS producer, DJI Innovations, is a Chinese firm.[94] OTA transactions mentioning the DIU in their description, all managed by an Army contracting office, accounted for about $25 million of FY 2018–FY 2020 OTA spending. However, while this amount is comparatively small, DIU's work is to establish on-ramps and relationships rather than being the primary buyer. These efforts may have contributed to wider commercial utilization across the DOD and even in civilian UAS contracting.

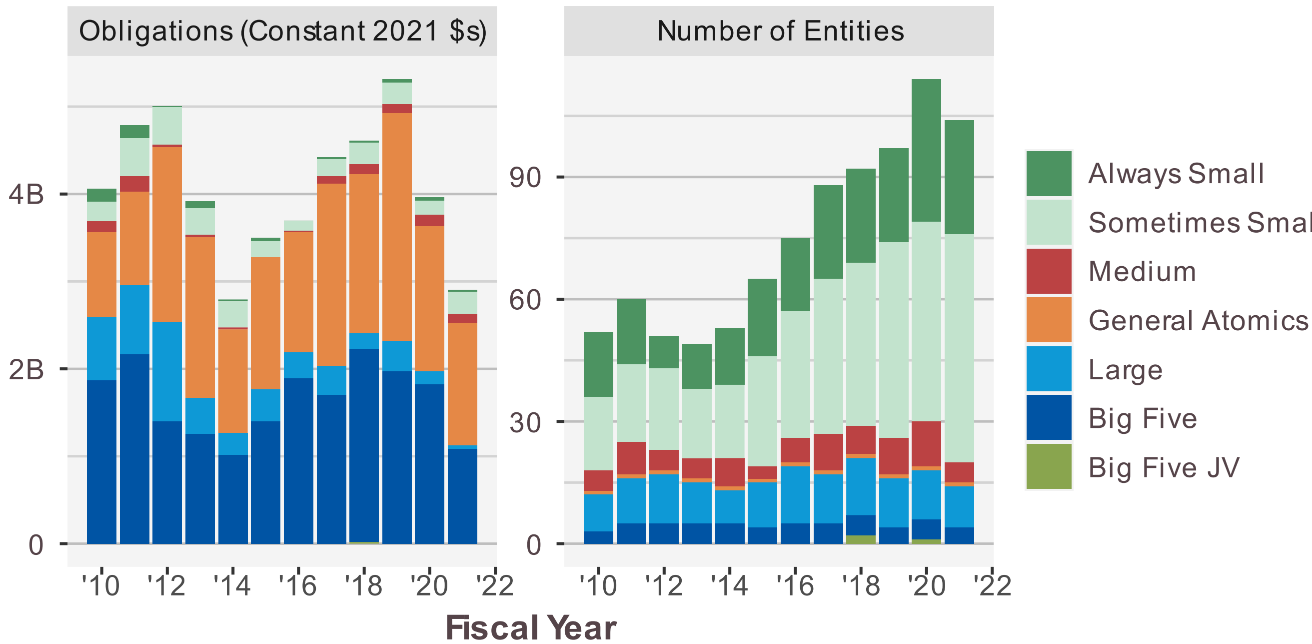
STRUCTURE OF THE U.S. UAS INDUSTRIAL BASE

The UAS industrial base is a niche within the larger U.S. defense industrial base. Across the reporting period, the inhabited aircraft sector was over 20 times its size and the ordnance and missiles sector more than five times larger. Analyzing those sectors also benefits from better labeling, which makes it more straightforward to capture if the government is directly contracting for an engine, electronic suite, or warhead to be placed on the platform. With those caveats in place, the data nonetheless reveal two central trends about the UAS industrial base, both shown in Figure 6. First, when measured by obligations as shown in the chart on the left, the sector is undergoing consolidation resulting from merger and acquisition activity as well as from some UAS programs finishing production without

[94] Jeremiah Gertler and Tom Zoretich, *World Civil Unmanned Aerial Systems: Market Profile & Forecast 2022/2023*, 2.

follow-on work for the vendor in question. Second, when looking at count, a wider range of vendors is participating even if their revenues are modest. Despite a small decline in FY 2021, the number of vendors has grown most years since FY 2014, even when the trend in the larger U.S. defense industrial base has been one of stability or decline; for example, in FY 2020 the number of defense vendors across all sectors fell by 10 percent even as the number of UAS vendors rose.[95]

Figure 6 – Count and Contract Obligations to Federal UAS Vendor by Size, FY 2010–FY 2021



Source: FPDS; CSIS analysis.

When looking at market share, the "Big Five" contractors—Lockheed Martin, Northrup Grumman, Boeing, Raytheon, and General Dynamics—collectively commanded 40.5 percent of the market during the period, with midsized specialist General Atomics receiving a slightly smaller 40.0 percent share. At the peak in FY 2019, the Big Five received $2.0 billion in obligations, and this dropped to only $1.1 billion in FY 2021 although their share of the market remained the same (37 percent). General Atomics, since FY 2012, has held a 37 to 49 percent share of the defense UAS market and went from receiving $2.7 billion in FY 2019 to only $1.4 billion in FY 2021, despite only a slight reduction in share (49 to 48 percent). That said, the Big Five defense primes do specialize in defense-unique items, including stealth technology such as that employed by the F-35 fighter and B-21 bomber. As a result, they likely play a prominent role in any expenditures for classified systems not included in this chart.

[95] Office of the Under Secretary of Defense for Acquisition and Sustainment, *State of Competition Within the Defense Industrial Base* (Washington, DC: U.S. Department of Defense, February 2022), https://media.defense.gov/2022/Feb/15/2002939087/-1/-1/1/STATE-OF-COMPETITION-WITHIN-THE-DEFENSE-INDUSTRIAL-BASE.PDF; Gregory Sanders, Won Joon Jang, and Alexander Holderness, *Defense Acquisition Trends 2021* (Washington, DC: CSIS, March 29, 2022), https://www.csis.org/analysis/defense-acquisition-trends-2021.

Large entities—defined as those vendors with $3 billion or more in revenue, including from non-federal sources, which are not among the Big Five—have steadily lost market share over the period. They received only $344 million in obligations in FY 2019, and that number reduced by an order of magnitude to $35 million in FY 2021. Instead, the growth in count has been in medium and small vendors, even though (setting aside General Atomics) their collective share of the market has not grown. The biggest jump has been for vendors that are sometimes categorized as small.[96] Across the past decade, the number of small and medium vendors went from 60 in FY 2011, to 75 in FY 2016, to 104 in FY 2021. In dollar terms, the share for these vendors has been comparatively small, dropping from a peak of $758 million in FY 2011 to only $127 million in 2016 before partially rebounding to $376 million in FY 2021.

This growth in count may be due to the success of outreach efforts like commercial contracting, the DIU Blue program, and OTA spending. OTA spending and vendors receiving only OTA funding are not included in Figure 6, but OTAs can play a role as a bridge for new vendors into the wider federal market.

Table 6 takes a closer look at the individual contractors that received the greatest share of defense obligations. The two largest providers of UAS during this period are General Atomics and Northrop Grumman, which cumulatively received $19.5 billion and $13.6 billion in obligations respectively from FY 2010 to FY 2021, with Northrop Grumman holding the lead in FY 2010 and FY 2011 and General Atomics thereafter. In addition to Northrop Grumman, three other members of the Big Five defense contractors, Raytheon, Boeing, and Lockheed Martin, place in the number three, five, and seven spots respectively. The largest overall defense contractor, Lockheed Martin, is also the second-largest provider of civilian UAS, with $339 million in the reporting period, of which $64 million was spent in FY 2021 alone, compared to $501 million in the reporting period and $78 million in FY 2021 for General Atomics.

Table 6 – Top 10 U.S. Federal Prime UAS Vendors for Contracts, FY 2010–FY 2021

Rank	Contractor	Obligations (Constant 2021 $ Millions)			
		History 2010–2021	Prior Decade 2010–2019	2020	2021
1	General Atomics		16,503	1,662	1,407
2	Northrop Grumman		11,727	1,126	775
3	Boeing		3,461	584	178
4	Textron		3,543	51	3
5	Raytheon		1,265	82	133
6	AeroVironment		1,074	34	68
7	Lockheed Martin		336	17	(0)
8	Kratos Defense & Security		245	30	75
9	Navmar Applied Sciences		312	(0)	-
10	Composite Engineering		222	-	-
All Other			3,402	379	267
Total			42,091	3,964	2,905

Source: FPDS; CSIS analysis.

[96] "Sometimes small" means that in a given year one contracting officer labeled them as other than small within their sector, and another contracting officer in an earlier year or working in a different sector perhaps made the judgment that they met the small business criteria when the contract started.

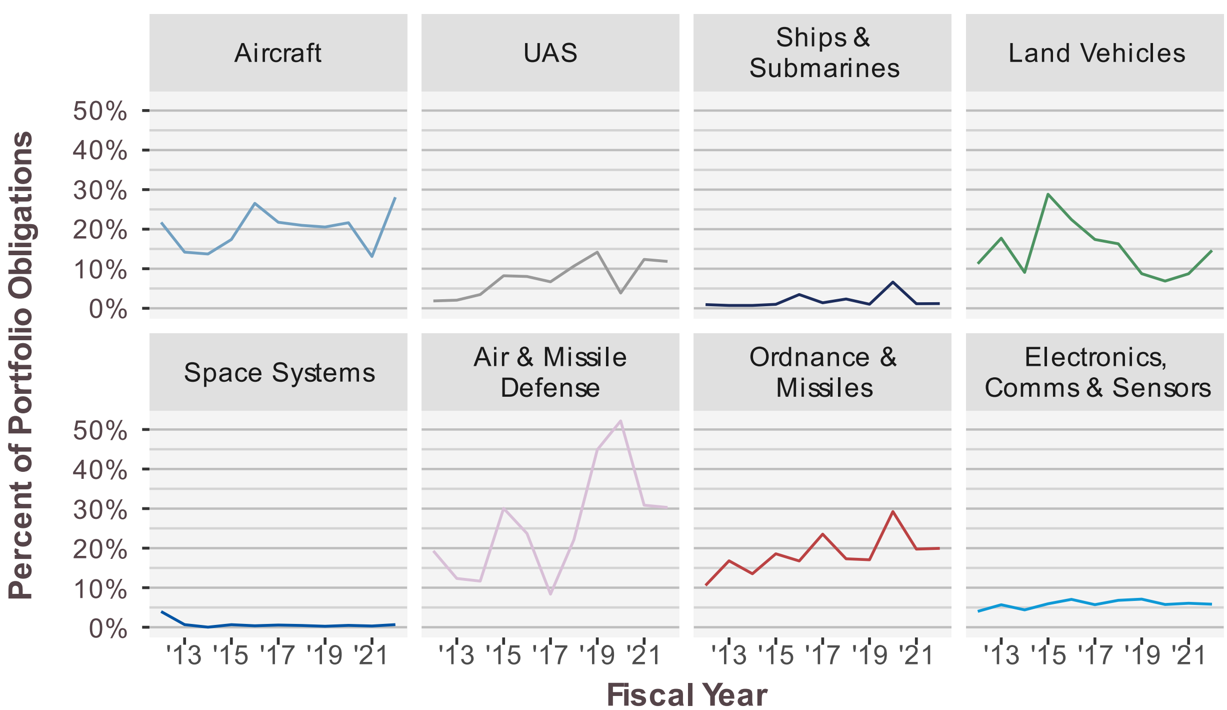
Turning to other large companies, as Table 6 shows these firms have been in relative decline in the reported data. Textron has undergone the largest change, with peak obligations in FY 2012 at over $1.0 billion. The remaining vendors fall within the medium to small tiers. AeroVironment stands out as a producer of multiple systems transferred to Ukraine via drawdowns, including the Puma unarmed UAS and the Switchblade loitering munition. Kratos Defense & Security is also notable as an example of consolidation within this sector, as it purchased the tenth-ranked Composite Engineering.

U.S. Exports

U.S. arms exports follow two main approaches: FMS, which employ the U.S. acquisition system and are government-to-government arrangements, and direct commercial sales, which are deals made between companies and foreign governments but still under the jurisdiction of arms export regulation. The contract data includes FMS exports because this method employs the U.S. acquisition system.

The past decade has seen a significant shift toward greater UAS exports, as seen in Figure 7 below. The true portion of contracting going to foreign buyers is lower than the proportion shown, as some of these contracts serve a mix of foreign and domestic recipients. This is a consequence of the fact that FMS is truly a part of the U.S. acquisition system; for jointly developed projects like the F-35 or for orders to support U.S. overseas bases, there may be administrative and industrial efficiencies from combining orders. The trends are nonetheless worth tracking as they can show how engaged each sector is with FMS. From FY 2012 to FY 2014, less than 2 percent of contracts for UAS included a FMS aspect, while across the last three years, the average share was nearly 11.9 percent. In absolute terms, $1,099 million in contract obligations from FY 2019 to FY 2021 had an FMS aspect.

Figure 7 – Defense System Portfolios by Share of Contracts Including Some FMS



Source: FPDS; CSIS analysis.

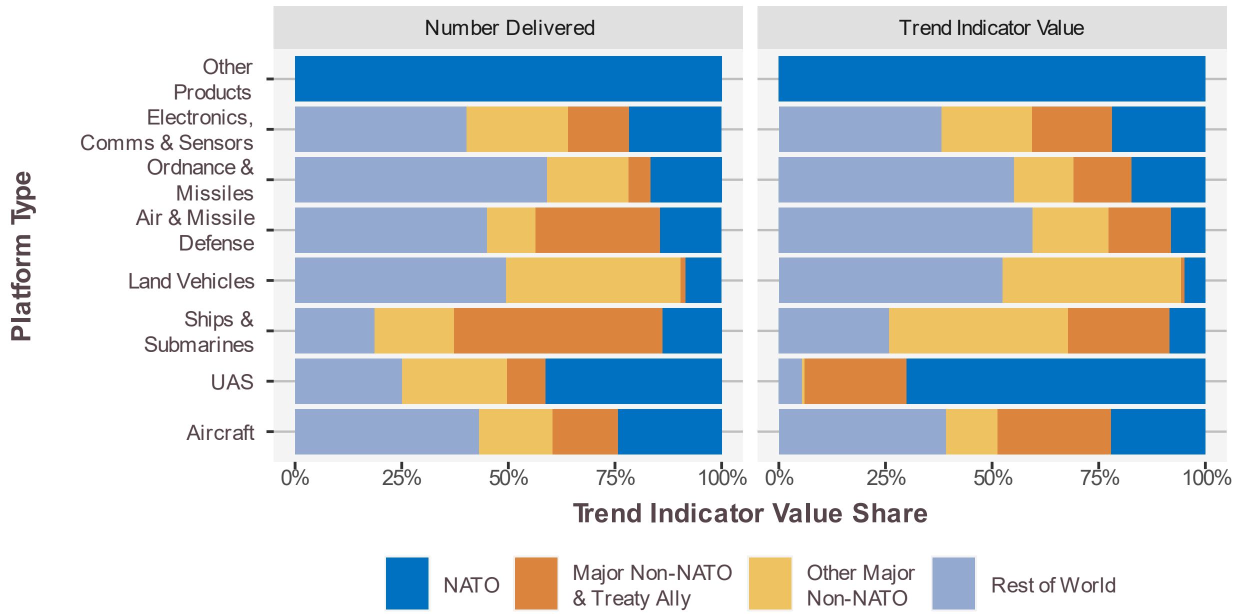
The share of UAS obligations with an FMS aspect in the past three years exceeds that of land vehicles (6.7 percent); electronics, comms, and sensors (3.6 percent); ships and submarines (2.8 percent); and space systems (0.1 percent). UAS still fall below aircraft (17.9 percent), a long-standing area of U.S. focus bolstered by the multinational joint strike fighter. The air and missile defense and ordnance and missiles categories, with average shares in the last three years of 42.6 and 21.8 percent respectively, have also shown steady growth despite a fair amount of volatility. Drawdown transfers to Ukraine do not employ the acquisitions system directly, but on the whole the backfilling of existing transferred systems from the United States and allies as well as the smaller portion of new acquisitions, even if donated, will likely contribute to a fairly widespread increase in exports in FY 2022, which may result in continued growth in FMS-related contracts as a share of UAS obligations. However, convergence with other sectors is less likely given the announcements of more countries purchasing F-35s and the prominence of ordnance and munitions as well as air and missile defense in the defense of Ukraine, along with steps to bolster defenses of neighboring states.

Turning back to SIPRI data, Figure 8 below shows the distribution of U.S. transfers based on the alliance and acquisition cooperation status of the recipient, which could include both FMS and direct commercial sales (although the latter is harder for SIPRI to track).[97] Strikingly, and in keeping with the history of U.S. arms control regulations, 92 percent of UAS exports by estimated production cost, and 52 percent by quantity, have gone to close U.S. treaty allies. Of the platform portfolios, UAS are second-most oriented toward major treaty allies by estimated production cost and third closest by the number delivered. The difference between the number delivered and estimated production cost is explained by the United States keeping more capable systems—which fell under MTCR presumptive denial criteria—held more closely. The United States has been more comfortable transferring a range of unarmed systems, notably the ScanEagle, RQ-21A Blackjack, and various models of the RQ-7 Shadow, to a wider range of recipients.

The recipients of high-capacity and armed systems have included NATO itself as well as member states and major non-NATO allies in mutual defense pacts, most relevantly for this example South Korea. Notable transfers to the rest of the world include transfers of Predators to the United Arab Emirates (UAE) in 2016 and 2017 and to India in 2020. This pattern may be beginning to shift after the 2019 U.S. UAS export guidance and 2020 MTCR interpretation revisions; both occurred under the Trump administration but have not been replaced by the Biden administration. In addition to the sending of UAS and loitering munitions to Ukraine, a series of new transfers have been announced under the Biden administration, including to treaty ally Australia but also to the UAE and Taiwan.[98]

[97] A limitation of FPDS data is that while FMS status is either labeled or derivable from funding account for nearly a decade, there is no column in FPDS that explicitly labels the destination of arms transfer.
[98] New agreements are reported by the Defense Security Cooperation Agency, and these reports are helpfully compiled at "Arm Sales," Security Assistance Monitor, accessed August 18, 2022, https://securityassistance.org/arm-sales/.

Figure 8 – U.S. Exports by Platform Portfolio and U.S. Relationship to Recipient, 2010–2021



Source: "SIPRI Arms Transfers Database," SIPRI, June 12, 2022, https://www.sipri.org/databases/armstransfers; CSIS analysis.

CHAPTER 5

Arms Control and the Trade in UAS

The past decade has seen an initial stage of proliferation of UAS technology go from potential to reality. The CSD estimates that 60 countries had an operational UAS or loitering munition program in 2010. That number grew by 58 percent to at least 95 countries in 2019 and continued to expand, reaching 102 countries or more for the April 2020 report update.[99] Of 173 military units conducting UAS or loitering munition operations with a known activation data, 113 activated in the decade leading up to the 2019 CSD report.[100] Comparing the 2001–2010 period to 2011–2020, in the latter period the number of UAS and loitering munitions transferred more than doubled, with the proliferation of armed UAS being the key driver. The range of exporters also diversified. In 2001–2010, Israel held a commanding lead, but the market changed in 2011–2020 with transfers of largely armed UAS from China and increasing transfers of high-end systems from the United States.

This expansion of suppliers has been accompanied by a great debate in the United States over arms control agreements regarding UAS. Although the United States is the world's largest arms exporter, under U.S. law arms transfers are a foreign policy tool first and foremost, to be used with attention to security implications. As a result, U.S. regulations place considerable attention to weapon characteristics, for example those with cutting-edge technologies or relating to nuclear weapons. UAS have been treated as a tightly regulated technology under U.S. regulations. However, that status came under pressure as this past decade has also seen more policy emphasis on the economics of arms exports and the number of competing UAS providers has grown.

To better understand how UAS supply and demand has shifted, this section will start with a look at some of the norms and regulations around arms transfers, particularly focusing on UAS. First, it will focus on the Missile Technology Control Regime (MTCR) and more recent multilateral agreements and declarations. Next it will turn to an examination of arms transfers, as reported by SIPRI and augmented by analysis by the CSD, focusing first on the major exporters before turning to a look of those countries that are the primary importers of UAS technology. Azerbaijan and Ukraine are both in the top 25 importers of UAS and loitering munitions, though Ukraine is near the tail of the list.

Arms Control Agreements and Regulations

While this report looks primarily at the advantages offered by uninhabited systems, U.S. arms control agreements and export laws primarily regulate those systems by their capabilities. The foundation of U.S. export controls is domestic

[99] Gettinger, *The Drone Databook*, IX, 1.

[100] Gettinger, *The Drone Databook*, X. The CSD tracks an additional 95 UAS or loitering munition military units with unclear activation dates. Of the entire set, "more than three-quarters—217 units—are believed to be dedicated mostly or wholly to drone operations."

law, notably 1976's Arms Export Control Act. The executive branch enforces this law and goes further to regulate arms and dual-use exports, with the Departments of State, Defense, and Commerce each having an important role. The executive branch can also give guidance through the conventional arms transfer policy and more specific policies such as the 2015 and 2019 updates to UAS export policy. There are multiple relevant international agreements, including the Wassenaar Arrangement, but one of the most important agreements for UAS has been the MTCR. The initial MTCR-based regulations introduced in 1992 considered all UAS as potential delivery platforms for missile technology—with a threshold based on speed and carrying capacity for stricter regulation. The heart of the current debate centers on whether UAS should be regulated more like aircraft. This would mean placing increasing attention on how UAS platforms are used and greater focus on strike-capable UAS.

This section will cover some of the norms and regulations governing U.S. arms exports. First, it will look at the MTCR. Then, it will follow the shift in export control laws to examining whether a UAS is strike-capable, as shown in multiple agreements from 2013 to 2016. Finally, it will look at U.S.-specific trade regulations that incorporate control of UAS, referencing the MTCR.

The MTCR includes rules on UAS that set a major brake on higher-end UAS exports, although that was not the original focus of the agreement. The G7 states signed the MTCR in 1987 after initial discussions started in 1983.[101] Today, the MTCR has 35 member states.[102] The MTCR was created to form "rules and norms that could be used to address sales of nuclear-capable missiles by the Soviet Union and China."[103] It divides missile-related capabilities into two categories. Category I includes "complete rocket and unmanned aerial vehicle systems . . . capable of delivering a 500-kg warhead to 300 km," their launch vehicles, and "major complete subsystems," among others.[104] The MTCR Annex includes the full list.[105] Category I items face a "strong presumption of denial" for export and should be rarely exported under MTCR guidelines. Category II items include dual-use items, less-sensitive components, and "other complete missile systems capable of a range of at least 300 km" and are more freely exported. The MTCR is nonbinding as an international agreement, although its member countries may (and do) create binding laws on a national level.[106] Instead, it operates through "export controls, meetings, and dialogue and outreach," putting the "burden for compliance onto the seller rather than the buyer."[107]

The MTCR was expanded in 1992 to counter the spread of chemical and biological weapons of mass destruction (WMDs), in addition to the nuclear warheads it was originally designed for.[108] 1992 also saw the MTCR expand to UAS, applying the same categorization rules that apply to missiles. This has caused widespread discussion. Some have

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[101] Peter van Ham, *The MTCR at 30: Ideas to Strengthen the Missile Technology Control Norm* (The Hague: Clingendael Institute, 2017), https://www.jstor.org/stable/resrep17354.
[102] William Alberque, *Revitalising Arms Control: The MTCR and the HCoC* (London: International Institute for Strategic Studies, November 2, 2021), https://www.iiss.org/blogs/research-paper/2021/11/revitalising-arms-control-the-mtcr-and-the-hcoc.
[103] Alberque, *Revitalising Arms Control.*
[104] "Missile Technology Control Regime (MTCR) Frequently Asked Questions," Bureau of International Security and Nonproliferation, accessed September 21, 2022, https://www.state.gov/remarks-and-releases-bureau-of-international-security-and-nonproliferation/missile-technology-control-regime-mtcr-frequently-asked-questions/.
[105] "Equipment, Software and Technology Annex – MTCR," Missile Technology Control Regime, accessed August 8, 2022, https://mtcr.info/mtcr-annex/.
[106] "MTCR Frequently Asked Questions," ISN.
[107] Ibid.; Alberque, *Revitalising Arms Control*.
[108] Ibid.

touted the addition of UAS as one of the MTCR's "notable successes," demonstrating that the MTCR can expand to include new technologies as additional types of platforms that are capable of delivering WMD-like payloads. This line of thought puts that the MTCR should continue expanding toward an even larger scope.[109] The primary contrasting view in the literature focuses on UAS's capacity for reuse, positioning them closer to aircraft—which are not regulated by the MTCR. This line of thought holds that UAS inclusion under the MTCR is *counterproductive*, a distraction from the primary purpose of the MTCR.[110]

The inclusion of UAS as a Category I system inherently puts the brakes on the widespread export of systems capable of carrying 500 kg at least 300 km. The United States reinterpreted the MTCR to move systems with an airspeed of less than 800 km/h into Category II in June 2020.[111] Opening opportunities for broader export—cited as a U.S. priority in the release—may make the regime more appealing to potential MTCR additions.[112] Shifting UAS into Category II removes the strong presumption of denial for export, making the threshold to export UAS systems more like that of other arms. Critics warned that making this change on a non-consensus basis risks undermining international norms and standards and opening the door to other countries to unilaterally reinterpreting international regimes in the future.[113] As of August 2022, neither the Department of State's MTCR Fact Sheet nor its International Traffic in Arms Regulations (ITAR) had been updated to reflect the new carveout for systems under 800 km/h, although the Department of Commerce's Export Administration Regulations (EAR) was updated in 2021.[114] ITAR and EAR will be discussed further later in this section, but the former was most recently revised in June 2022. Israel, an MTCR signatory, produces a UAS with a 450 kg payload, carefully below the MTCR's 500 kg limit.[115] Russia and Ukraine are MTCR signatories, as is the United States; Armenia and Azerbaijan are not. China, now the largest exporter of armed UAS (all nominally below the capacity thresholds), is a self-proclaimed adherent of the MTCR but has not formally joined.[116]

How, then, should UAS exports be controlled? The 2013 Arms Trade Treaty (ATT) does not specifically mention UAS but does include combat aircraft as one of its categories and so "does implicitly apply to drones."[117] In this, the ATT draws a distinction that the MTCR does not—not on the craft's crewing and theoretical potential to deliver a

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[109] Alberque, *Revitalising Arms Control*.
[110] William Schneider, *Modernizing the Missile Technology Control Regime* (Washington, DC: Hudson Institute, August 6, 2020), 2022, http://www.hudson.org/research/16293-modernizing-the-missile-technology-control-regime.
[111] Ibid.
[112] Office of the Spokesperson, "U.S. Export Policy for Military Unmanned Aerial Systems," U.S. Department of State, February 17, 2015, https://2009-2017.state.gov/r/pa/prs/ps/2015/02/237541.htm.
[113] David G. Kimball, "U.S. Reinterprets MTCR Rules," Arms Control Association, September 2020, https://www.armscontrol.org/act/2020-09/news/us-reinterprets-mtcr-rules.
[114] "MTCR Frequently Asked Questions," ISN; "Part 121 - The United States Munitions Lists," Code of Federal Regulations, National Archives, July 22, 1993, https://www.ecfr.gov/current/title-22/chapter-I/subchapter-M/part-121; "Change to the License Review Policy for Unmanned Aerial Systems (UAS) To Reflect Revised United States UAS Export Policy," Federal Register, January 12, 2021, https://www.federalregister.gov/documents/2021/01/12/2020-27983/change-to-the-license-review-policy-for-unmanned-aerial-systems-uas-to-reflect-revised-united-states.
[115] van Ham, *The MTCR at 30*.
[116] Alberque, *Revitalising Arms Control.*
[117] "The ATT | Arms Trade Treaty," armstrade.info, accessed July 20, 2022, http://www.armstrade.info/the-att/; Rachel Stohl and Shannon Dick, *The Arms Trade Treaty and Drones* (Washington, DC: Stimson Center, August 2018), https://www.stimson.org/2018/arms-trade-treaty-and-drones/.

warhead, but on its strike capabilities, a different set of priorities than the MTCR that places more emphasis on compliance with the laws of war. The United States and Ukraine have signed but not ratified the ATT; Armenia, Azerbaijan, and Russia have neither signed nor ratified.[118]

The 2015 U.S. Export Policy for Military Unmanned Aerial Systems also emphasized the laws of war. Despite its name, the policy applies to both military and commercial-origin UAS. It evaluates transfers on a case-by-case basis; its principles for evaluation cite the MTCR, humanitarian law, "lawful basis for use of force under international law," proper training, and avoidance of unlawful surveillance or force.[119] The United States built on the export policy in 2016 with the Joint Declaration for the Export and Subsequent Use of Armed or Strike-Enabled Unmanned Aerial Vehicles (UAVs).[120] This multilateral declaration was proposed at an ATT conference and sought to be a step towards a future agreement covering both exports and imports.[121] Ukraine has signed on to the United States' declaration; Armenia, Azerbaijan, and Russia have not. The United States again revised its export policy in 2019, which listed "increases trade opportunities for U.S. companies" first among its five objectives.[122]

The 2016 declaration and 2019 export policy draw a strike vs. non-strike distinction, which captures armed and strike-enabled UAS that would fall beneath the MTCR's capacity thresholds. These smaller UAS have become a growing part of arms transfers in the past decade. In examining these four together, the strong suggestion is that UAS will increasingly be regulated according to their combat capabilities. Examining the Department of State's International Traffic in Arms Regulations (ITAR), which regulates U.S. exports and transfers to third countries, finds a broad but capability-based distinction: it regulates "aircraft, whether manned, unmanned, remotely piloted, or optionally piloted."[123] These characteristics are not related to whether they are uninhabited, but by their relation to defense or to the MTCR. ITAR separates aircraft and UAS only when regulating UAS launch vehicles or swarm-capable UAS—two capabilities without inhabited system parallels. Its missile-related language reflects the MTCR, referencing "MT [missile technology] if usable in rockets, SLVs [space launch vehicles], missiles, drones, or UAVs [unmanned aerial vehicles] capable of delivering a payload of at least 500 kg to a range of at least 300 km."[124] Missile technology here designates the MTCR. ITAR outlines a policy of denial for "defense articles and defense services" to Russia, except for some commercial and government space capabilities.[125] No ITAR policy of denial applies to Armenia, Azerbaijan, or Ukraine, but all four countries are controlled countries under the Department of Commerce's EAR.[126] The EAR bases

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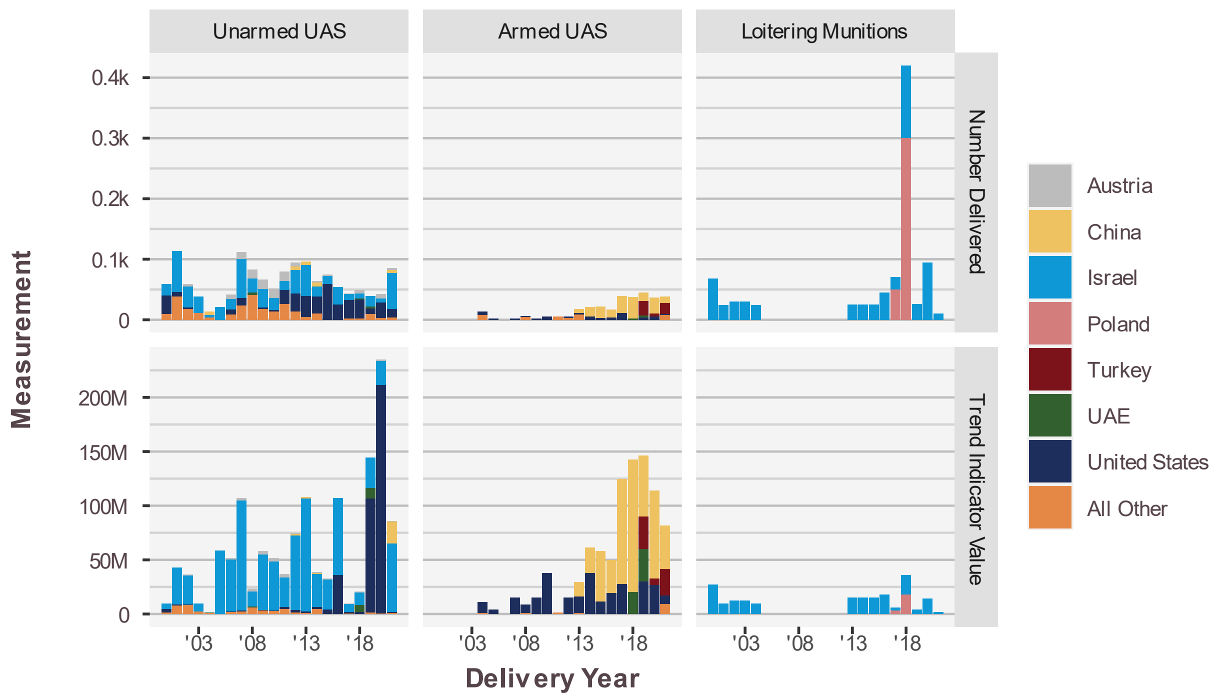
[118] "Arms Trade Treaty (ATT)," Nuclear Threat Initiative, accessed July 5, 2022, https://live-nuclear-threat-initiative.pantheonsite.io/education-center/treaties-and-regimes/arms-trade-treaty-att/.
[119] Office of the Spokesperson, "U.S. Export Policy for Military Unmanned Aerial Systems."
[120] Office of the Spokesperson, "U.S. Export Policy for Military Unmanned Aerial Systems"; Bureau of Political-Military Affairs, "Joint Declaration for the Export and Subsequent Use of Armed or Strike-Enabled Unmanned Aerial Vehicles (UAVs)" fact sheet, October 16, 2017, https://2017-2021.state.gov/joint-declaration-for-the-export-and-subsequent-use-of-armed-or-strike-enabled-unmanned-aerial-vehicles-uavs/.
[121] van Ham, *The MTCR at 30*.
[122] "U.S. Policy on the Export of Unmanned Aerial Systems," May 21, 2019, https://2017-2021.state.gov/u-s-policy-on-the-export-of-unmanned-aerial-systems-2/.
[123] "Part 121," Code of Federal Regulations.
[124] "Part 121," Code of Federal Regulations.
[125] "Part 126 - General Policies and Provisions," Code of Federal Regulations, accessed July 26, 2022, https://www.ecfr.gov/current/title-22/chapter-I/subchapter-M/part-126.
[126] "§ 772.1 Definitions of terms as used in the Export Administration Regulations (EAR)," Code of Federal Regulations, July 22, 2022, https://www.ecfr.gov/current/title-15/subtitle-B/chapter-VII/subchapter-C/part-772/section-772.1.

its reasons for controlling *nonmilitary* UAS technology in part on missile technology; however, its restrictions on "unmanned 'airships'" are much broader than the MTCR or ITAR. While still tied to capabilities, the EAR restricts craft by speed, range, and altitude rather than solely by strike capability.[127]

UAS Arms Trade Trends

MAJOR EXPORTERS

Figure 9 – UAS and Loitering Munitions Deliveries by Exporter, 2000–2021



Source: "SIPRI Arms Transfers Database," SIPRI, June 12, 2022, https://www.sipri.org/databases/armstransfers; CSIS analysis.

From 2011 to 2020, SIPRI tracked 1,612 transfers of UAS and loitering munitions, compared to 736 in 2001 to 2010. Armed UAS and loitering munitions were largely responsible for this growth: armed UAS took off from 30 transfers in the first decade to 368 in the second, while loitering munitions exploded, growing sevenfold from 108 units transferred in 2001–2010 to 731 in 2011–2020. As can be seen in Figure 9, this growth was driven in large part by China's emergence as an exporter, going from less than 10 units exported in the first decade to nearly 300 in the second. In the first decade, Israel had a commanding lead, with 75 percent of UAS and loitering munition exports as weighted by estimated production cost. [128] In the second decade, however, China emerged, with 28 percent of estimated production costs; the United States adjusted its arms exports policy and grew to account for 33 percent, and

[127] "Category 9 - Aerospace and Propulsion," Commerce Control List, Bureau of Industry and Security, U.S. Department of Commerce, accessed September 21, 2022, https://www.bis.doc.gov/index.php/documents/regulations-docs/2340-ccl9-4/file.

[128] Trend indicator value (TIV) is often more useful for measuring UAS proliferation, because estimated production costs weigh the value of larger and more lethal or otherwise capable systems far higher than other platforms. While proliferation of the number of platforms is certainly important, the proliferation of capabilities lends greater insight into the state of the global market and the status of export controls.

Israel dropped to only 30 percent. That said, according to CSD, in 2019 the United States still provided UAS or loitering munitions to a plurality of countries:

> Nineteen countries have exported drones that are currently in active military service. Most foreign-made systems are acquired from China, Israel, or the U.S. Aside from the military services in these three countries, a total of 79 countries—83 percent—operate at least one active drone type made in China, Israel, or the U.S. Thirty-two countries operate at least one drone made in China, 39 countries operate at least one from Israel, and 49 operate at least one from the U.S.[129]

Across the entire 2000–2021 period, Israel, the United States, and China are the largest exporters of UAS by estimated production cost. Israel has long been an exporter of midsize UAV surveillance systems and has notably made the choice not to sell armed systems (with the exception of loitering munition transfers). China, on the other hand, is a relative newcomer to the market and has seen most of its sales with high-end armed systems, often selling to nations limited in their ability to buy U.S. armed UAS because of U.S. humanitarian and arms control concerns. In Israel, the Israeli Defense Force's armed UAS capability was until recently treated as an important enough state secret that discussion was censored, which still applies to advertising capabilities to potential international customers. These rules did not limit discussion of loitering munitions, however, and "arms-capable UAVs have been reportedly sold to Germany and India under special agreements."[130] The United States occupies a distinct position in the export market, since while it has some of the most advanced capabilities on offer, it sells relatively few of them. Because of how advanced U.S. systems are, they have much higher estimated production costs, meaning that while the United States exports relatively few systems, these represent a substantial portion of global capability.

There is a significant step down from the three largest exporters to the runners-up, the UAE and Turkey, both of which sell larger armed platforms. While the UAE and Turkey do not export the volume of systems that some larger exporters do, they do export armed UAS capabilities (based in part on Western technology) and could be major players in the global market depending on how foreign policy concerns shape different states' willingness to export systems.[131] The last two countries with notable exports in the period are both niche players. Poland is a relatively limited proliferator of capabilities, only exporting the Warmate loitering munition.[132] Of the top seven exporters shown in Figure 9, Austria makes up the smallest portion of the global export market, selling only a single surveillance UAS. CSD lists Austria as the fourth-largest provider by number of countries served. In addition to those mentioned

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[129] Gettinger, *The Drone Databook*, IX.

[130] Emanuel Fabian, "Israel Says IDF's Armed Drones Can Now Be Talked about, Unless It's to Sell Them," *Times of Israel*, July 27, 2022, https://www.timesofisrael.com/israel-says-idfs-armed-drones-can-now-be-talked-about-unless-its-to-sell-them/.

[131] Dan Sabbagh and Bethan McKernan, "Revealed: How UK Technology Fuelled Turkey's Rise to Global Drone Power," *The Guardian*, November 27, 2019, https://www.theguardian.com/news/2019/nov/27/revealed-uk-technology-turkey-rise-global-drone-power.

[132] SIPRI's TIV system assigns a much lower value to loitering munitions than other armed drones. This is likely because of follows from their low production cost and limited use nature. So, while Poland sold more systems than any other country in some years, in terms of proliferating capabilities, other states that sold more reusable and larger systems will have higher exports by TIV.

here, CSD also notes exports by Denmark, France, Germany, Iran, Italy, Russia, Slovenia, South Africa, South Korea, Spain, Sweden, and Switzerland.[133]

Implications

The Chinese and Israeli prominence in the market likely has to do with both political and military concerns. On the military side, Israeli and Chinese systems offer lower unit costs than their often-larger U.S. counterparts. On the political side, both Israel and China are willing to sell to states with mixed human rights records where U.S. companies are often barred from selling advanced long-range weapon systems. China in particular is willing to sell large armed UAS to countries without regard to whether the country has a history of respecting humanitarian and human rights concerns with their use of precision munitions. Since these states are driving demand, this can make it difficult for U.S. companies to export systems, given the government's legitimate export concerns. The United States has however made some recent gains in the global market, with long-planned sales of the Global Hawk platform which, while unarmed, had fallen under stringent MTCR category I controls.

MAJOR IMPORTERS

Regional Import Trends

The Near East and Africa saw the largest percentage growth in UAS and loitering munition demand in the 2011–2020 period. Because of domestic manufacture, this trend does not align with overall regional spending on military UAS. The Teal Group reports that the United States is the largest spender, followed by Europe and the Asia-Pacific region.[134] As seen in the top portion of Figure 10, the Near East is responsible for the largest share of UAS and loitering munitions by value (accounting for $719 million in Trend Indicator Value (TIV), compared to $665 million for second-place Europe and Eurasia). The leading two purchasers, Saudi Arabia and the UAE, account for two-thirds of the TIVs for the region and are the number one and number five importers respectively for the entire 2000–2021 period, as seen in Table 7. The growth in African imports was driven by Nigeria and Sudan, which while representing a much smaller portion of global demand also displayed a striking increase that followed similar dynamics as the Near East. Algeria, Egypt, and Iraq also appear on the top 25 importer list from the Near East, and all seven nations covered here have turned to China as their plurality source of UAS, although Algeria notably turned to the UAE as well.

Here China's entry as a supplier provides a straightforward explanation for the greater than order of magnitude rise in demand. Most of the Near East and African buyers are unlikely to buy from Israel because they do not have formal diplomatic ties to that country (with the long-standing exception of Egypt, partially joined by Sudan and UAE in 2020). This cut them off from the largest supplier of UAS in 2001–2010, and while many of these Near East nations are major importers from the United States, a presumptive denial policy for larger UAS limited their range of options. Interestingly, as with Azerbaijan, funding from oil dollars is a notable part of this story. As seen in the bottom half of Figure 10, UAS and loitering munitions do not stand out as a proportion of total Near East weapons imports; they only comprise 0.7 percent on average from 2011–2020, with a peak of 1.3 percent of the region's estimated production costs for import in 2018.

Europe and Eurasia is the second-largest regional importer in estimated production cost terms but also has been a fairly persistent source of demand throughout the entire period. The United Kingdom and NATO are the number

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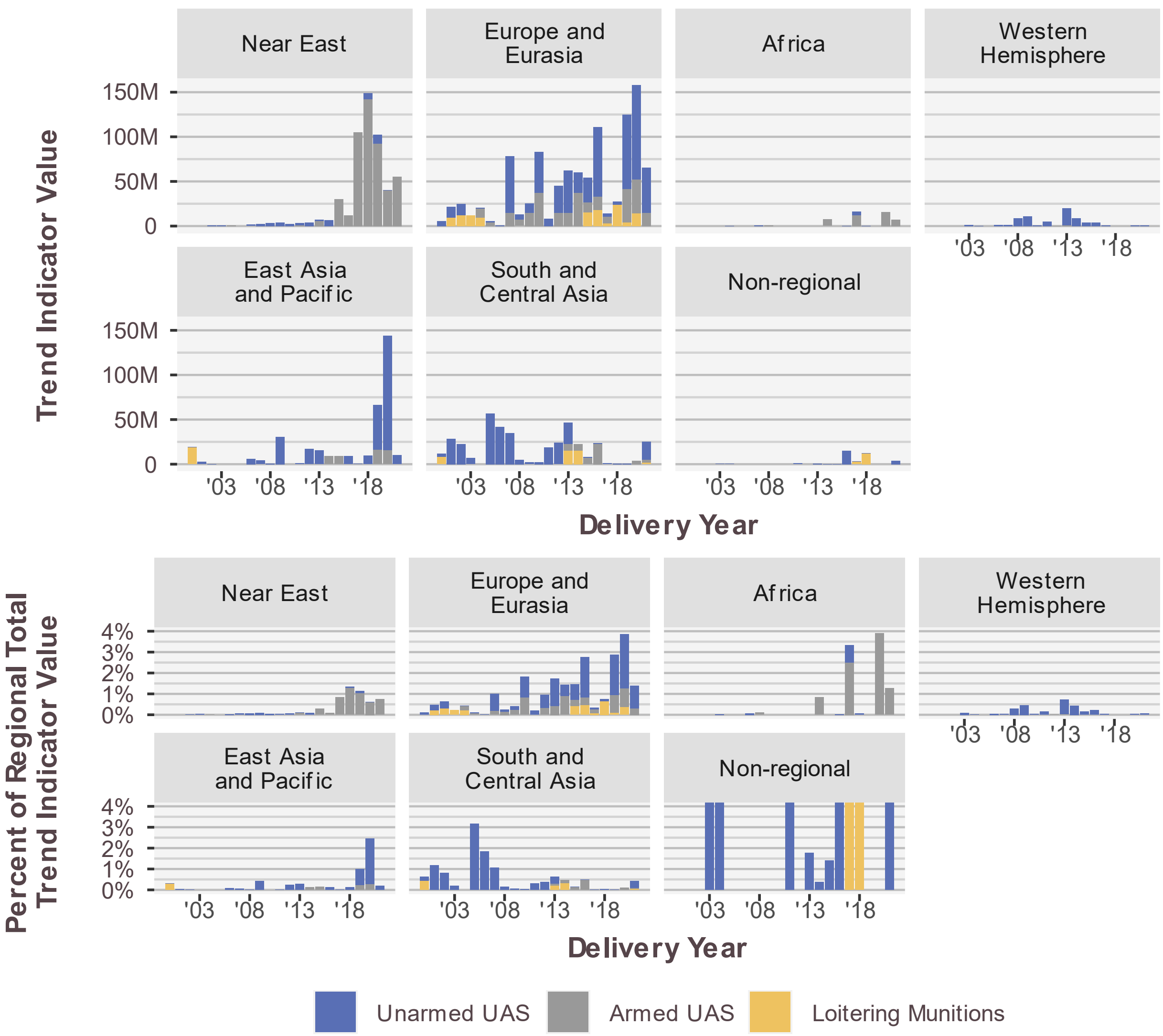
[133] Gettinger, *The Drone Databook*, IX, X.

[134] Teal also notes that "the Asia-Pacific region may represent an even larger segment of the market, but several significant players in the region, namely Japan and China are not especially transparent about their plans compared to Europe." Zaloga, Rockwell, and Zoretich, *World Military Unmanned Aerial Systems*, 2.

three and four importers across the period, with Azerbaijan and Germany in the top 10 and Turkey, France, Italy, Spain, and ultimately Ukraine appearing in the top 25. Israel is a longtime provider to the region, but liberalizing U.S. policy toward major exports and a new supplier in Turkey have also contributed to more than doubling the imports from 2001–2010 to 2011–2020. East Asia and the Pacific has been the third-largest importer, with purchases by South Korea from the United States, Indonesia from China, and the Philippines and Singapore from Israel each coming in the past decade. South and Central Asia has been in slight decline, as Indian purchases have fallen off and rising Pakistan imports from China have not closed that gap. Non-regional deliveries to the United Nations and unknown recipients have made up a small portion of UAS transfers in estimated production cost terms, but across the period 12.9 percent of imports to the United Nations or imports that could not be traced were UAS. The proportionally large share of UAS and loitering munitions among deliveries to unknown importers suggests a note of caution for this analysis, as UAS and loitering munition deliveries may prove harder to track than some traditional weapon systems.

Figure 10 – UAS and Loitering Munitions Deliveries by Recipient Region, 2000–2021



Source: "SIPRI Arms Transfers Database," SIPRI, June 12, 2022, https://www.sipri.org/databases/armstransfers; CSIS analysis.

Choice of Systems for Top Importers

Closer examination of UAS transfers to the top 10 importers reveals that just a handful of systems make up the bulk of UAS exports when measured by estimated production cost. Figure 11 shows that bulk of the proliferation of capabilities has happened in the last five years, with the sale of a large number of Wing Loong-2 systems, in conjunction with a smaller number of highly capable U.S. Global Hawks (RQ-4A) systems. The Wing Loong-2 is a Chinese UAS that is similar to the U.S.-made Reaper family. Both have long loiter times, can be armed, and are of similar size.[135] The Israeli Hermes and Heron are similar and size and capability to the TB2, though only the TB2 is marketed as an armed platform.[136] The final high-end systems that make up a significant portion of capability proliferation are the Global Hawk, which is the largest system of the group and can remain aloft for up to 30 hours, miles above where even commercial airliners fly, and is often used to conduct strategic reconnaissance tasks, and the MQ-9 Reaper, which is well known for its role as an armed UAV in U.S. counterterrorism and counterinsurgency efforts.[137] Considering that the U.S. Reaper and the Wing Loong-2 are similar systems, demand for further armed UAS, including U.S. systems, may now be limited for states that made their first import of armed UAVs in the past decade and do not show signs of sustained demand.

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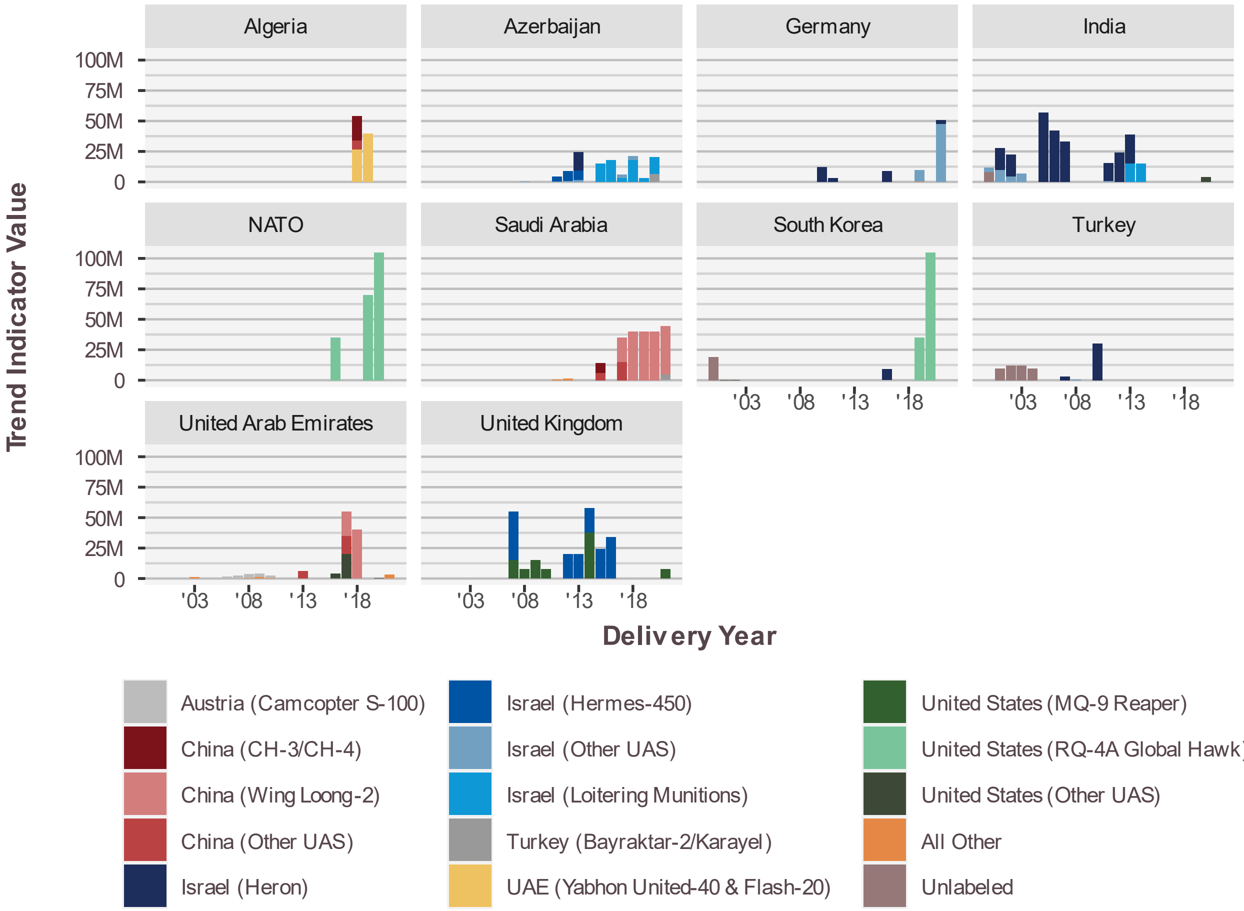
[135] "MQ-9 Reaper," Air Force, accessed August 8, 2022, https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104470/mq-9-reaper/https%3A%2F%2Fwww.af.mil%2FAbout-Us%2FFact-Sheets%2FDisplay%2FArticle%2F104470%2Fmq-9-reaper%2F; "Wing Loong II Chinese Medium-Altitude Long Endurance (MALE) Unmanned Aerial Vehicle (UAV) - WEG MediaWiki," OE Data Integration Network (TRADOC), accessed August 8, 2022, https://odin.tradoc.army.mil/mediawiki/index.php/Wing_Loong_II_Chinese_Medium-Altitude_Long_Endurance_(MALE)_Unmanned_Aerial_Vehicle_(UAV).

[136] "Hermes™ 450," Elbit Systems, accessed August 8, 2022, https://elbitsystems.com/products/uas/hermes-450/; "MALE UAV: The Heron TP Is a Multi Role, Advanced, Long Range UAS," Israel Aerospace Industries, accessed August 8, 2022, https://www.iai.co.il/p/heron-tp; "Bayraktar TB2," Baykar, accessed August 8, 2022, http://www.baykartech.com/en/uav/bayraktar-tb2/.

[137] "Global Hawk," Northrop Grumman, accessed August 8, 2022, https://www.northropgrumman.com/what-we-do/air/global-hawk.

Figure 11 – Top 10 Recipients of UAS and Loitering Munitions Deliveries



Source: "SIPRI Arms Transfers Database," SIPRI, June 12, 2022, https://www.sipri.org/databases/armstransfers; CSIS analysis.

Characteristics of Top Importing States

Looking deeper to the top 25 importer countries, this group includes nine larger U.S. treaty allies with advanced militaries (including NATO itself, along with the complicated case of Turkey and the possibly frontline South Korea), 10 countries spending above 2.65 percent of their GDP on their militaries between 2000 and 2020 (with India the lowest at 2.69 percent), and two frontline states, the Philippines (a less wealthy U.S. ally) and Ukraine. Outside of those three groupings, Egypt, Indonesia, and Nigeria—in the number 16, 18, 22 spots respectively—are pivotal countries in their respective regions but not as large proportional spenders. Large U.S. treaty allies predominantly bought from Israel or the United States. In the other categories, China and Israel are the largest players, often selling midsize systems like the Heron—though there are exceptions like Ukraine, which primarily imported UAS and loitering munitions from Turkey.

Frontline states also have a distinctive set of needs that may guide their future procurement decisions on UAS, even if they share some traits with other importers. For states prioritizing military spending, UAS may be particularly appealing because of their ability to project presence at lower cost than crewed counterparts. Frontline states, on the other hand, may be more interested in developing a minimum viable capability that can manage an adversary with more robust counter-UAS capabilities than those Armenia deployed in the Nagorno-Karabakh war. This may lead to needing features like autonomy, which allows systems to operate even if remote control is temporarily disabled, but more broadly raises the importance of the attritability of UAS. Attritability in this case means that the system is still a good value proposition to deploy even in the face of a potentially high loss rate. This will likely drive those states to purchase lower-end systems (like the TB2) in order to meet their immediate needs. By bifurcating the market, it becomes clear where future demand may exist, demand that will surely create new proliferation concerns for the policy community.

Table 7 – Top 25 Recipients of UAS, 2000–2021

Rank	Buyer	Distribution over Time (2000–2021)	Total TIV	UAS as % of Total Imports	Unarmed UAS	Armed UAS	Loitering Munition	Top System (# Imported)	Top Exporter (% of Import TIV)	Top Overall Exporter (% of Import TIV)	% of GDP Spent on Mil. (2000–2020)	Arms Sale Risk Index (2020) 100=Most Risk	MTCR	ATT	Joint Decl.
1	Saudi Arabia		403.3	1.1%	14	104	0	Wing Loong-2 (90)	China (98%)	United States (65%)	9.13	72			
2	India		298.2	0.5%	152	2	70	Heron (68)	Israel (86%)	Russia (66%)	2.69	60	2016		
3	United Kingdom		248.2	1.9%	84	12	0	Hermes-450 (79)	Israel (64%)	United States (74%)	2.32	18	1987	Ratified	Signed
4	NATO		210.0	15.8%	6	0	0	RQ-4A Global Hawk (6)	United States (1(	United States (49%)					
5	United Arab Emirates		183.0	0.8%	79	52	0	Wing Loong-2 (30)	China (77%)	United States (57%)	5.04	40		Signed	
6	South Korea		168.8	0.7%	11	0	48	RQ-4A Global Hawk (4)	United States (8	United States (69%)	2.49	16	2001	Ratified	Signed
7	Azerbaijan		121.7	3.0%	41	5	325	Harop (50)	Israel (59%)	Russia (54%)	3.53	55			
8	Algeria		121.3	0.8%	5	25	0	Yabhon United-40 (5)	China (45%)	Russia (76%)	4.39	51			
9	Pakistan		94.4	0.5%	108	40	0	CH-3 (40)	China (64%)	China (55%)	3.73	78			
10	Germany		84.3	2.5%	17	0	0	Heron-Tp (6)	Israel (100%)	United States (49%)	1.23	13	1987	Ratified	Signed
11	Turkey		76.8	0.5%	15	0	108	Harpy (108)	Israel (56%)	United States (38%)	2.51	77	1997	Signed	
12	France		69.5	3.8%	23	6	0	MQ-9 Reaper (6)	United States (6	United States (52%)	1.96	19	1987		
13	Indonesia		65.9	0.8%	12	16	0	CH-4 (16)	China (97%)	South Korea (17%)	0.75	52		No	
14	Italy		65.0	0.9%	26	15	0	MQ-9 Reaper (6)	United States (9	United States (60%)	1.50	22	1987	Ratified	Signed
15	Spain		58.6	1.2%	18	7	6	MQ-9 Reaper (7)	United States (9	Germany (33%)	1.37	23	1990	Ratified	Signed
16	Nigeria		47.9	3.0%	9	18	0	CH-4 (4) / Wing Loong-2 (4)	China (98%)	China (27%)	0.52	80		Ratified	Signed
17	Singapore		40.5	0.3%	27	0	0	Heron (10)	Israel (99%)	United States (53%)	3.66	14			Signed
18	Burma		37.0	0.9%	5	24	0	CH-3 (24)	China (97%)	China (41%)	2.70				
19	Egypt		34.4	0.2%	22	10	0	Wing Loong-1 (10)	China (87%)	United States (37%)	2.09	78		No	
20	Philippines		34.1	1.8%	30	0	0	Hermes-900 (9)	Israel (98%)	South Korea (38%)	1.22	72		Ratified	Signed
21	Iraq		32.9	0.3%	10	11	0	CH-4 (8)	China (97%)	United States (55%)	2.92	89			Signed
22	Australia		31.6	0.1%	26	0	0	Heron (10)	Israel (95%)	United States (60%)	1.86	10	1990	Ratified	Signed
23	Unknown recipient(s)		27.8	9.6%	75	0	250	Warmate (250)	Poland (54%)	Israel (26%)	2.16				
24	Sudan		25.0	1.2%	0	11	0	CH-4 (6)	China (96%)	Russia (49%)	3.57	88			
25	Ukraine		21.0	12.5%	0	12	100	Bayraktar TB2 (12)	Turkey (71%)	United States (32%)	2.33	66	1998	Signed	Signed

Source: SIPRI, World Data Indicators available at https://data.worldbank.org/indicator/MS.MIL.XPND.GD.ZS; CATO Arm Sale Risk Index available at https://www.cato.org/study/2021-arms-sales-risk-index; and CSIS analysis.

CHAPTER 6

Discussion and Conclusions

Recent years have seen overarching changes in demand and supply for UAS trends, shaping the options facing the U.S. government and industry when considering UAS policies and investments. First, the Nagorno-Karabakh war and Russia's invasion of Ukraine have seen the use of UAS in conventional conflict against foes capable of contesting airspace, though not at a time and place of their enemies' choosing. Other nations are taking lessons from their perception of that use, which has gained considerable attention thanks in part to the information warfare capabilities of UAS. Second, UAS and loitering munitions, especially armed UAVs, are now more available to aspiring and frontline states. The supply of UAS has been expanded by the growing commercial sector, in addition to new military UAS exporters China, Turkey, and the UAE. Meanwhile, frontline powers are not yet a major driver of imports, but Ukraine has demonstrated that for a state with the right human capital and resource access, a domestic industrial base can be rapidly built.[138]

During this same period, U.S. strategic focus has shifted—primarily toward a focus on great power competition and away from the counterterror and counterinsurgency missions. The Air Force's planned replacements for mainstay U.S. systems, the RQ-4 Global Hawk and MQ-9 Reaper, are several years from expected availability (and as classified systems, have limited public data available).[139] Unclassified U.S. budgets and contract spending on UAS have declined even as new unclassified investments are made in uninhabited maritime and counter-UAS, and the United States seeks to more broadly engage commercial industry through efforts like the DIU Blue UAS. Furthermore, the DOD is investing in lower-end systems—such as the Switchblade and recently unclassified Phoenix Ghost UAS—which have been a focus on new acquisition, as opposed to transfers of existing stocks, in support of the Ukrainian war effort.

In this past year, Ukraine has provided a real-world example of how UAS may be used in a peer- or near-peer conflict, as well as how a country can rapidly scale its industrial base. Replacing the U.S. and allied equipment to Ukraine or building up a truly attritable supply of UAS is a challenge comparable to the rapid acquisition of up-armored vehicles in the most recent U.S. wars. The post–Cold War peace dividend and consolidation of a defense industrial base is not optimized toward large-scale production, in part due to the specialized nature of modern military technology.[140]

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[138] Andrew E. Kramer and David Guttenfelder, "From the Workshop to the War: Creative Use of Drones Lifts Ukraine," *New York Times*, August 10, 2022, https://www.nytimes.com/2022/08/10/world/europe/ukraine-drones.html.
[139] Tirpak, "Secret Global Hawk Successor Due in 2027-2029."
[140] Mark F. Cancian, "Will the United States Run Out of Javelins Before Russia Runs Out of Tanks?" CSIS, *Commentary*, April 12, 2022, https://www.csis.org/analysis/will-united-states-run-out-javelins-russia-runs-out-tanks.

Commercially adjacent systems, like UAS and loitering munitions, may have the promise to be part of the solution to the challenge of addressing the intense production demands of higher-end conflict.[141]

U.S. export policy has also shifted in recent years, slowly delineating areas where exports would likely meet the burden of proof to overcome—and then not be subject to—a presumption of denial. This has encouraged a growing number of exports of systems subject to the 1992 Missile Technology Control Regime revisions, most notably the MQ-4 Global Hawk and MQ-9 Reaper. This has been primarily to U.S. treaty allies, but there have also been agreements announced for UAS sales to the United Arab Emirates and Taiwan.

Nonetheless, UAS and loitering munitions still make up a small portion of imports around the globe, which suggests limits to total demand among countries that can afford more imports. During the global war on terror, high-end UAS were particularly useful in prosecuting targets throughout the U.S. Central Command area of responsibility. In contemplating the possibility of conflict with great powers with effective air defenses, however, interest is shifting toward a mix of a handful of high-end systems and a large number of low-end systems. High-end low-observable systems are still largely in the classified domain and the history of stealth aircraft suggests that unit costs will be considerable. Low-end systems will be used to cause direct effects on the enemy, while high-end systems (that are not low-observable) will have an operational, as opposed to tactical, ISR role along with providing critical network capabilities.[142] Established U.S. allies often find themselves in a different fiscal environment than states prioritizing military spending, who are more likely to turn to midsized but still capable systems like the TB2 and Heron due to decreased operational complexity across the whole of their force.

The rapid growth of armed UAS imports, especially in the Middle East and Africa, presents two competing paths forward for UAS export goals. One approach would be to continue arguing for further moves to converge the treatment of UAS with forms of aircraft and ordnance and munitions that the United States more freely exports. This approach does not address concern as to the impact of UAS on nations' willingness to use force and related concerns. Given these challenges, this may be easier for states that are party to the Joint Declaration on UAS, members of the Arms Trade Treaty or MTCR, and those that have a history of abiding by end-use agreements. However, the Nagorno-Karabakh conflict is a reminder that both UAS and conventional weapons transfers can be destabilizing, and major UAS purchaser Saudi Arabia is notably not a party to any of these arrangements. This path will also face price competition for countries looking to build budget airpower in the style of Azerbaijan, which does not play to the traditional strength of the United States in high-end systems.

Another option would be a heightened focus on frontline nations concerned about great powers, with special attention to Asia and the Pacific.[143] The Nagorno-Karabakh war showed that innovative use of UAS technology is not restricted to the cutting-edge systems, as demonstrated by the Azeri use of legacy planes repurposed as remotely piloted decoys to draw out Armenian air defenses and then target them with loitering munitions. In addition to their

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[141] Past CSIS analysis of wheeled vehicles has found that systems with civilian analogs may have "shorter replacement times than other systems." Adam Saxton et al., *Industrial Mobilization: Assessing Surge Capabilities, Wartime Risk, and System Brittleness* (Center for Strategic and International Studies, January 8, 2021), 47, https://www.csis.org/analysis/industrial-mobilization-assessing-surge-capabilities-wartime-risk-and-system-brittleness.
[142] Center for Strategic and International Studies, "Maritime Security Dialogue: A Discussion with the Assistant Commandant of the Marine Corps," CSIS, YouTube video, 1:02:07, https://www.youtube.com/watch?v=-XZwtMBwrYo.
[143] Traditional employment cases for UAS systems have focused on counterinsurgency or low-intensity conflicts. However, as they prove increasingly useful in higher-end conflict, and as more capable UAS systems enter the market, that traditional mission set that focused on the Middle East and Africa is evolving as perceived threats also shift toward the Indo-Pacific.

ISR role, even budget UAS can support information warfare and combined operations. The ability of UAS to substantiate battlefield claims was prominent in Azeri operations and may prove relevant even in non-kinetic and gray zone conflicts with great powers that may otherwise control the narrative.[144] More importantly, the command-and-control support role is inherently high-emission in a way that may be less suitable to low-observability high-end UAS and aircraft inhabited by troops. For this approach, keeping low unit costs is especially important. For these systems to be useful for frontline states, they must be produced in sufficient quantities so that they can tolerate the attrition that comes with targeting by modern integrated air defenses. This need could foreseeably be met by evolving established systems or newer technology, but in either case, the export control approach would likely remain similar to legacy systems. Additionally, these UAS would have to be paired with manufacturing capacity and technical know-how for regular software updates and to support command-and-control integration.

While both government and industry will face choices of conflicting priorities and uncertain technological bets, there are several steps that would benefit a range of U.S. approaches:

FURTHER DEVELOP MODULAR OPEN SYSTEMS FOR UAS TO ADDRESS EXPORTABILITY CONCERNS AND ENHANCE U.S. COMPARATIVE ADVANTAGES IN SECURITY COOPERATION

Interoperability is a key motivation for U.S. security assistance, which both supports U.S. cooperation with allies and partners and is a potential strength for U.S. arms that cannot be matched by competitors outside of the U.S. alliance network. Related to this concept are modular open systems approaches (MOSA), which allow for upgrade of specific platform components that could facilitate meeting technological security concerns. UAS design and manufacture has included a growing amount of MOSA implementation, notably in cases of ground systems produced by a different company, sometimes based out of a different country. MOSA has some potential to address exportability concerns, such as those relating to the Multi-Spectral Targeting System located on the Gray Eagle UAS. The Defense Technology Security Administration has reviewed whether the risk of Russian capture of this system precludes its use, which suggests that supplying frontline states may sometimes require the use of less sensitive mission packages.[145] Greater ease in keeping systems up to date—especially vital for command-and-control missions—and the possibility of working more effectively with UAS produced by U.S. allies would be another potential benefit of MOSA employment. That said, aligned technical standards do not ensure a common view on political risk: Turkey is a member of NATO and thus a part of a range of interoperability efforts but has not signed on to the U.S. Joint Declaration on UAS export. Technological solutions cannot repair political ruptures, and technology security is not relevant to many potential end use concerns. Additionally, selling less capable systems in the name of reducing risk could impact a state's acquisition decision.

REFRESH THE U.S. ROADMAP FOR UAS OR OTHERWISE INSTITUTIONALIZE TRACKING TO ADDRESS TRANSPARENCY GOALS AND AID INDUSTRY INVESTMENTS

The last DOD *Roadmap for Unmanned Systems* was published with FY 2017 data, before the two conflicts covered in this report and major shifts in U.S. export policy. U.S. spending for UAS and other uninhabited systems is poorly

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[144] Stories of heroism in wartime can be inherently difficult to verify, but in Ukraine UAS footage lent credibility to accounts. As one story noted, "not all the details of these claims could be independently verified . . . [but] the huge amount of aerial combat footage published by the Ukrainians underlines the importance of drones to their resistance." Borger, "The Drone Operators Who Halted Russian Convoy Headed for Kyiv."
[145] Alexander Ward and Lee Hudson, "Why the Gray Eagle Still Hasn't Landed in Ukraine," *POLITICO*, August 9, 2022, https://politi.co/3Sz0oVT.

tracked, and it is often grouped with other systems of the same category when it comes to R&D or service support. The present growth of the number of vendors in the industrial base is a laudable development that cuts against trends in other parts of the U.S. defense industrial base, but being clear about existing spending and plans may be necessary to sustain investments and participation—especially if addressing inflation pushes off major new investments.

Both the Arms Trade Treaty and the 2016 Joint Declaration emphasize the importance of transparency and international law while regulating systems by whether they are combat-capable or, in the case of the latter, strike-enabled. This suggests that domestic and international standards might focus most closely on export controls for these UAS systems. For example, the 2019 U.S. Policy on the Export of UAS covers all military UAS but also delineates transfer conditions for "Armed UAS," "Unarmed UAS," and "Civil UAS." These boundaries can be blurry; technology such as swarming or autonomy will be of interest in any form of UAS, and even commercial UAS, let alone unarmed military UAS, can be part of a long kill chain or in many cases converted to become armed. In a world with a growing number of exporters and domestic producers, trends in arms controls suggest an increasing focus on how UAS are used—and thus also a renewed focus on importing and employing nations, to complement the historic MTCR-based focus on high-end exporters.

To put in practice the principles of transparency underlined in treaties and policies, reporting foreign sales agreements and deliveries and new harmonized international trade codes would help further policy goals and help address concerns in Congress. In addition, a greater transparency on use, especially for armed UAS, is an area where the United States should set a high standard—or else have little hope of cultivating norms among other nations.

DEVELOP SHARED GOALS AND PRACTICES FOR THE MANAGEMENT OF UAS AND LOITERING MUNITIONS EXPORT CONTROL REGIMES

Loitering munitions provide important capabilities to actors across the spectrum of capabilities. As loitering munitions become increasingly capable, they are adopting tactical, operational, and strategic roles. Given this range of capabilities, and the kinetic and unarmed nature of these platforms, the line between loitering munitions and cruise missiles is becoming increasingly blurred. Some smaller systems clearly only can cause kinetic effects on a small portion of the battlefield would not alter how capabilities proliferate, but many systems in this category could. This suggests that there is no easy resolution between whether UAS and loitering munitions should operate under missile-based rules, as in the MTCR, or similar to other aircraft, as in the ATT.

While advanced UAS, especially low-observable ones, still have a very limited set of manufacturers, low-cost systems have increasingly proliferated. Influencing importers directly may prove more plausible than bringing China in on new arrangements. At the same time, China's accession to the ATT, along with Turkey, Israel, and the UAE's signatures, suggest that that arrangement may be the best available locus for tracking armed UAS exports. In turn this may reward a closer U.S. embrace of the treaty, even if the votes may not be present in the Senate for ratification.

BE PREPARED FOR AN INCREASING DEMAND FOR COUNTER-UAS TECHNOLOGY

The Nagorno-Karabakh conflict saw Armenia's more conventionally focused defenses drawn out by decoys and otherwise outmaneuvered and overwhelmed by combined armed attacks including UAS. Given the growing number of states capable of producing military-grade UAS, the growing export market, and even the option to adapt commercial UAS in a long or all-in-one kill chain, demand for defenses is only likely to grow. The United States has proven more willing to export air and missile defenses to states that are not treaty allies and, to the extent that counter-UAS systems are prove effective and affordable, there is likely unmet demand in this area. Moreover, wider export may reduce the demand for UAS imports by states seeking to project power over unguarded neighbors in a way that is contrary to U.S. foreign policy objectives.

PAY ATTENTION TO THE POSSIBLY CHANGING ROLE OF SERVICES AND MILITARY ASSISTANCE FOR UAS

Azerbaijan's success in the Nagorno-Karabakh relied not just on imported and adapted hardware, but also on support from Turkey in incorporating UAS into its doctrine and allegedly more direct military assistance. While military assistance is beyond the scope of this paper, this topic deserves additional study, as effective deployment of UAS is not just a matter of having the right hardware. Just as UAS may lower barriers to employing force, they may also simplify third-party intervention. Military assistance can be provided in different ways with remotely piloted systems, and this may be worth further attention in updates to the Joint Declaration and other arms control agreements.

From a U.S. contracting perspective, services related to UAS are poorly tracked and appear to be a declining portion of spending. Services can play a variety of important roles for UAS: training operators and building facilities, providing updates to a hardware-based, software-driven adaptable system, or working to integrate UAS into a larger combined arms structure. In addition, a self-described strength of the U.S. FMS system is that it can provide a full package of support rather than end with the transfer. An ongoing relationship could also aid in end-use monitoring but also more closely implicate a country in the use of UAS.

As the role of UAS changes across the battlefield, U.S policymakers will have to understand when other nations use different and distinct employment concepts for UAS to monitor end use and accurately understand the proliferation of technologies. Very few countries can employ UAS as effectively as the United States has been able to do. The United States uses drones in the context of a highly sophisticated ISR network that is supported by a complex command-and-control infrastructure. Few countries have similar capabilities and, instead, they are likely to employ UAS that deliver different capabilities to the battlefield. The wars in Ukraine and Nagorno-Karabakh have proven that smaller militaries can be important tactical innovators, and if the United States fails to understand these new use cases it could imperil future efforts to understand proliferation and meet the demands of the global UAS market. The United States and likeminded states can also shape this future through UAS and counter-UAS shared and denied as well as through norms and international agreements, but the range of suppliers means that such efforts will take place in a highly competitive environment.

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