SYM-AM-23-060

Excerpt from the Proceedings of the Twentieth Annual Acquisition Research Symposium

Acquisition Research: Creating Synergy for Informed Change

May 10–11, 2023

Published: April 30, 2023

The research presented in this report was supported by the Acquisition Research Program at the Naval Postgraduate School.

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Rising Demands and Proliferating Supply: The Future of the Global UAS Market

Gregory Sanders—is a Fellow in the International Security Program and Deputy Director of the Defense-Industrial Initiatives Group at the Center for Strategic and International Studies (CSIS), where he manages a research team that analyzes data on U.S. government contract spending and other budget and acquisition issues. In support of these goals, he employs SQL Server, as well as the statistical programming language R. Sanders holds a master's degree in international studies from the University of Denver, and he holds a bachelor's degree in government and politics and a bachelor's degree in computer science from the University of Maryland. [gsanders@csis.org]

Alexander Holderness—is a Research Assistant with the Defense-Industrial Initiatives Group at the Center for Strategic and International Studies (CSIS). His analytical focus is on issues relating to national security, government acquisition, supply chain risk, and industrial capacity. Prior to joining CSIS, Holderness worked as an intern for the U.S. Army Futures Command, Joint Army Concepts Division. He holds a BA in government and history from the College of William & Mary. [aholderness@csis.org]

Contributing Authors: Rose Butchart, Astrid Price, and Dan Steinberg

Abstract

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 Uninhabited Aerial Systems (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. Across these analyses, the paper reaches three broad conclusions. First, UAS and loitering munitions offer a wide range of capabilities to a growing range of states. Second, countries now have a range of alternatives for acquiring UAS and loitering munitions. Third, the United States has increased its exports of UAS but with a comparatively greater focus on wealthy trusted allies compared to other weapon platforms.

Introduction

The military use of powered Uninhabited Aerial Systems (UAS) has evolved since their inception in the 20th 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 (Hall & Coyne, 2014). 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 (Blom, 2010).[1] 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 (Wezeman et al., 2021). For the United States, UAS became increasingly integrated

[1] There were unsuccessful armed UAS attempts in combat during World War II (Hall & Coyne, 2014).

into the use of precision guided munitions, proving critical for tactical level intelligence collection, battlefield damage assessment, and target validation during the Gulf War (Miller, 2013). 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 (Hall & Coyne, 2014).

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" (Department of Defense [DoD], 2013, p. 20). 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 (Keating et al., 2021, p. 16). 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 (Fuhrmann & Horowitz, 2017).

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 (O'Rourke, 2020, p. 48). A mix of rapid technological developments and classified approaches makes summarizing that concept difficult. As the 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" (Performance Assessments and Root Cause Analyses, 2018, p. 4). 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" (Performance Assessments and Root Cause Analyses, 2018, p. 4). Some analysts have forecast that UAS will be pivotal in future great power conflict, often invoking specific technological developments like swarming maneuvers (Work, 2015).

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" (*Study on Armed Unmanned Aerial Vehicles*, n.d.) The Center for the Study of the Drone (CSD) reports that "at least 28 countries have deployed UAVs beyond their borders since the 1980s" (Gettinger et al., n.d., p. XIII).[2] Within or beyond their borders, "at least 10 countries—Azerbaijan, Israel, Iraq, Iran, Nigeria,

[2] This number includes peacekeeping and coalition operations (e.g., 21 countries deploying UAS to Afghanistan).

Pakistan, Turkey, UAE, U.K., and U.S.—are believed to have used UAVs to conduct aerial strikes" (Gettinger et al., n.d., p. XIII).[3]

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% increase in UAS delivered internationally and a 577% 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% increase over FY 2023 spending (Zaloga et al., 2022, p. 1). 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 (Zaloga et al., 2022, p. 2). 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 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. 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

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

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[4]

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

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.[5] The FPDS tracks UAS spending with a code for "complete unmanned aircraft systems and subordinate air vehicles."[6] 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 estimates the U.S. military UAS budget will be $10.6 billion in FY 2023 but only $5.4 billion, just 51% of that funding, will be unclassified (Zaloga et at., 2022, p. 3). 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 (Strickland, 2013, p. 6). 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.[7] 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

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[4] CSIS Defense Industrial Initiatives Group Data Analysis

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

[6] 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.

[7] 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.

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 1.

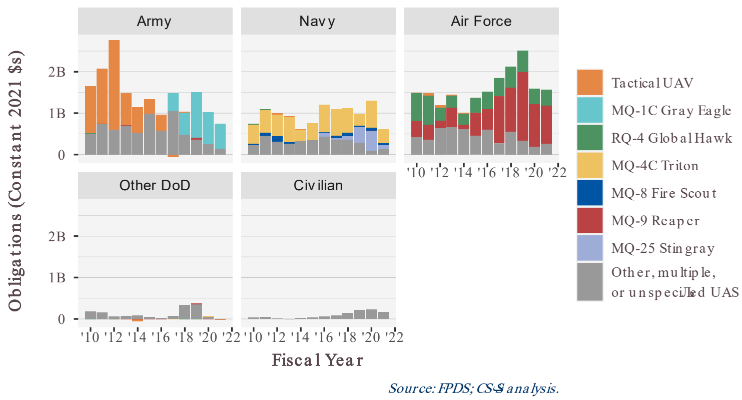

Figure 1. Federal Prime Contracts for UAS, FY 2010–FY 2021 (FPDS, n.d.; CSIS, n.d.)

Totaling across all five DoD and civilian customers shown in Figure 1, 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, testing, and evaluation and procurement spending in FY 2023 is $5.4 billion (Zaloga et al., 2022, p. 3).[8] 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 include the RQ-7 Shadow and the MQ-1C Gray Eagle, a successor to the 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 (Tirpak, 2021). 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% over the reporting period), as shown in Figure 2, and the decline in overall spending is largest in absolute

[8] 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.

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% of UAS obligations went to R&D, varying between 6 and 17%. For contrast, seven other defense system portfolios are included in Figure 2, which has a variable y-scale because remotely crewed systems are by far the smallest of the group.[9] While the UAS R&D rate is below that of space systems (55%); electronics, comms, and sensors (14%); and air and missile defense (25%), it still exceeds that of aircraft (7%), ships and submarines (2%), land vehicles (4%), and ordnance and missiles (4%).[10] 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.

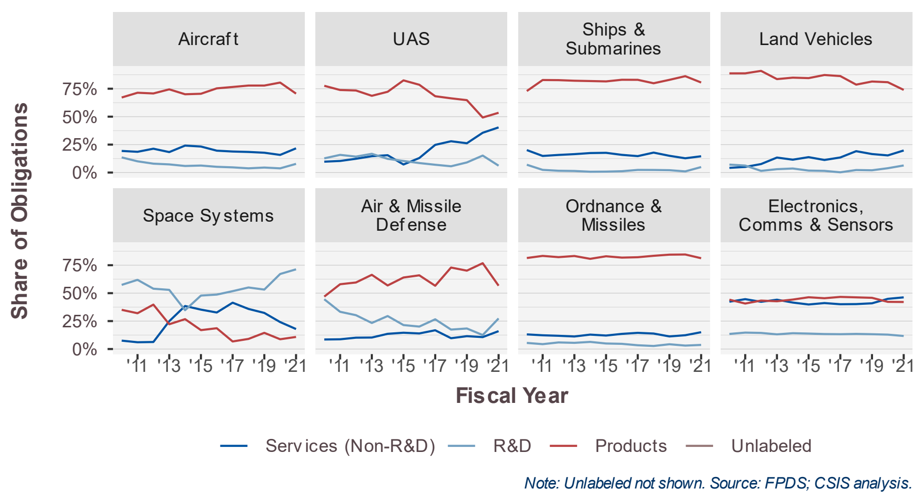

Figure 2. Defense System Platform Contract Obligations and Share of Obligations by Product, R&D, and Service, FY 2010–FY 2021
(FPDS, n.d.; CSIS, n.d.)

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%), lagging slightly behind space systems (23%) and well behind electronics, comms, and sensors (42%). 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.

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[9] 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.

[10] 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.

Federal Acquisition 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 (Gertler & Zoretich, 2022, p. 1). 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.[11] As seen in Figure 3, 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 4 years have seen an average of 5% of federal contract dollars for UAS use a commercial approach, compared to higher average levels for aircraft (7%), space systems (9%), and ships and submarines (14%)—let alone the 26% 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%, respectively), showing that rates do exceed that of exclusively defense-focused sectors.

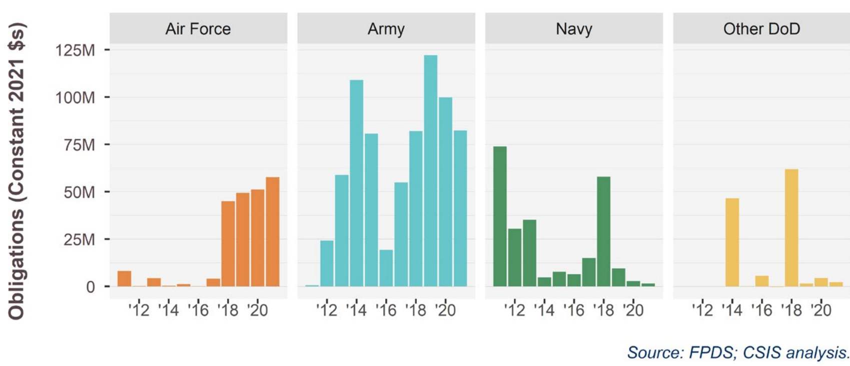

Figure 3. Federal Obligations for UAS Using Any Commercial Authorities, FY 2011–FY 2021 (FPDS, n.d.; CSIS, n.d.)

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

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[11] For this paper, "commercial contracting" refers to federal contract procedures for items that are commercially available according to the definitions in Federal Acquisition Regulation 2.101. The authorities available for commercial contracting are available in Part 12 of the Federal Acquisition Regulation. 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.*

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 4. 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 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% even as the number of UAS vendors rose (Office of the Under Secretary of Defense for Acquisition and Sustainment [OUSD(A&S)], 2022; Sanders et al., 2022).

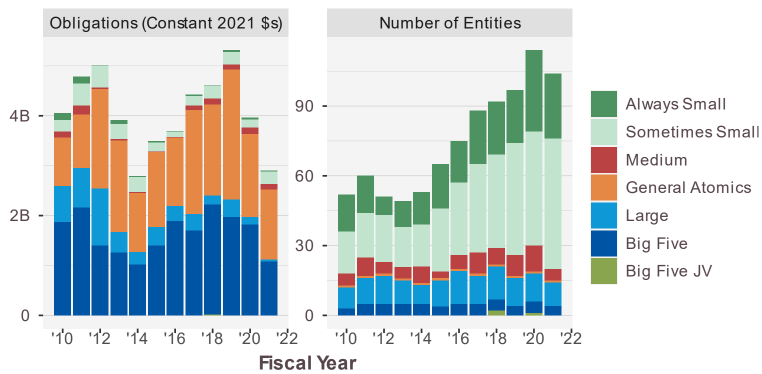


Figure 4. Count and Contract Obligations to Federal UAS Vendor by Size, FY 2010–FY 2021 (FPDS, n.d.; CSIS, n.d.)

When looking at market share, the "Big Five" contractors—Lockheed Martin, Northrup Grumman, Boeing, Raytheon, and General Dynamics—collectively commanded 40.5% of the market during the period, with midsized specialist General Atomics receiving a slightly smaller 40.0% 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%). General Atomics, since FY 2012, has held a 37 to 49% 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%). 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.

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.[12] 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.

Table 2 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 2. Top 10 U.S. Federal Prime UAS Vendors for Contracts, FY 2010–FY 2021

		Obligations (Constant 2021 $ Millions)			
Rank	Contractor	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

Turning to other large companies, as Figure 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 10th-ranked Composite Engineering.

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 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

[12] "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.

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 Missile Technology Control Regime (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 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 (van Ham, 2017). Today, the MTCR has 35 member states (Alberque, 2021). 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" (Alberque, 2021). 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 (Bureau of International Security and Nonproliferation, n.d.). The MTCR Annex includes the full list (MTCR, n.d.). 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 (Bureau of International Security and Nonproliferation, n.d.). Instead, it operates through "export controls, meetings, and dialogue and outreach," putting the "burden for compliance onto the seller rather than the buyer" (Bureau of International Security and Nonproliferation, n.d.; Alberque, 2021).

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 (Bureau of International Security and Nonproliferation, n.d.). 1992 also saw the MTCR expand to UAS, applying the same categorization rules that apply to missiles. This has caused widespread discussion. Some have 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 (Alberque, 2021). The primary contrasting view in the literature focuses on UAS' 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 (Schneider, 2020).

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 (Schneider, 2020). Opening opportunities for broader export—cited as a U.S. priority in the release—may make the regime more appealing to potential MTCR additions (Office of the Spokesperson, U.S. Department of State, 2015). 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 future other countries to unilaterally reinterpreting international regimes (Kimball, 2020). 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 (Bureau of International Security and Nonproliferation, n.d.; Code of Federal Regulations, 1993; Federal Register, 2021). 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 (van Ham, 2017). 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 (Alberque, 2021).

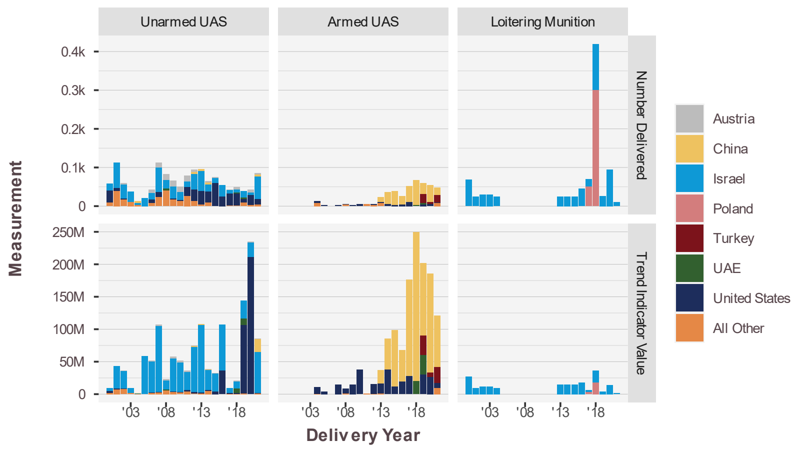
How, then, should UAS exports be controlled? The 2013 Arms Trade Treaty (ATT) does not specifically mention UAS but does include combat aircraft as one of its categories and so "does implicitly apply to drones" (*The ATT | Arms Trade Treaty*, n.d.; Stohl & Dick, 2018). In this, the ATT draws a distinction that the MTCR does not—not on the craft's crewing and theoretical potential to deliver a 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 (NTI, n.d.).

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 (Office of the Spokesperson, U.S. Department of State, 2015). The 2016 Joint Declaration for the Export and Subsequent Use of Armed or Strike-Enabled Unmanned Aerial Vehicles (UAVs; Office of the Spokesperson, U.S. Department of State, 2015; Bureau of Political-Military Affairs, 2017). The United States sought to build support for the latter on the occasion of an ATT conference and has a similar hope for multinational agreement around both exports and imports (van Ham, 2017). 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 (*U.S. Policy on the Export of Unmanned Aerial Systems*, 2019).

The 2016 declaration and 2019 export policy draw a strike versus 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" (Code of Federal Regulations, 1993). 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" (Code of Federal Regulations, 1993). 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 (General Policies and Provisions, n.d.). 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 (Definitions of Terms as Used in the Export Administration

Regulations [EAR], 2022). The EAR bases 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 (Commerce Control List, n.d.).

UAS Arms Trade Trends



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

Figure 5. UAS and Loitering Munitions Deliveries by Exporter, 2000–2021 (SIPRI Arms Transfers Database, 2022; CSIS, n.d.)

From 2011 to 2020, SIPRI tracked 1,734 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 73% of UAS and loitering munition exports as weighted by estimated production cost.[13] In the second decade, however, China was on top, with 43% of estimated production costs; the United States adjusted its arms exports policy and grew to account for 28%, and Israel dropped to only 22%. 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

[13] 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.

drone made in China, 39 countries operate at least one from Israel, and 49 operate at least one from the U.S. (*The Drone Databook*, 2019, p. IX)

Across the entire 2000–2021 period, Israel and China are, by a healthy margin, 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" (Fabian, 2022). 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 (Sabbagh & McKernan, 2019). 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.[14] 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. The CSD lists Austria as the fourth largest provider by number of countries served. In addition to those mentioned here, the CSD also notes exports by Denmark, France, Germany, Iran, Italy, Russia, Slovenia, South Africa, South Korea, Spain, Sweden, and Switzerland (*The Drone Databook*, 2019, p. IX).

Implications

The Chinese and Israeli dominance of 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

[14] 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.

Global Hawk platform which, while unarmed, had fallen under stringent MTCR category I controls.

Major Importers and Regional Import Trends

The Near East and Africa were the most prominent source of the increase 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.[15] As seen in the top portion of Figure 6, 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 6. 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 the 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 6, UAS and loitering munitions do not stand out as a proportion of total Near East weapons imports; they only comprise 0.7% on average from 2011–2020, with a peak of 2.2% of the region's estimated production costs for import in 2018.

Europe and Eurasia are the second-largest regional importer in estimated production cost terms but also have been a fairly persistent source of demand throughout the entire period. The United Kingdom and NATO are the number 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 have 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 have 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 10.1% 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

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[15] 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 et al., 2022, p. 2).

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.

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 the bulk of the proliferation of capabilities has happened in the last 5 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 Hawk (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 (Air Force, n.d.; OE Data Integration Network [TRADOC], n.d.). The Israeli Hermes and Heron are similar in size and capability to the TB2, though only the TB2 is marketed as an armed platform (Elbit Systems, n.d.; Israel Aerospace Industries, n.d.; Baykar, n.d.). 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 (Northrop Grumman, n.d.). 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.

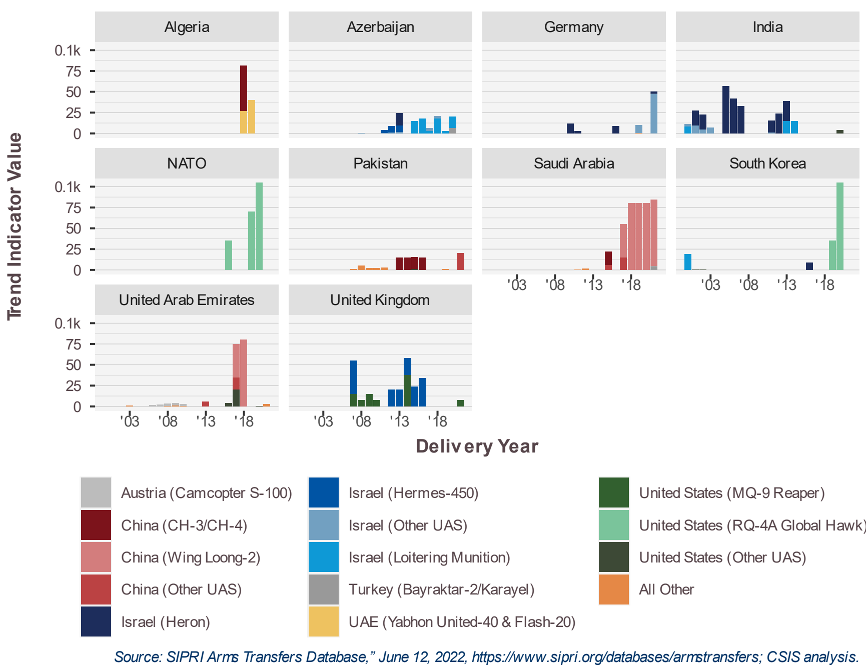

Figure 6. Top 10 Recipients of UAS and Loitering Munitions Deliveries (SIPRI Arms Transfers Database, 2022; CSIS, n.d.)

Characteristics of Top Importing States

Looking deeper to the top 25 importer countries, this group includes nine larger U.S. treaty allies with advance militaries (including NATO itself, along with the complicated case of Turkey and the possibly frontline South Korea), 10 countries spending an average of

2.65% of their GDP on their militaries between 2000 and 2020 (with India the lowest at 2.69%), and two frontline states, the Philippines (a less wealthy U.S. ally) and Ukraine. Outside of those three groupings, Indonesia, Nigeria, and Egypt—in the number 13, 16, and 19 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 a 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. 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.

Conclusions

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.

Another option would be a heightened focus on frontline nations concerned about great powers, with special attention to Asia and the Pacific.[16] The ability of UAS to substantiate battlefield claims to dominate the information environment may prove relevant during the competition phase with great powers that may otherwise control the narrative.[17] 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 these systems to be useful for frontline states, they must be produced in sufficient quantities to tolerate the attrition that comes with targeting by modern integrated air defenses. This demand could be met by evolving established systems or new

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[16] Traditional employment cases for UAS systems have focused on counterinsurgency or low-intensity conflicts. However, as they prove increasing 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.

[17] 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, 2022).

technology, but in either case, the export control approach would likely remain similar to legacy systems.

Striking the right balance between unnecessarily proliferating capabilities and ensuring that allies and partners have the systems they need will be the key balancing act going forward. U.S. companies are largely at the whim of how the government decides to navigate these questions of proliferation. While domestic demand may continue to grow alongside new concepts for UAS employment, the future of global demand is likely to be robust as front line states seek to access new capabilities. Navigating these competing interests will certainly prove to be a complex challenge for both industry and government.

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Acquisition Research Program
Department of Defense Management
Naval Postgraduate School
555 Dyer Road, Ingersoll Hall
Monterey, CA 93943

www.acquisitionresearch.net