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FROM THE BATTLEFIELD TO THE FUTURE OF WARFARE:
HARNESSING UKRAINE'S DRONE INNOVATIONS TO ADVANCE U.S. MILITARY CAPABILITIES

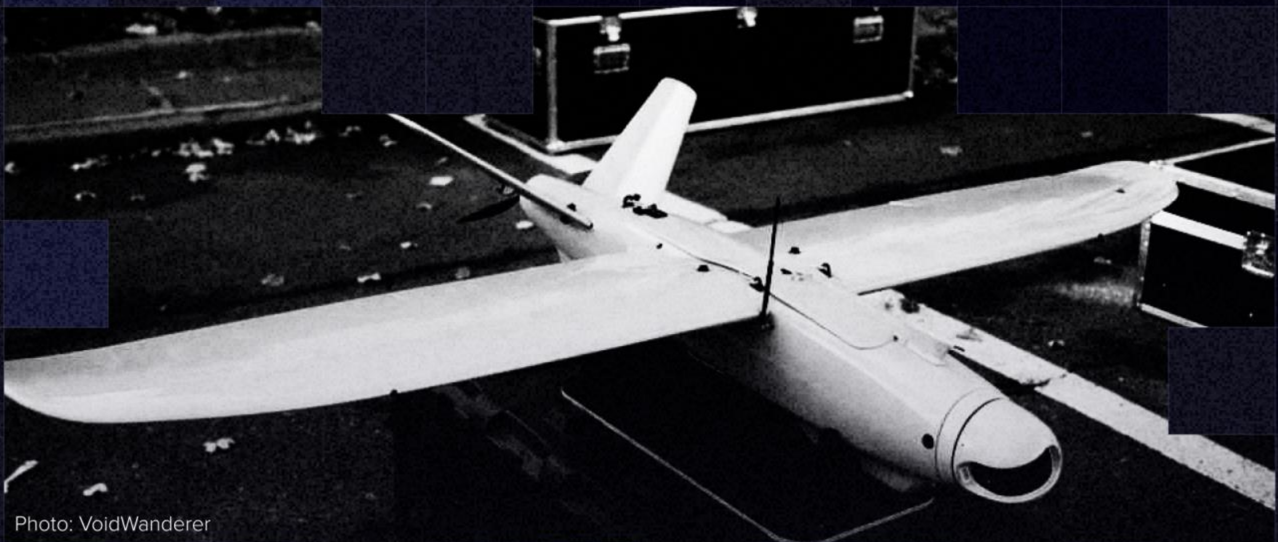

Photo: VoidWanderer

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EXECUTIVE SUMMARY

The war in Ukraine has made drones the central weapon of modern conflict. By 2025, **80–85% of frontline targets were engaged by UAVs**, with at least **215,000 strikes** in summer alone. This shift was enabled by a nationwide ecosystem of rapid innovation and low-cost adaptation. Ukraine's capacity now reaches 10 million drones annually, reinforcing its role as a "drone state."

While Ukraine has scaled fast, the U.S. remains constrained by procurement systems built for complex, long-cycle programs. This creates a gap between emerging threats and U.S. capabilities, highlighting the need to adapt policies, logistics, and training to drone-centric warfare. NATO's intensified air defense after Russian drone incursions into Poland and Romania confirms that drones are no longer peripheral but a core security challenge.

The rapid evolution of unmanned aerial systems (UAS) has made them a decisive factor on the modern battlefield. Since 2022, Ukraine has transitioned from reliance on commercial off-the-shelf components to the development of proprietary, military-grade solutions in **communications, navigation, and autonomy—the three core pillars of drone effectiveness**. Enemy electronic warfare (EW) and the fluid nature of combat operations have rendered traditional systems insufficient, accelerating demand for innovative technologies and indigenous production.

- **Communications** are the backbone of unmanned operations. Ukrainian firms developed resilient solutions using open-source platforms, multi-band modems, and military-grade systems that withstand EW. Satellite links (notably Starlink) and innovations like phased-array antennas, MANET networks, and directional links ensure continuity.
- **Navigation** has advanced beyond GPS, with inertial systems, ground triangulation, and AI-powered visual navigation (e.g., Bavovna.ai, Twist Robotics' Oscar) enabling operations in GPS-denied environments.
- **Autonomy** is shifting drones from operator-dependent tools to independent combat systems. From flight automation in 2022, Ukraine now fields drones with target recognition, strike coordination, and swarm intelligence (e.g., The Fourth Law, Swarmer), reducing human workload and amplifying combat effects.
- **Integration** of drone types with each other and with conventional weapons expands roles—from FPVs and bombers working in tandem to naval drones equipped with air-to-air missiles for striking fighter jets. Each drone type now serves as a modular platform, with functions and payloads added as needed—giving the industry virtually unlimited room for growth.

These technologies are shaping the future of all unmanned systems in Ukraine's Armed Forces. Drones have been adapted for diverse missions across varying battlefield conditions, with the main categories including:

- **FPV drones**: agile first-person-view systems used for precision strikes at close range
- **Multicopter bombers**: heavy-lift UAVs carrying multiple munitions for frontline fire support
- **Middle Strike drones**: medium-range drones delivering payloads deep behind tactical lines
- **Deep Strike drones**: long-range systems targeting strategic infrastructure far from the front
- **Interceptor drones**: UAVs designed to hunt and neutralize enemy ISR and strike drones
- **Reconnaissance drones**: ISR assets providing real-time intelligence and artillery adjustment
- **Ground drones (UGVs):** robotic vehicles for logistics, assault, demining, and fire support
- **Maritime drones**: Surface or subsurface systems used for reconnaissance and strikes

Acknowledging the shift to low-cost mass and rapid frontline iteration of sUAS as routine combined-arms tools, the United States responded in 2025 by releasing the June executive order Unleashing American Drone Dominance and SecDef Hegseth's July memo Unleashing U.S. Military Drone Dominance, which reclassify small sUAS as consumables, push authority to O-6 commanders, and prioritize modular, swappable designs. For the United States, scale is emerging as the central obstacle in adapting to the new era of drone warfare. Boutique Blue UAS vendors remain limited by high costs and low production volume. Meanwhile, supply chains for essential components remain heavily concentrated in East Asia, exposing the U.S. to strategic vulnerabilities. In the absence of a sustained demand signal, certification milestones and pilot deployments have not translated into mass fielding. These dynamic risks leaving the U.S. behind its peers: Ukraine, Russia, and China are already iterating designs on the battlefield, compressing development cycles, and scaling production in ways the U.S. has not yet matched.

Addressing this challenge requires a practical and industrially focused approach. First, the Department of Defense must establish a multiyear, multi-billion-dollar demand signal for attritable sUAS and institutionalize a "fly-before-you-buy" model within brigade-level exercises, thereby allowing only platforms proven resilient to electronic warfare and sustainable at scale to move forward. Second, domestic production capacity should be expanded through two to three federally backed drone corridors under Defense Production Act authorities—consolidating test infrastructure, localizing key components, and reducing investment risks for private firms. Third, the armed forces should embed sUAS proficiency as a baseline skill at squad and platoon level and incorporate piloting, swarm coordination, and low-signature operations. Legislative enablers, such as targeted tax credits, FAA-cleared test corridors, and a national reserve of drones to stabilize demand across budget cycles should complement this effort. Finally, U.S.–Ukraine co-production offers a force multiplier: pairing Ukraine's combat-validated designs and rapid feedback loops with U.S. manufacturing, logistics, and financing would create interoperable fleets at the speed and scale the modern battlefield requires.

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OVERVIEW: THE NEW DRONE WAR

At the outset of Russia's full-scale war against Ukraine, both sides relied mainly on conventional means of warfare: artillery, aviation, tanks, and infantry weapons. Drones were largely confined to reconnaissance missions and adjusting artillery fire.

In 2022, Russian forces were firing 40,000[1]–60,000[2] artillery rounds per day. This created a wall of fire. Ukrainian stocks and limited Western assistance allowed only 5,000–7,000 rounds per day.

That imbalance created an urgent problem. Ukraine needed a mass weapon, affordable and effective, that could compensate for its shortage of artillery. Precision-guided weapons supplied by partners proved vulnerable to Russian countermeasures, and the pace of their production and deliveries fell far short of the needs of a frontline stretching some 1,500 kilometers.

The problem began to be addressed nationwide. Soldiers, private companies, government, and volunteers understood that the key is in adapting widely available civilian technologies. With low entry barriers, the whole country became an incubator for frontline solutions. Over time, a decentralized ecosystem emerged, delivering innovation to the military.

Aerial drones became the most widespread segment of military innovation. Ground and maritime unmanned systems also appeared, addressing specific operational tasks.

The rapid development of aerial UAVs has led to a situation where 80–85% of frontline targets are now engaged by drones. In absolute terms, during the summer of 2025, Defense Forces of Ukraine struck at least 215,000 targets using UAVs. The balance of weapon systems has shifted so significantly that it is now reflected in the doctrines and guidance documents of both Ukrainian and Russian forces.

One of the drivers of this rapid success has been the fast cycle of "development – combat testing – modification – combat testing." This adaptive process makes it possible to adjust existing weapon systems to a dynamic battlefield within months and to integrate new technologies.

Aerial UAVs provided both mass and precision in target engagement. Their low cost became another critical factor in a war of attrition, where the aim is to inflict maximum damage on the adversary's military and state apparatus at minimal expense. Ukraine's UAV Forces estimate that damaging one target with a drone costs on average $850[3].

Another response to the war of attrition has been the use of Deep Strike drones—relatively low-cost systems that sustain a high tempo of attacks deep behind enemy lines, forcing both sides to react to a constant, growing threat.

A clear trend has emerged: offensive UAV capabilities are developing and scaling faster than defenses against it. Yet UAV technology itself is changing this balance. Interceptor drones are several times cheaper than reconnaissance UAVs. Drone-on-drone combat is becoming as common as past battles between surface-to-air missiles and cruise or ballistic missiles.

[1] See "U.S. and NATO Scramble to Arm Ukraine and Refill Their Own Arsenals," The New York Times,
[2] See "Russia Targeted Ukrainian Ammunition to Weaken Kyiv on the Battlefield," The Washington Post
[3] See "Unmanned Systems Forces of the Armed Forces of Ukraine," Telegram [ua]

As of 2025, Ukraine can produce up to 10 million drones annually and generate new solutions in this domain, reinforcing its brand as a “drone state”. This capacity is sufficient both to meet both national needs and exports.

At the same time, the United States is only beginning to face the full implications of drone warfare. Despite having advanced defense industries and cutting-edge aerospace companies, the U.S. military has been slower in adopting small, expendable, and mass-produced drones for frontline use. Procurement systems remain optimized for complex, long-cycle programs rather than for rapid innovation and high-volume production. This has created a gap between the scale of threats emerging in modern conflicts and the pace at which the U.S. can field countermeasures or offensive swarms. The Pentagon is now grappling with how to adapt its acquisition policies, logistics, and training to the reality that drones—rather than traditional platforms—are defining the tempo of war.

Ukraine’s experience offers an unparalleled case study for the U.S. defense community. No other country has tested millions of drones under real combat conditions, across every domain of warfare, and against a technologically sophisticated adversary. Lessons from Ukraine show how decentralized innovation, flexible production, and fast battlefield feedback loops can outpace rigid systems. By leveraging Ukraine’s technological breakthroughs and operational practices, the United States has the opportunity not only to improve its own defense posture, but also to shape a broader allied approach to drone warfare—where speed, scale, and adaptability determine strategic advantage.

Recent NATO responses underscore that drones are no longer a peripheral issue but a central challenge for European security. After repeated incidents of Russian drones crossing into or crashing on the territory of Poland and Romania, NATO had to intensify air defense coordination. Whatever form future conflicts may take, every country must prepare to deal with drones, because adversaries and potential threats are already integrating them into their arsenals at scale.

UKRAINIAN DRONE LANDSCAPE

Drones—a collective term for unmanned systems operating in the air, on land, and at sea, with varying levels of automation (ranging from continuous manual control to autonomous mission execution with decision-making capability).

Over three years of full-scale war, several key types of unmanned systems have emerged:

- FPV drones
- Multicopter bombers
- Middle Strike drones
- Deep Strike drones
- Interceptor drones
- Reconnaissance drones
- Ground drones (UGVs)
- Maritime drones

This categorization developed organically and based on their tactical purpose, technical characteristics, domains of employment, and the expertise of the Defense Forces.

OPERATIONAL RANGES OF DRONE CATEGORIES

NAME	FIGURATION	OPERATIONAL RANGE
DEEP STRIKE DRONES		up to 2000 km
MARITIME DRONES		up to 1600 km
MIDDLE STRIKE DRONES		up to 200 km
RECONNAISSANCE DRONES		up to 200 km
MULTICOPTER BOMBERS		up to 60 km
FPV DRONES		up to 40 km
INTERCEPTOR DRONES		up to 30 km
GROUND DRONES		up to 20 km

Each type has established its own role in fulfilling military tasks. The categories are broad, without strict boundaries, and often overlap. Within each type there are subcategories. For example, ground drones include logistics, engineering, and combat variants.

Overall, the unmanned systems sector is highly dynamic, and categorization continues to evolve. In 2023, the "Middle Strike" did not yet exist as a category. Although some models of this type were already in use, they did not account for a sufficient pace of production and employment to be considered a distinct category.

FPV Drones

Operational range
up to 40 km

Production capacity
8-10 million units per year

Cost
$700-2,000

Example models
Shrike, Vyriy, Pegas

Annual capacity growth
+300%

Share of all targets engaged at the tactical level
~40-45% (estimation)

Primary target types
armored and unarmored vehicles, shelters, infantry

FPV drones first appeared in this conflict in 2022. At that time, military personnel, working alongside volunteers, adapted commercial racing drones to deliver munitions to designated points of interest, thereby enabling target engagement. The high precision of FPV drones operating at the tactical depth, combined with the growing shortage of artillery ammunition during 2022–2024 and the enemy's numerical superiority, generated a strong demand for scaling up the FPV drone production.

From limited strikes in 2022, the Defense Forces of Ukraine have progressed to conducting 30,000–45,000 target engagements per month using FPV drones. Owing to their mass employment and versatility, Ukrainian operators are able to strike every target within 0–10 km from the frontline (the so-called kill zone), and at longer distances they can engage most high-priority targets.

Real-time control and the maneuverability of FPV drones translate into relatively high accuracy compared to other types of weapons. Operators can circle a target, identify its most vulnerable point, and strike precisely there. This type of drones is also highly effective in eliminating enemy infantry conducting daily assaults on Ukrainian positions. In practice, every Russian soldier becomes a potential target for a drone.

In the relative rear, Ukrainian forces disrupt enemy logistics chains, engage tanks, strike enemy pilot positions, and target concentrations of infantry and equipment. This degrades command and control as well as sustainment, rendering enemy units combat-ineffective before they reach the frontline.

Beyond their main purpose, FPV drones perform a logistical role—delivering supplies to friendly forces—and a communication function, relaying signals for other drones. In other words, they have evolved into a multi-purpose platform. Some manufacturers and units are testing the integration of small arms on FPV drones, including shotguns, rifles, and grenade launchers, etc.

Although FPV drones are traditionally compared to artillery, they have effectively occupied a broader role within the army's weapons system.

A separate task undertaken by manufacturers is the replacement of Chinese components—ranging from circuit boards to cameras—with Ukrainian and Western alternatives. In March, Vyriy Drone presented its first batch of 1,000 drones entirely built from Ukrainian components. Overall, according to a study[4] by the Ukrainian Technological Forces and BRDO, 38% of UAV, electronic warfare (EW) systems, and other system manufacturers incorporate more than 50% Ukrainian or Western components into their products.

One of the newest technologies in the FPV drone field is fiber-optic cable control. This allows drones to be made resilient against Russian electronic warfare.

Ukrainian R&D teams and companies are actively iterating to enhance platform autonomy: automatic target reacquisition, automated target identification, autonomous decision-making, drone swarm operations, and more. These solutions increase overall strike effectiveness, reduce the impact of human factors and EW, and enable operations in complex terrain.

Multicopter Bombers

Operational range
20-60 km

Annual capacity growth
+300%

Primary target types
shelters, buildings

Production fact
30,000 units in 2024

Share of all targets engaged at the tactical level
~25-30% (estimation)

Example models
Vampire, Kazhan, Nemesis

Cost
~$5,000–25,000

Unlike FPV drones, reusable multicopter bombers have been developed in Ukraine since 2014–2015, but the full-scale invasion provided a significant impetus for the sector.

Multicopter bombers, like FPV drones, compensate for artillery shortages on the battlefield. They can carry up to 15 kg of payload but typically operate at night due to their large size and consequent visibility. Their operational range depends on the type of communication link (radio or satellite) and payload weight. Bombers usually fly up to 15–20 km, which is sufficient for tactical missions, but there are special operations designed to engage high-priority targets at distances of up to 40–60 km.

Each brigade on the frontline employs this type of drone. The primary mission of bombers is the precision engagement of shelters and buildings—locations where Russian forces are concealed. The drone hovers over the target and typically releases several munitions sequentially. After each “shot,” the operator can adjust the drone for maximum strike accuracy. A lesser-known advantage of bombers is their ability to effectively engage targets hidden in forested terrain. Other types of drones perform worse in such conditions, as they cannot penetrate deeply into the forest.

During a single night shift, a drone can carry up to 100 kg of payload. Bombers are also actively used for remote anti-tank and anti-personnel mining. This enables control over enemy supply routes and forested areas through which infantry advances, thereby preventing breakthroughs.

[4] See “War-Driven: The Rise of Ukrainian Defence Tech and the Private Industry Behind It,” Tech Force in UA and BRDO

With the development of UAVs in the Russian military, Ukrainian logistics near the frontline is also significantly affected. It has become increasingly difficult for any vehicle, from IFVs to pickup trucks, to reach Ukrainian positions. Under these conditions, the military has developed an alternative method of delivery—aerial, using bombers. Drones transport munitions, food, water, medicine, clothing, parcels from family, and even other drones. There is a recorded case where a drone delivered an electric bicycle to enable the evacuation of a wounded soldier. This has led to the practice of assigning crews exclusively for logistical operations.

One of the specialized UAV units (429th UAV Regiment "Achilles") conducted 1,603 cargo deliveries in 2024[5], averaging 4.4 per day. Over the first seven months of 2025, the same unit remotely emplaced approximately 11,000 mines, averaging 52 mines per day.

In navigation, multicopter bombers rely on CRPA GPS-receivers, which provide resilience against EW interference. For more precise positioning, some bombers also use visual stabilization through cameras and software.

Enhancing the effectiveness of this category of drones depends on continuous improvements in mission autonomy and communications between drone and operator.

Middle Strike Drones

Operational range
up to 200 km

Example models
RAM-2X, FP-2, Backfire

Cost
~$1,200–50,000

Number of Ukrainian models
10+

Primary target types
armored and unarmored vehicles

The Middle Strike category is defined by its engagement range into the operational depth, generally assessed between 20–40 km to 150–200 km beyond the frontline. It includes mainly fixed-wing loitering munitions and fixed-wing bombers. The U.S. Switchblade 600 and the Ukrainian RAM-2X are classic examples. Some experts also include extended-range FPV drones and long-range multicopter bombers in this category.

The development of Middle Strike systems was driven by the decline in effectiveness of precision-guided munitions reliant on satellite navigation during 2022–2023, as Russian systemic countermeasures evolved. Another factor was the challenge of engaging moving targets or recently moved targets on long distances. Loitering strike UAVs were able to pursue such targets and engage them dynamically—a capability largely unavailable to Ukraine's artillery and missile systems.

Middle Strike UAVs are capable of destroying vehicles, armored platforms, artillery, air defense systems, radars, and more. Their key distinction from tactical UAVs is based on their range, achieved through aerodynamic design, increased battery capacity, and sometimes reduced warhead weight. Operating at these ranges also requires extended communication links or even satellite connectivity.

[5] See "The Achilles Battalion Destroyed and Hit 12,000 Targets in a Year," Mediaport [ua]

Attacks with Middle Strike UAVs directly affect assets of enemy formations in rear areas, disrupting logistics and force integrity, with tangible effects on the battlefield.

Fixed-wing loitering munitions are among the most effective assets in this class. They strike at depths of 30–200 km, typically carrying warheads of 1.5–6 kg, though some models can deliver up to 105 kg. Depending on their electro-optical systems, they can operate both day and night. Most models are equipped with digital communications and terminal guidance systems.

Fixed-wing bombers are employed at ranges up to 90 km with warheads of up to 9 kg. They engage targets by releasing munitions from above. These systems generally operate at night and at low altitude to improve accuracy. Missions are pre-programmed and executed autonomously, relying on GPS navigation. UAVs are designed to strike stationary targets such as shelters, buildings, equipment, vehicles and infantry positions, including those under tree cover.

The term Middle Strike first appeared in early 2025. By mid-2025 more than 10 models were already in operational use. Promising directions for development include automation of target detection, acquisition and terminal guidance and integration of real-time communications and control for canceling the mission or changing the target.

Deep Strike Drones

Operational range
up to 2,000 km

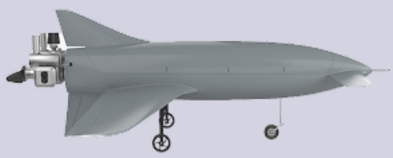
Jet drone cost
up to $1,000,000

Production capacity
over 33,000 units per year

Share of all targets engaged at the tactical level
~25-30% (estimation)

Production growth
22 times (2024 compared to 2022)

Example models
AN-196 Liutiy, UJ-26 Beaver, FP-1



Primary target types
defense industry facilities, oil refining infrastructure, military depots

At the onset of the full-scale war, Ukraine was without strategic weapons. Thanks to the initiative of manufacturers, the military, volunteers and government, a new type of drone emerged in the country—Deep Strike (long-range one-way attack drone). By the end of 2022, only 2–3 companies were producing long-range drones. These systems performed a basic function: delivering munitions without a high level of technological sophistication.

From isolated Deep Strike drone attacks in 2022, Ukraine progressed to 377[6] successfully engaged targets in 2024. The number of manufacturers increased to 11+, and production capacity now exceeds 33,000 UAVs per year.

[6] See "The Deep Strike's Range Deep Into the Territory of the Russian Federation Has Already Reached 1,700 km, We are Preparing New Long-Range Weapons, – Syrskyi," Novynarnia [ua]

The variability in range (300–2,000 km) and warhead weight (8–250 kg) allows projection of force over 25% of the territory controlled by the Russian Federation. Strikes with low-cost systems are conducted in regions that have not experienced military operations even during World War II.

Ukrainian forces focus on military depots, command posts, defense industry, airfields, logistics hubs, and the oil industry, which supplies fuel and finance to the Russian military. Beyond the direct effects—asset destruction and production stoppages—these strikes reduce pressure on the frontline, force the Russian government and military to develop countermeasures, expend additional resources on protecting facilities, relocate assets, restore infrastructure, and mitigate social pressures. In effect, long-range drones compel the adversary to focus on defense and recovery rather than offense.

Deep Strike drones have become an integral part of Ukraine's security and future deterrence strategy.

To support and enhance their effectiveness, manufacturers continuously refine the drones as Russia increases countermeasures. Engineers improve overall UAV reliability, integrate sensors for low-altitude flight, develop solutions to counter Russian EW, design specialized warheads, and more.

A relatively new type of Deep Strike drone is the drone-missile—systems with jet engines capable of reaching speeds up to 900 km/h. This category combines the advantages of both conventional UAVs and missiles: scalable production, low cost, significant kinetic energy, etc.

Long-range drones continue to evolve toward precision positioning, reduced vulnerability to EW, visual target acquisition, and other capabilities.

Interceptor Drones

Operational range
~30 km

Cost
~$800–7,000

Example models
Taras-P, Sting, Shulika

Primary target types
reconnaissance UAVs such as Zala, Supercam, Orlan, Merlin, and strike UAVs such as Lancet, Shahed/ Geran and Gerbera

The mass use of reconnaissance UAVs by Russia during 2022–2024 enabled it to maintain battlefield situational awareness, adjust artillery fire, and conduct strikes with precision-guided weapons.

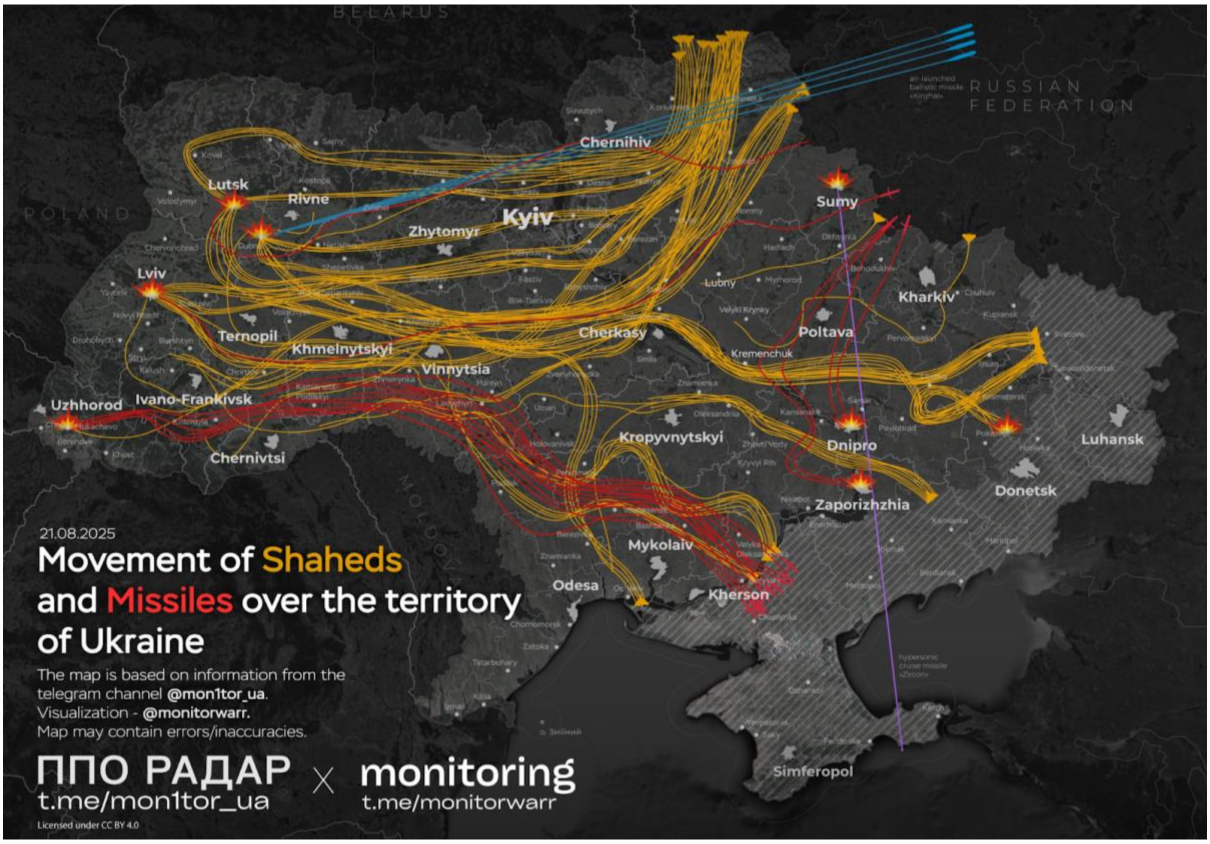
In the face of a shortage of conventional air defense assets, during 2024–2025 the Defense Forces developed a systemic capability to shoot down reconnaissance aircraft using UAV interceptors. This capability emerged through the rapid evolution of unmanned aerial systems and the effective integration of radar technologies with UAVs as kinetic effectors. Radars provided sufficient accuracy to detect aerial targets and guide UAV interceptors, which were operated by skilled operators. Scaling was facilitated by the low cost (starting at $800) and the accessibility of such drones.

Interceptor platforms include high-speed multicopter and fixed-wing UAVs capable of destroying targets at altitudes of up to 5 km and speeds up to 120 km/h. The main targets near the frontline are reconnaissance UAVs such as Orlan, Supercam, Zala along with the Lancet loitering munition.

A cost-effectiveness analysis at the tactical level comes to a ratio of roughly 1 to 10 between the cost of interceptors/auxiliary equipment and the value of the UAVs destroyed. Reconnaissance UAVs are usually equipped with expensive payloads, long-range communications, and reliable navigation systems. By contrast, interceptors require only simple line-of-sight communications and inexpensive optical seekers for target guidance.

Although official statistics on enemy UAV destroyed by interceptors are not disclosed, open-source analysis reveals clear trends. In October 2024, the number of interceptions did not exceed several hundred per month. By the summer 2025, the figure exceeded one thousand successful engagements of enemy reconnaissance and strike UAVs per month.

VISUALIZATION OF A RUSSIAN AIR STRIKE IN WHICH IT EMPLOYED 574 DEEP STRIKE DRONES, 33 CRUISE MISSILES, AND 6 BALLISTIC MISSILES



Source: monitoring Telegram channel

The establishment of an interception system has drastically limited the enemy's ability to deliver strikes with short-range ballistic missiles, artillery, guided bombs, and loitering munitions, while significantly reducing the risk of Ukrainian positions being detected.

Traditional air defense methods have proven economically inefficient in countering Deep Strike drones. The cost of interception using surface-to-air missile (SAM) systems (~$400,000–1,000,000 per missile) often far exceeds the cost of the target (up to $200,000). Another limiting factor is the imbalance between production rates of SAM interceptors and the mass manufacture of enemy UAVs.

To counter such threats, new high-speed UAVs (300+ km/h) are being developed. The first confirmed successful interceptions of Shahed drones by UAV interceptors were recorded in early 2025.

The first interceptors used to target reconnaissance UAVs were technologically similar to standard FPV drones employed for ground strikes. The main requirement was a reliable digital video link for high-quality image transmission.

Today, engineers have already created and continue to create specialized UAVs designed exclusively for engaging aerial targets. They feature streamlined aerodynamic designs, more powerful engines, and high-energy batteries, allowing speeds of over 300 km/h and interceptions more than 30 km from the launch point. Automated guidance systems are being introduced, which are indispensable for systematic and effective interception at high speeds.

The Defense Forces are also testing reusable platforms equipped with onboard weapons to improve interception efficiency, as well as airborne interceptors launched from drone carriers—expanding the engagement envelope. To enable coordinated, simultaneous use of multiple interceptors, automated launch and coordination systems are being developed.

Experience gained over the past two years shows a clear trend: the most effective way to counter enemy UAVs is to employ UAVs of one's own.

Reconnaissance UAVs

Operational range
up to 200 km

Number of Ukrainian models
30+

Example models
AN-196 Liutiy, UJ-26 Beaver, FP-1

Cost
~$1,500–400,000

Growth in number of models
more than five times increase (2025 compared to early 2022)

Primary missions
observation, reconnaissance, detection of enemy forces and weapons, fire adjustment

Aerial reconnaissance is a key element in providing situational awareness, detecting enemy forces, directing strikes, and conducting damage assessment. Under current conditions, unmanned aerial vehicles are the primary tool of tactical reconnaissance. In active combat zones, approximately 80–90% of targets are identified by UAVs, while the frontline remains under continuous round-the-clock surveillance.

Until 2022, the Defense Forces had only a limited number of Ukrainian fixed-wing reconnaissance UAVs. Approximately five models were used for real-time reconnaissance, observation, and fire adjustment. For imagery and terrain mapping, about three models of 'photo-drones'—UAVs equipped with downwardfacing fixed cameras—were in service. The multicopter segment used for close frontline monitoring was dominated by products of the Chinese company DJI.

The onset of the full-scale invasion triggered a sharp surge in demand for reconnaissance UAVs. This was reflected in large-scale procurement of available domestic and foreign systems, as well as the launch of new development programs. Numerous manufacturers entered the market, producing increasingly effective reconnaissance platforms.

Since early 2022, the number of new Ukrainian-made UAV models has increased to more than 35. Ukrainian teams, in particular, have developed and are actively testing about 10 analogues of the DJI Mavic, the most widely used reconnaissance drone.

The latest UAV models have the following typical parameters:

TYPICAL PARAMETERS OF RECONNAISSANCE UAV MODELS

Characteristic	Fixed-wing	Multicopter
Payload (kg)	1–5	2–9
Combat radius (km)	30–50	8–10
Operating altitude (m)	500–1500	100–175
Service ceiling (m)	2000–3500	550–1250
Cruise speed (km/h)	70–110	45–65
Endurance (min)	120–180	30–50

Some models demonstrate outstanding performance within their category. For instance, the ACS-3 Raybird, with a takeoff weight of only 23 kg, can remain airborne for more than 28 hours. The Shark-M, weighing 14.5 kg and powered by an electric motor, achieves over 7 hours of endurance.

There are also serially produced UAVs capable of operating without GPS, relying instead on optical navigation and AI-based positioning algorithms. One such system is the Soika.

Since mid-2025, the enemy has actively employed interceptor drones against Ukrainian reconnaissance UAVs. This has increased losses and significantly complicated aerial reconnaissance, imposing new requirements on systems.

The new battlefield reality reduces reconnaissance effectiveness and increases attrition rates. To mitigate risks, reconnaissance UAVs are forced to operate at higher altitudes, limit time over target, fly at greater speeds, and dodge interceptor attacks. This creates the necessity to integrate higher-resolution electro-optical systems for operations at greater altitudes, enhance speed and altitude performance, add sensors to detect approaching enemy drones, and program autopilots to dodge attacks. Manufacturers are also tasked with reducing both visual and radar signatures.

Unmanned Ground Vehicles (UGVs)

Operational range
up to 20 km

Endurance
up to 20 km with payload

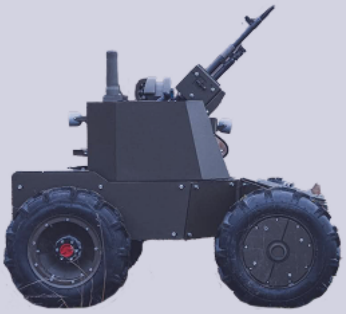
Example models
Termit, Targan, Zmiy

Cost
~$1,000–60,000 (depending on type)

Production fact
~2,000 units – 2024

Planned production
~15,000 units – 2025

Primary missions
logistics, mine-laying, fire engagement, evacuation



Usage volume
one brigade transports 20,000+ kg of cargo per week

Unlike aerial unmanned systems, UGVs remained on the "periphery" until 2024: there was a lack of operators, technical infrastructure (workshops, communication systems, auxiliary equipment), employment tactics were still being developed, and effectiveness at the unit level had not been proven. Consequently, procurement was many times lower than in the UAV sector (hundreds of times by quantity). Military demand existed, but it was not for mass deployment—rather, for testing new technologies, ranging from logistics to fire support.

In 2024–2025, the sector experienced significant acceleration in development. This was driven in part by the enemy creating tactical challenges for Ukrainian infantry, prompting the military to formulate demand for specific technological solutions that could be scaled.

As of early 2025, the country had over 200[7] teams developing unmanned ground vehicles and more than 280[8] models, indicating a high level of competition and experimentation in this sector.

In addition to small experimental platoons and companies, the first strike UGV company was formed within the 3rd Assault Brigade, and the first UGV battalion within the 20th UAV Regiment "K-2" This demonstrates positive sector development, with advanced units gradually increasing their capabilities in employing unmanned ground systems in response to a battlefield environment that is becoming increasingly hazardous for personnel. The mentioned 3rd Assault Brigade transports several dozen tons of cargo per week using UGVs.

UGVs perform tasks that, in the context of modern warfare, pose significant risks to human life and health. The most common of these is logistics: delivering ammunition, water, and food into areas controlled by enemy UAVs and under intense fire. Enemy drone activity is so pervasive that most logistics missions using pickups or armored vehicles end in damage or destruction.

[7] See "More Than 200 Companies in Ukraine Involved in Ground Drone Production," Militarnyi
[8] See "Ukraine hosts hackathon dedicated to long-range strikes and remote mining," Militarnyi

UGVs are also increasingly employed for casualty evacuation (CASEVAC), remote mine-laying, demining, and transporting and emplacing obstacles. Initiative units are deploying kamikaze drones and UGVs equipped with machine gun and grenade launcher turrets for fire engagement.

Unlike UAVs, which operate in relatively "free" airspace, employing UGVs requires much more meticulous planning. Despite these challenges, development teams and military personnel cooperate to refine both the systems and their employment methods to enhance effectiveness.

The technological development of UGVs is directly linked to improvements in communication systems and increased platform autonomy. Future robotic operations will require solutions enabling the simultaneous deployment of dozens of vehicles within unified battle formations.

Another development vector is vehicle modularity. This will provide units with flexibility in preparing UGVs for specific tasks, ranging from logistics and evacuation to fire support and mine-laying.

UGVs are gradually transitioning from an "experimental addition" to a fully integrated element of combat operations. Key technological development areas include autonomy, resilient communications, modularity, and mass production. These advancements will enable the use of unmanned ground vehicles not only for individual tasks but also for complex operations in coordination with UAVs and other units. In the long term, this will allow the emergence of fully integrated "robotic groups" on the frontline, capable of executing a wide range of high-risk missions without endangering soldiers' lives.

Maritime Drones

Operational range
up to 1,600 km

Cost
up to $300,000

Confirmed vessels damaged or destroyed
at least 21

Primary target types
ships, boats, port and logistics infrastructure

Warhead weight
up to 1,000 kg

Example models
Magura, Sea Baby, Katran

Russia initially held a significant advantage in fleet size and capability in the Black Sea region. This allowed it, in early 2022, to establish full control over the Sea of Azov and largely block Ukraine's access to the Black Sea coast. The successful use of the Ukrainian Neptune anti-ship missile to sink the cruiser Moscow forced the Russian Navy to act more cautiously but did not change its strategic objective: the naval blockade of Ukraine.

Maritime shipping is strategically vital for Ukraine's economy and for global food security, given that most grain exports are transported by sea. The July 2022 grain deal guaranteed safe passage for agricultural shipments from Ukraine. However, the presence of Russian warships continued to pose a real threat—historical precedent shows that Russia often disregards agreements. Ukrainian engineers, together with the military, began developing a solution to degrade Russia's naval capabilities. The result was an asymmetric answer: unmanned surface vessels (USVs). These systems fit into the Ukrainian Navy's "mosquito fleet" strategy.

Ukrainian maritime drones (Magura, Sea Baby, Katran, and others) are typically equipped with a camera, satellite communications for control, a warhead, and satellite navigation. Some variants also feature redundant communications, acoustic sensors, backup cameras, and radars. Armament configurations vary and may include conventional explosives or aerial bombs, machine guns, short-range air defense systems based on R-73/AIM-9 missiles, multiple-launch rocket systems, and naval mines for dynamic mining.

This variety of weaponry allows them to engage not only ships but also land and air targets. In 2025, **a maritime drone intercepted a Su-30 fighter for the first time**. Modularity has also influenced tactics: drones operate both individually and in packs, with some acting as kamikazes while others provide cover against helicopters and aircraft.

The systematic employment of maritime drones led to a strategic outcome: the complete expulsion of Russia's fleet from the western Black Sea. As a result, merchant vessels can now reach Ukrainian ports without agreements from Russia.

To date, maritime drones have been credited with damaging or destroying at least 21 vessels of various sizes, 3 helicopters, 2 aircraft, and the Crimean Bridge. This "long naval spear" has become not only a strike weapon, but also a tool of deterrence and a guarantor of maritime security.

The maritime drone sector remains in active development. New engineering teams are emerging, riverine models are being introduced, new weapon systems are integrated, and undersea drones are in progress. Tested platforms already exist that can carry loitering munitions for strikes against land targets. Such solutions pave the way for integrating interceptors, reconnaissance UAVs, and multicopter bombers into maritime and littoral operations.

TECHNOLOGICAL FOUNDATIONS AND EMERGING TRENDS OF UNMANNED SYSTEMS' DEVELOPMENT

Communication, autonomy, and navigation constitute the three cornerstones enabling the operational use of UAVs.

The period of 2022–2023 served as a testing ground for scaling available technological solutions, where mass adoption often prevailed over quality. Most UAVs relied on flight controllers, communication and navigation modules, and electro-optical systems adapted from the hobbyist market and easily purchased online. Only manufacturers active prior to 2022 had integrated proprietary or specialized solutions into their platforms.

Enemy countermeasures and the rapidly evolving battlespace demanded advanced technologies unavailable on the mass market. Moreover, specialized military-grade systems—seemingly proven by time—also quickly lost effectiveness for the same reasons or proved unsuitable in terms of cost and scalability under current battlefield conditions. This created strong demand for the development of indigenous technologies, the contours of which were outlined and tested during the early years of the war.

The years 2024–2025 have become the most active in terms of integrating new technological solutions. In each of the key domains, Ukrainian manufacturers have been developing proprietary—and often innovative—capabilities.

Communication

Communication remains the most critical component of unmanned aerial systems (UAS). It is communication that enables remote, external control—ultimately defining these systems as unmanned. Although the time is inevitably approaching when drones will be able to carry out missions with minimal operator intervention, communication will continue to play a vital role—either in supporting human–machine interaction or enabling autonomous coordination between unmanned systems.

Ensuring resilient communications for UAVs on the battlefield requires a variety of solutions. For example, the openness of the ELRS platform allowed military engineers and volunteers to rapidly adapt modules for the operational environment, adjusting to the intensity of electronic warfare (EW) in specific frequency bands. This flexibility enabled continued use of drones despite adversary interference. Another effective solution has been the adoption of multi-band modems and specialized military-grade systems.

One such company, **Teletaktica**, which has already raised $1.5 million from MITS Capital and Green Flag Ventures, manufactures military-grade modems and antenna systems for UAVs. Their products cover a wide frequency range and employ frequency-hopping spread spectrum (FHSS). Combined with amplifiers, signal filters, and a tailored approach to end-users, these solutions ensure reliable communications even under heavy electronic warfare conditions.

Another company, **Sine.Engineering**, also develops integrated UAV communication systems designed for contested electromagnetic environments. Their solutions deliver robust connectivity through an effective combination of advanced hardware components and specialized software.

STAND WITH SINE.ENGINEERING COMMUNICATION SOLUTIONS

Source: Militarnyi

Expanding frequency ranges is not the only pathway for the development of UAV communication systems. The use of highly directional antennas with tracking systems, phased-array antennas, and MANET (Mobile Ad Hoc Network) technologies for creating decentralized networks can also ensure the required quality of communications on the battlefield.

Satellite communications—most notably **Starlink**—have also become an integral component of unmanned systems. The relatively low weight of terminals, minimal latency, and the difficulty of suppressing satellite links with electronic warfare measures have made their integration into UAV platforms both feasible and operationally advantageous.

Navigation

A prerequisite for the autonomous employment of unmanned systems is the ability to determine position in time and space with high precision. Many civilian and military platforms have traditionally relied on satellite navigation systems. However, as the current conflict has demonstrated, such signals are easily jammed or spoofed—often resulting in the loss of a drone. The ability of a UAV to orient itself independently is therefore a cornerstone capability for mission accomplishment.

For some UAVs, Controlled Reception Pattern Antennas (CRPA) capable of filtering out false signals can mitigate these challenges. Yet, under conditions of intensified adversary interference, such systems may also fail to provide sufficient reliability. In these cases, navigation tasks shift either to human operators (if communication with the UAV is maintained) or to inertial systems. Standard UAV-grade inertial systems can typically return a drone to base but cannot ensure accurate targeting.

Since 2023, alternative solutions for resilient navigation have started to appear on the battlefield. Within line-of-sight operations, triangulation algorithms using pre-installed ground beacons have been employed. Ukrainian engineers have also pioneered visual navigation methods, in which imagery captured by onboard cameras is compared against pre-loaded maps or satellite imagery.

The startup **Bavovna.ai** has developed an inertial navigation kit that provides location data independent of both satellite systems and electronic warfare interference. For accurate positioning, the module combines an accelerometer, gyroscope, compass, barometer, multi-vector airflow sensor, and artificial intelligence to process data from multiple sources. Developers note that the module can also integrate ultrasonic, infrared, and optical sensors, further enhancing navigation resilience.

BAVOVNA.AI HYBRID INS NAVIGATION KIT

Source: Bavovna.ai

The company **Twist Robotics**, known among the military for its FPV drone simulator Obriy, has also developed a dedicated module called Oscar, designed to integrate visual navigation capabilities into UAVs.

Autonomy

The ability to automate basic functions such as takeoff, landing, course and altitude holding, following a pre-planned route, or executing a mission along a programmed pattern was largely taken for granted by 2022.

Further automation of UAVs on the battlefield during 2023–2025 enabled some models to visually acquire and track targets, guide themselves toward the object, and strike it. The effective range of such target acquisition depends on the quality of the electro-optical system and the robustness of the algorithms, typically ranging from 500 to 5,000 meters. This capability allows UAVs to operate effectively in complex terrain and under conditions of electronic warfare (EW).

The current level of computing modules and sensor technology is already sufficient to support mission sets that include target detection, recognition, coordinate transmission, and handover of strike commands from one drone to another. This, in turn, creates the possibility of developing swarm technologies, which are already being tested in Ukraine.

Among the most prominent Ukrainian companies in the field of UAV autonomy are **The Fourth Law** and **Swarmer**. The Fourth Law has outlined a roadmap consisting of five levels of drone autonomy: (1) automatic terminal guidance to a designated target (so-called "last-mile" guidance), (2) automatic target bombing, (3) autonomous target selection, (4) autonomous navigation, and (5) full drone autonomy. The company has already implemented the first level of autonomy with the **TFL-1 module**, which can be integrated into FPV drones. The module enables an operator to designate a target from several hundred meters away, after which control of the drone is executed automatically—with the option for the operator to intervene. This ensures mission completion even under EW or in difficult terrain.

Swarmer focuses on another domain of drone autonomy—software enabling the operation of swarms. The defining feature of swarms, compared to merely launching multiple UAVs simultaneously, is the ability of drones to communicate with each other to synchronize their actions. In September 2025, The Wall Street Journal reported on the successful frontline use of Swarmer's technology. Operators deployed one reconnaissance drone and two multirotor bombers. After defining the area of operation, the reconnaissance drone plotted the route, while the strike drones coordinated the sequence of munitions release. According to the unit, the technology had been employed more than 100 times. The key advantages of swarms are reducing the number of operators required and concentrating firepower on the adversary.

The continued process of automation—and ultimately full autonomy—will increasingly remove humans from routine tasks, allowing operators to focus on situational awareness, planning, and higher-level decision-making. The question is not whether machines will take over the most dangerous missions from humans, but when this will occur and who will be the first to achieve it.

Combining Unmanned Systems

Beyond the development of shared technologies, another trend is emerging in the UAV sector: companies are beginning to integrate different types of drones into unified platforms, or to combine unmanned systems with conventional weapons. This approach leverages the strengths of both domains.

Earlier examples included pairing a surface-to-air missile system or a heavy machine gun with a naval drone. In Ukraine, reconnaissance UAVs and multirotor bombers have also been employed to carry FPV drones. Naval drones are increasingly used to transport FPVs as well, significantly expanding the range of littoral targets. Similar integration efforts are under way in the production of loitering munitions. Such solutions pave the way for incorporating interceptor drones capable of engaging targets such as helicopters deep in the adversary's rear.

DRONE CARRIER FOR FPV DRONES

UGV CARRIER FOR FPV DRONES

Source: [The Defender Media](), [Mezha]()

Just as tracked platforms in the past could serve as the basis for infantry fighting vehicles (IFVs), armored personnel carriers (APCs), surface-to-air missile systems, or bridge layers, today UAV platforms are being adapted to produce systems with a wide range of purposes.

The pace of military drone technology development has remained high over the past three years. The conditions of war generate demand for new technological solutions, and these new solutions, in turn, reshape the conditions of warfare. Even in the event of a potential halt in hostilities in the Russia–Ukraine war, this cycle will not end: Ukraine and its partners will continue seeking solutions for deterrence, while Russia and its allies will pursue more effective weapons for offensive operations.

Unmanned systems have not yet reached their ceiling of development. The trend suggests that UAV platforms will continue to integrate both emerging innovations and existing technologies from military and non-military domains alike. This most dynamic segment of defense technology will increasingly shape the overall defense-industrial landscape across nations worldwide.

UKRAINE'S DRONE ECOSYSTEM

In the conditions of modern war, where innovation cycles are measured in weeks rather than years, the **involvement of all actors** across the defense ecosystem becomes decisive.

A distinctive feature of Ukraine's defense ecosystem is the **decentralization of procurement**. Decentralized procurement is not a weakness but a necessity: it enables rapid testing, adaptation, and scaling of new technologies without waiting for protracted bureaucratic approval. Unlike traditional centralized systems, Ukrainian brigades and units often source equipment through multiple channels:

- The **Ministry of Defense (MoD)** is the primary contracting authority, responsible for scaling production and ensuring logistics. With the integration of the **Ministry of Strategic Industries (MSI)** into the MoD, Ukraine has unified strategic planning and procurement under one institution. This strengthens the state's ability to align **industrial capacity, innovation policy, and military demand**. Current structure ensures coordination between the Defense Procurement Agency, General Staff, and industrial clusters, while giving the MoD more direct influence over innovation scaling and localization.
- In addition to the Armed Forces, other components of Ukraine's defense forces, including the **National Guard**, **the Security Service of Ukraine (SBU)**, and the **Defence Intelligence of Ukraine (GUR)**, maintain their own procurement budgets and procedures. These parallel structures increase the diversity of demand signals within the ecosystem. Each institution focuses on mission-specific requirements: the National Guard prioritizes urban combat and territorial defense; the SBU emphasizes counterintelligence and counter-UAV technologies; the GUR demands long-range strike and reconnaissance capabilities. Their procurement autonomy further amplifies the plurality of innovation pipelines, ensuring that technologies are tested across multiple operational domains before being scaled nationally.
- **Direct Brigade-Level Procurement:** Commanders use discretionary funds or trusted suppliers to secure drones and EW systems tailored to their missions. This reduces bureaucratic delay but creates variety in models and standards. Ukrainian brigades are not only end-users of drones and electronic warfare systems; they have become co-creators in the production process itself. Through direct feedback to manufacturers, battlefield testing, and even making design modifications by themselves, frontline units actively shape the final configuration of products.
- **Volunteer and Private Foundations:** Organizations such as **Come Back Alive**, **Sternenko Community** and the **Serhiy Prytula Foundation** supply large volumes of drones directly to units. This system, born from necessity, proved highly effective in filling gaps before MoD contracts matured. Volunteers are now engaged in all stages of the production cycle, from funding to delivery. Direct cooperation with brigades allows them to gather fast operational feedback and act as mediators between producers and frontline users. Unlike government procurement, which requires longer verification procedures, volunteer networks can often procure and deploy the latest innovations first, making them a vital accelerator of battlefield adaptation.
- **Public Campaigns (UNITED24, Army of Drones):** State-backed fundraising mobilizes society to deliver drones, training, and spare parts. This hybrid model integrates civilian resources into official procurement channels.
- **Innovation Pipelines (Brave1, Ministry of Digital Transformation):** Startups and civilian engineers can move from prototype to front-line testing rapidly. Successful systems then transition into broader procurement by MoD.

Ukraine has also introduced the “Drone Army Bonus” system, which rewards units with combat points for confirmed destruction of enemy personnel and equipment using UAVs. Verified through the **Delta situational awareness system**, points can later be exchanged for military equipment (including drones) via the Brave1 Market, a state-funded platform delivering equipment directly to units. This gamified approach incentivizes effective drone use and ensures the fastest, most successful formations are reinforced first.

The surge in demand for drones and defense technologies has led to the emergence of hundreds of new businesses, many of them immature startups lacking both basic business skills and an understanding of defense-specific procurement processes. To bridge this gap, a wide network of accelerators and support programs were made, including Defence Builder, MITS, and university-led initiatives. These platforms provide mentorship, training, and access to investors, while also helping companies navigate regulatory requirements and procurement standards unique to the defense sector.

The most important initiative is **Brave1**, the government-backed defense tech cluster. It provides a comprehensive package of support: grant financing, access to testing fields, certification pathways, and a “military acceptance” mechanism to fast-track promising technologies into service. In 2024 alone, Brave1 distributed **$40 million** in grants to support perspective innovations. Beyond financing, Brave1 serves as a bridge to investors, who themselves often act as informal accelerators by providing not only capital but also strategic guidance, scaling expertise, and international connections.

A defining strength of Ukraine’s defense ecosystem is the **extraordinary personal commitment of its people**. Citizens donate at scale, enabling funds to finance strategic projects such as the purchase of **ICEYE satellites**. Thousands choose to establish defense startups or join existing firms despite sometimes lower pay in comparison with their previous jobs and extreme workloads, driven by a sense of duty rather than profit. At the grassroots level, every individual can contribute: initiatives like **Victory Drones’ training courses** teach the public to assemble simple UAVs, while networks such as **Win UA Hub** unite hobbyists with 3D printers to produce components for the frontline. This broad-based engagement ensures that defense innovation is not confined to institutions but sustained by society as a whole. This model is not easily to replicate in peacetime, but instead other motivating factors may be implemented.

U.S. CURRENT STATE AND CHALLENGES

While small UAS were being used in asymmetric wars for years before Russia's full-scale invasion of Ukraine, 2022 served as an inflection point in the public consciousness—and in the Pentagon. Ukraine showed how the acute necessity of dealing with a much larger enemy, along with proper government incentives, can accelerate battlefield innovation. In comparison to the resources commanded by the U.S. Department of Defense and the American military-industrial complex (MIC), Ukraine, operating with far less, succeeded in rapidly designing and fielding UAS systems that challenged conventional military doctrine. The war has combined traditional, manpower- and materiel-intensive combat with technological advancements; innovation in the UAS sphere has helped Ukraine offset the imbalance of conventional strength.

No one technology has proven to be a silver bullet for either side of the war. It has been Ukraine's ability to outpace Russia's innovation, rather, that has advantaged Ukraine and made it a valuable model for Western militaries to emulate.[9] Ukraine's influence on the Pentagon's planning was made clear by Secretary of Defense Pete Hegseth's July memorandum, "Unleashing U.S. Military Drone Dominance."[10] The memo signalled a departure from the long-standing, centralized acquisition model that has constrained UAS innovation and deployment across the US military. Ukraine's rapid innovation cycle, which quickly transitions from prototype to battlefield deployment and back again, is an implicit aspiration throughout.

In this section, we assess the Pentagon's proposed reforms, challenges that remain, and opportunities for it to learn from (and cooperate with) Ukraine in the UAS sphere.

Catch Up and Overtake? The US' Plans to Get in the Drone Game

The Hegseth memo and accompanying executive order, "Unleashing American Drone Dominance" from June 2025, prioritized the streamlining of regulatory barriers and the acceleration of development and procurement.[11] A few changes, in particular, stand out in the US' plans to confront the drone paradigm, which Secretary Hegseth called "the biggest battlefield innovation in a generation."[12]

First, Secretary Hegseth ordered that Class 1 and Class 2 (i.e., 'small' UAS) be reclassified as "consumable commodities, not durable property." This treats small UAS less like airplanes and more like munitions, emphasizing that they should be "cheap [and] rapidly replaceable." This will allow small UAS to be issued, expended, and replaced without the bureaucratic penalties that would accompany lost or damaged durable equipment, thus facilitating soldiers' experimentation and innovation.[13]

Second, the Pentagon is decentralizing the procurement of small UAS. Under Secretary Hegseth's new policy, O-6 level officers (i.e., colonels) are authorized to buy, test, and train with pre-approved UAS. This bypasses the slow, layered approvals once required from organizations such as the Marine Corps Systems Command for procurement, the Marine Corps Warfighting Lab (MCWL) for testing, and the Marine Corps

[9] See "What Ukraine Can Teach Europe and The World About Innovation in Modern Warfare," Chatham House
[10] See "250710 DOD Memo Unleashing U.S. Military Drone Dominance," DocumentCloud
[11] See "Unleashing American Drone Dominance," The White House
[12] See "250710 DOD Memo Unleashing U.S. Military Drone Dominance," DocumentCloud
[13] See "Good News and Bad News About Changed U.S. Military Drone Policy," The Heritage Foundation

Installations Command for base authorization. By moving decisions closer to the operational level, the reform accelerates both acquisition and deployment, providing additional space for units to adapt technology to mission needs in real time.[14]

Third, the DOD's reforms seek to create a "UAS continuous-adaptation model" for iteration, aiming to "prevent vendor lock before scale purchases endorsed by warfighters" and to create "front-line modularity that permits [troops] to assemble systems using commercial parts and swappable payloads and software packages," according to the Hegseth memo. In effect, this is an effort to replicate Ukraine's successes in UAS R&D, and an acknowledgment of the systemic challenges that the US' extraordinarily top-heavy MIC and procurement processes are not necessarily well-suited to the rapidly changing UAS environment.

These reforms come at a time when the US is manifestly behind its adversaries in both the manufacturing and technology of small UAS. Large, complex, and expensive systems (e.g., the MQ-9 Reaper) have long been the focus of the Pentagon's attention. While these systems are still relevant and effective, the US has entirely missed the bottom end of the cost spectrum. The US' entire manufacturing base produces fewer than 100,000 small UAS each year—an order of magnitude less than Ukraine, Russia, and China. The disparity is particularly stark when compared to the US' greatest adversary, China, has the undisputed global leader in technology and scale, DJI. Based in Shenzen, the company produces millions of drones each year.[15]

In the balancing act between iterative innovation and mass production, the American UAS industry comes out behind on both fronts. The DOD has attempted to streamline testing and scalability by creating the Blue UAS Cleared and Select lists ('Blue List') certification system. The Blue List includes UAS sourced from both American and allied nations' companies—though both the Hegseth memo and White House executive order specify that American companies should be prioritized—that are pre-screened for procurement. The Hegseth memo included orders to transfer responsibility for the Blue List from the Defense Innovation Unit to the Defense Contract Management Agency and to turn the list into a "digital platform." FAs of September 2025, 35 models from 25 companies (predominantly from the US, but also from Switzerland, Norway, and France) have been approved for the list. Unfortunately for the Pentagon, however, none of these models can be manufactured at any meaningful scale.

The Replicator initiative, a Biden-era program meant to experiment and scale the production of low-cost drones, has been all but abandoned.[16] With a budget of around half a billion dollars, the program produced a few thousand drones before it was scrapped.[17] The DOD still funds drone startups through the Defense Innovation Unit but an effective and scalable solution remains elusive.[18] The Trump administration has also scrapped the Rapid Defense Experimentation Reserve (RDER), which was designed to put new technologies into field testing early for testing, but institutionalized the core principle of the program. While many of the overarching goals and strategies have persisted across the two presidential administrations, it is difficult to imagine that this back-and-forth of new programs has aided development.

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[14] See "Good News and Bad News About Changed U.S. Military Drone Policy," The Heritage Foundation

[15] See "Why the U.S. Is Way Behind China in Making Drones for War," The New York Times

[16] See "Pentagon Seeks to Surge Its Multi-Domain Drone Arsenal," DefenseScoop

[17] See "What Drones Can—and Cannot—Do on the Battlefield," Foreign Affairs; "How Did the World's Most Sophisticated Military Fall So Far Behind With Drone Warfare?," POLITICO

[18] See "Why the U.S. Is Way Behind China in Making Drones for War," The New York Times

Other funding schemes have also come into play, including private equity and the International Drone Capability Coalition, a European coalition of countries led by Latvia and the UK. One recipient of the latter is Neros Technologies, a California-based startup that produces a short-range quadcopter called the Archer (on the Blue List). The Archer has performed well in public tests, in no small part due to Neros' presence in Ukraine: the company was contracted to provide around 6,000 to the Ukrainian Armed Forces in 2025, and has an office in Ukraine to facilitate battlefield feedback.[19] Private equity, on the other hand, has made bets on a range of companies, sensing an opportunity to access the DOD's immense procurement funds in a niche with no dominant incumbents. Both the Pentagon and the White House have made clear that small UAS will merit large sums of investment; while these sums have yet to materialize, the war in Ukraine and tensions with China—the technological and manufacturing leader in the space—suggest that they will, sooner or later.

Challenges Remain

The success of the US' small UAS ecosystem will depend on overcoming three key challenges. First, there must be a sufficient demand-side signal—in other words, the Pentagon must commit significantly greater resources to developing, procuring, and deploying small UAS. The Pentagon devotes tens of billions of dollars annually to maintaining traditional equipment and materiel (aircraft carriers, F-35 fighters, tanks, etc.) but even the DOD's flagship program under the Biden administration, the Replicator initiative, allocated only $500 million for low-cost drones in 2023.[20] Second, there must be a real acceleration in technological development. Whether it is via AI-powered targeting, drone swarm technology, or resistance to counter UAS (C-UAS) measures like frequency jamming, the American ecosystem of small UAS must develop a competitive edge. As it stands now, the US is quite far behind. Third, the US must overcome its deficiencies in (or complete lack of) its manufacturing base. This includes both final assembly and intermediate components, like small motors or batteries. Though the least flashy—billion dollar investments and AI-powered drones make for better headlines than localizing commodity-level component production—this is likely the most intractable of the three challenges.

Demand

Secretary Hegseth and the Pentagon are saying the right things—they point to the wars in Ukraine and the Middle East as evidence of a paradigm shift in battlefield technologies, and the US' need to catch up—but their actions will need to back up their words. As the Replicator initiative will not be revived under the Trump administration, it will need to be replaced by a funding mechanism that is greater in value. Furthermore, the Pentagon will need to prove that it can overcome the institutional resistance that has kept the drone ecosystem in stagnation.

Technology

Public accounts of the DOD's drone technology have caused some embarrassment for the department. There was the US Army's Twitter post bragging about the branch's first ever UAS-dropped live grenade—

[19] See "Why the U.S. Is Way Behind China in Making Drones for War," The New York Times; "Neros Wins Contract To Send 6,000 American-made Drones To Ukraine," Forbes

[20] See "What Drones Can—and Cannot—Do on the Battlefield," Foreign Affairs

published, then deleted, in July 2025.[21] There was also a four-day exercise in July 2025 showcasing a number of DOD-backed drone start-ups, whose products failed to meet even minimal expectations.[22]

With Ukraine and Russia innovating their small UAS practically every day, it is somewhat difficult to imagine how the US could catch up in the short-term, even with the DOD's deep pockets. And China has DJI, whose technology is manifestly superior to any small UAS that the US is producing.[23] This is a complete inversion of the situation at the top of the cost spectrum, where American UAS are regarded as top of class.

It is, of course, possible that a Pentagon contractor has developed a technological breakthrough—drone swarms, EW protection, etc.—without public knowledge. After all, the US is the global leader in the AI race, and Silicon Valley capital has clearly bought into the drone market.[24] But, even if this were the case, one can confidently say that it is not being done 1) at scale, or 2) cheaply.

Manufacturing

Arguably the most significant challenge facing the small UAS industry in America is its insufficient manufacturing base. Not a single company has scaled production to a level that would support a high intensity conflict. Worse, even, is that the combined production of the entire industry pales in comparison to a single Chinese company, DJI. This is not to say that Beijing would send the PLA across the Taiwan Strait armed with consumer-grade DJI drones. Rather, it is proof that the core components necessary to scale military-grade production—the supply chains, engineers, and production lines—are already present and ready to be contracted with or nationalized.

Part of the bottleneck stems from components. Brushless motors, electronic speed controllers (ESCs), camera modules, and lithium-polymer batteries are overwhelmingly sourced from East Asia, particularly China, which dominates every category.[25] This dependence constrains both volume and competitiveness, since American firms either pay a premium for non-Chinese suppliers or face shortages when export restrictions tighten. Unlike semiconductors or EV batteries—where Washington has mobilized billions to build domestic supply chains—small drone components remain largely overlooked in U.S. industrial policy. The consequence is clear: no equivalent of the CHIPS Act or Inflation Reduction Act exists for drones, leaving the industry to operate in an ad hoc fashion with limited federal support.[26]

While limited procurement contracts prevent 'vendor lock-in,' they prevent firms from producing at scale. Partially thanks to this, the Blue List's UAS are considerably more expensive than comparable Chinese models, and are produced at a fraction of the scale that Chinese competitors are. At the same time, the U.S. lacks the industrial clustering that powers Shenzhen's drone hub, where suppliers, engineers, and logistics sit side by side. American manufacturing is fragmented across states, split between primes and startups, without the network effects that drive rapid innovation and cost reduction. Efforts to create 'drone corridors' remain embryonic, and Washington has yet to treat drones as a

[21] See "The U.S. Army Looks Lost in the Drone Age," National Security Journal
[22] See "Why the U.S. Is Way Behind China in Making Drones for War," The New York Times
[23] See "How Did the World's Most Sophisticated Military Fall So Far Behind With Drone Warfare?,"POLITICO
[24] See "Anduril Raises Funding at $30.5 Billion Valuation in Round Led by Founders Fund," CNBC
[25] See "Study On the Battery Supply Chain Shows China's Global Dominance - and Options for Europe," Fraunhofer FFB; "Top 20 Brushless Motor Manufacturers in the World in 2025," Greensky Power; "Camera Modules Component Market Size, Share, Growth, and Industry Analysis," Market Growth Reports
[26] See "Inflation Reduction Act of 2022," Internal Revenue Service; "H.R.4346 - 117th Congress (2021-2022): CHIPS and Science Act," Congress

strategic production priority. In the meantime, defense budgets also continue to favor legacy systems over attritable drones. Without a multiyear procurement pipeline and industrial strategy, U.S. production will remain boutique—capable of fielding prototypes, but not the mass-manufactured fleets that modern conflict now demands.

ROADMAP: WHAT THE US CAN LEARN AND IMPLEMENT

Procurement Reform

The U.S. procurement system remains too centralized, small-scale, and risk-averse, slowing the transition from prototype to battlefield deployment. Anduril's Ghost 4 exemplifies the challenge: despite technical maturity, the system became mired in protracted certification cycles and was limited to pilot deployments, [27] By contrast, Ukraine has demonstrated an alternative model by including soldiers in design and testing from the outset, where feedback loops shortened development timelines from years to weeks. A "fly-before-you-buy" model subjects drones to stress-testing in contested environments prior to adoption, reducing the risk of failures like the Excalibur artillery round, which revealed its vulnerability to GPS jamming only in combat. U.S. reforms should dedicate considerable resources to fielding prototypes, exempt low-cost attritable systems from acquisition law, and mandate that new platforms prove combat adaptability before scaling.

Industrial base diversification

The U.S. drone ecosystem is constrained by limited breadth and inflated costs. Production, meanwhile, has stagnated in a low-volume, high-cost equilibrium that benefits neither the Pentagon nor operators in the field. Ukraine's Brave1 cluster offers a contrasting approach: by integrating startups, accelerators, and frontline brigades into a single ecosystem, it advanced more than 200 projects from concept to combat in under a year. A U.S. analogue could take the form of regional drone technology corridors—federally backed through the Defense Production Act—that connect primes, dual-use manufacturers, and universities. Such corridors would lower entry barriers for small firms, provide shared testing ranges for operator-driven prototyping, and diversify supply chains across batteries, motors, and sensors, thereby reducing dependence on Chinese imports. Absent this kind of structural diversification, the United States risks remaining trapped in boutique production while adversaries scale.

Training and doctrine

Drones in the U.S. military are still treated as specialized assets—e.g., platforms like MQ-9 Reapers or Raven ISR units—rather than everyday infantry tools. Ukraine shows the opportunity cost of this mindset. By 2024, platoons were routinely integrating FPV drones into maneuver cycles, training gunners and radio operators to double as pilots. Groups of 20–30 FPVs preceded infantry assaults, suppressing trenches and convoys while overwhelming Russian EW defenses. U.S. doctrine has to adapt: small-unit training pipelines should integrate drone piloting, swarm coordination, and low-signature operations into the same category as radios and mortars. This shift would democratize access to aerial assets, ensuring that frontline units—not just specialized formations—can exploit unmanned systems at scale.

Legislative policy

Ukraine's wartime policies focused on lifting import tariffs on components, loosening certification requirements, and authorizing brigades to buy directly from startups, created the regulatory space for innovation to scale during a period of acute need. Without the urgency of war, the U.S. has not developed an equivalent framework. The Biden-era Replicator initiative, which produced only a few thousand units, pales in comparison to Ukraine's million-per-year output. To close this gap, Washington should legislate

[27] See "Anduril Introduces Ghost 4," Anduril; "Ghost Approved for the Blue UAS Cleared List," Anduril

a dedicated set of incentives: tax credits for domestic drone production, modeled on renewable energy policies; FAA exemptions or designated corridors for dual-use firms to accelerate commercial-military crossover; and a national reserve stockpile of attritable drones to stabilize demand cycles for small and medium enterprises. Such measures would anchor a predictable market signal, preventing the boom-and-bust procurement cycles that have helped keep production boutique.

Coproduction with Ukraine

Ukraine has moved beyond the role of a passive recipient of Western assistance, emerging as an innovator capable of fielding battlefield-proven platforms at scale. As shown in Ukraine's drone portfolio (see Table 1), FPV quadcopters costing as little as $400–2,000 have proven effective against Russian armor and personnel, while systems such as the UJ-22 and Beaver UAV have executed deep strikes hundreds of kilometers into Russian territory. A strategy of joint coproduction would marry Ukraine's combat-validated designs with the United States' industrial capacity, laying the foundation for a transatlantic drone base. Under Defense Production Act authorities and targeted bilateral agreements, Ukrainian firms could contribute intellectual property, prototypes, and operational feedback, while U.S. manufacturers provide production lines, logistics safe from Russian attacks, and reliable financing pipelines.

Both costs and benefits could be distributed across NATO. The alliance would gain interoperable, attritable drone fleets that strengthen collective deterrence; Ukraine would secure predictable funding, economic integration with the West, and supply chains safe from Russia; and the American defense industrial base would receive much-needed help to overcome its drone struggles. The U.S. and NATO have not shown themselves to be capable of manufacturing or deploying small UAS at scale; thus, an institutionalized coproduction framework could create a more realistic pathway to competing with Russia (with its Alabuga special economic zone) and China (with its Shenzhen cluster).