Six Key Lessons from Ukraine's Drone War

By Nolan Peterson

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Today's world is rife with flashpoints for future conflicts, and America's baptism by fire into drone warfare, such as we've seen in Ukraine, may be close at hand. Tactics and technologies born in the Russo-Ukrainian war have already appeared in Myanmar, Colombia, and Mexico, as well as in Gaza, Lebanon, Iran, and Iraq. In the hands of both regular and irregular warfare operators, drones can have tactical, operational, and strategic effects — from precision strikes on the battlefield to disabling power stations and oil refineries, shutting down airports, or destroying nuclear-capable bombers sitting on the tarmac at an air base.

Unmanned technologies are now a bridge between conventional and unconventional warfare, having democratized long-range precision strike capabilities that were once exclusive to well-funded national militaries. And there's no doubt that China is using Russia's experiences against Ukraine as a basis for its own drone warfare doctrines and technologies.

In this evolutionary era of warfare, the U.S., along with our partners and allies, must anticipate all the novel ways in which our adversaries can leverage unmanned weapons systems against us — both on expeditionary battlefields as well as in defending our homelands.

Since April 2024, the Irregular Warfare Center has offered an unmanned warfare course for the Ridge Runner Irregular Warfare Exercise, held at Camp Dawson, West Virginia. Hosted by the West Virginia National Guard, Ridge Runner provides irregular warfare training for U.S. Special Operations Forces and international partners.

The IWC's half-day course in drone warfare provides a continuously updated overview of the latest trends in tactics and technologies in Ukraine and around the world. Based on more than a decade of field research in Ukraine, the course identifies six key lessons, building a foundation of knowledge from which students can use their own initiative and imagination to become more lethal and survivable in future conflicts.

1. Adaptation at the speed of war.

Following Russia's 2014 invasion of eastern Ukraine and Crimea, a generation of technologically savvy Ukrainian soldiers and civilian volunteers launched grassroots programs to modify small, commercial drones for combat. Over the ensuing eight years of mostly static, trench warfare in the eastern war zone, Ukraine became a battlelab for the advancement of drone warfare tactics and technology. The Russians followed suit, and by the time Moscow fully invad-

ed in February 2022, both sides had already gained years of experience field-testing small, militarized drones. This pre-existing base of experimentation kickstarted a wholesale revolution in unmanned warfare during the full-scale war.

What began as ad hoc substitutes for artillery and airpower has since evolved into an entirely new paradigm of warfare defined by the mass-scale use of cheap and expendable unmanned systems. Both Russia and Ukraine now employ small and medium-sized drones at unprecedented levels to conduct a wide range of operations, including tactical and strategic strikes, logistical support, and ISR (intelligence, surveillance, and reconnaissance) missions. While Russia's armed forces initially lagged in small drone innovation and employment, they've since adapted, and the full-scale war has transformed into a tit-for-tat competition between drones and counter-drone measures, with each side trying to out-adapt the other – a contest some Ukrainians call a "duel between sword and shield."

Since 2014, unmanned technology development in Ukraine has been a bottom-up process. Many of the technical and tactical changes transforming the war come from soldiers in the field who understand battlefield realities and are trying to make the most of their limited budgets. Rather than focusing on expensive, over-engineered, silver bullet platforms, Ukrainians generate products that are like a ball of clay that can be constantly remolded. Their priority is to get effective, modular tools in warfighters' hands as rapidly as possible, and to then upgrade and modify that hardware at the speed of war.

In a war where technologies have a shelf life measured in weeks, a new weapons system that takes months or years to develop is already obsolete by the time it reaches a warfighter's hands. To keep pace with this dynamic environment, most Ukrainian drone developers have teams of technicians who travel to the front lines to gather information and make upgrades. It's a non-stop rotation of combat feedback, re-engineering, and operational testing. There is no such thing as a final product. "Even in Ukraine, you need to be close to the front to keep up with changes," said Taras Semeniuk, the founder and CEO of the Ukrainian drone startup Huless. Although some Western analysts question whether Ukraine's battlefields are a true bellwether for future conflicts, it certainly looks as if Ukraine and Russia see unmanned warfare as elemental to their future force structures and military-industrial bases. The number of Ukrainian drone manufacturers grew from seven in 2022 to at least 500 in 2026. The country's annual drone production capacity also skyrocketed from about 5,000 in 2022 to a projected 7 million in 2026.

Ukraine now has a dedicated Unmanned Systems Force, and drone operations are woven into Ukraine's force structure at every level. Apart from these organizational changes, there's a broader push to make drone operations as fundamental to basic training as shooting a rifle. One Ukrainian commander explained to the author in a June 2024 interview in Kyiv, "Every soldier must know how to shoot a gun, drive a car, and fly a drone."

There are also efforts to educate Ukraine's civilian population and schoolchildren about drones. Youth scouting programs and high school military skills training now often include courses in drone operations. According to one Ukrainian drone operator: "We need to train our 16-year-olds the skills they need to survive. And that includes flying drones."

Russia has also created an "Unmanned Systems Force" with plans for 165,000 personnel by the end of 2026, according to a Telegram post by Ukraine's commander in chief, Oleksandr Syrskyi. And in 2025, Russia opened its first drone training school for children. Named "Kindness and Sky," the school's curriculum includes classes in drone assembly and piloting taught by war veterans, the Kyiv Post reported.

2. Drones are not tools — they are a new combat ecosystem.

Through its adoption of unmanned warfare tactics and technologies, Ukraine's military has offset many of its attritional disadvantages against Russia. In terms of manpower, Ukraine is now killing and wounding Russian soldiers at a faster rate than Moscow can field replacements. This March alone, Ukraine's military command claimed 35,351 Russian casualties — a new monthly record. Of that number, 96% reportedly came from tactical drone strikes. When it comes to ammunition and materiel, drones offer cost-effective ways to precisely put rounds

on targets, reducing the number of wasted shots. A comparison of Ukrainian combat units on one section of the front-line in February 2026 is illustrative. According to data published online by a Ukrainian drone operator, the targeting efficiency of artillery units in that sector generally hovered between 0.5% to 1.5%. In contrast, the efficiency rating for first-person view strike drone units operating in the same area was around 50% to 60%. In an attritional war in which Ukraine aims to maximally leverage every available resource to impose costs on its adversary, drones clearly offer a force-multiplying advantage.

Drones haven't changed warfare at the margins; they have transformed every aspect combat between Ukraine and Russia. Ukrainian President Volodymyr Zelenskyy claimed in April that Ukrainian aerial and ground drones had captured a Russian position without the use of human soldiers, marking a historic milestone in an increasingly robotic war. With both sides unable to achieve air superiority with manned warplanes, there is now a battle for supremacy of the "air littoral," the low-altitude airspace where small drones mostly fly. To that end, Ukraine now fields dedicated unmanned warfare battalions that operate a variety of drones with different, complementary functions — from aerial surveillance to dropping bombs — creating low altitude analogues of the manned aircraft stacks the U.S. Air Force flew in Afghanistan and Iraq. The interplay between these unmanned aerial systems (UAS) creates lighting fast kill chains that deliver effects to ground forces previously out of reach without achieving air superiority or air dominance. This novel battlefield architecture has transformed the first few hundred feet of airspace into a contested warfighting domain.

First-person view, or FPV, drones are now Ukraine's preferred option as tactical strike platforms, as well as airborne interceptors to down Russian reconnaissance drones and loitering munitions. Originally conceived for racing, FPV drones include multirotor and fixed-wing platforms controlled by an operator wearing virtual reality goggles that display footage from the drone's onboard camera. With a munition attached to their fuselages, these hobby drones become miniature cruise missiles, guided to their target in real time by a pilot's commands. After modifications to improve their top speeds, Ukrainian FPVs have even downed Russian helicopters in flight.

Ukrainian special operations and intelligence units also use aerial drones for ferry missions to arm and supply resistance and sabotage groups operating within Russian-occupied territory. At sea, Ukraine's maritime drones helped break the Russian blockade of Ukraine's Black Sea ports and have forced the bulk of Russia's fleet to retreat from Crimea. Unmanned ground vehicle (UGV) development has also accelerated, sparing soldiers from high-risk missions such as front-line supply runs, mining and de-mining operations — even evacuating casualties in some cases. Ukraine's military plans to purchase 25,000 UGVs in the first half of 2026 — more than double the number for all of 2025. "The goal is to move up to 100% of frontline logistics to robotic solutions," Ukraine's Ministry of Defense announced in a statement.

3. Humans remain more important than technology.

Similar to the advent of fighter pilot culture in World War I, a unique warrior culture has emerged among Ukraine's FPV pilots. Like the fighter pilots before them, FPV pilots are assigned callsigns. The best pilots earn a special status, equivalent to aces in World War I. They are highly respected and excluded from all other duties. People know their names.

Fighter aircraft demand elite pilots to be effective; the same goes for drone warfare. FPV drones must be hand-flown, requiring a degree of touch analogous to playing a piano or knitting. Pilots need quick reaction times, fine-tuned hand-eye coordination, and situational awareness. They must also possess an understanding of combat tactics and techniques, such as using foliage and the sun's angle to conceal a drone's approach path or using the prevailing wind to hide the sound of its motors. Good FPV pilots must also make split-second decisions about choosing targets and where to place a munition for it to be most effective. They must also process all that information while hunkered down in an active war zone wearing video display goggles. These pilots "exist in two worlds," a Ukrainian FPV operator who goes by the callsign "Ronin" explained to the author in a July 2024 interview.

"Obsession is an important skill," Ronin said in the interview. "Around the pilot, weapons of various types and classes often work. But in the same way,

the pilot must be mentally present with his team, and his drone. I can't describe it in words; it's like you are in two realities and both need to be controlled."

These drone pilots, who virtually experience the final instants of their enemies' lives, must also be psychologically conditioned to kill. Speaking to the author in a July 2025 interview, a Ukrainian National Guard commander said that in the span of a single, two-week battle in the summer of 2025, it wasn't unusual for some of his drone operators to have killed dozens of Russian soldiers. Projected over a longer timeline, those lethality rates are on par with history's deadliest snipers.

4. You're being hunted.

Drones are uniquely effective psychological weapons, leaving swaths of terrain under the specter of a lethal threat from above. That kind of constant pressure is paralyzing for soldiers who aren't used to it. According to this author's numerous front-line reporting trips to Ukraine's front lines dating back to 2014, it was clear that even the most battle-hardened Ukrainian troops can adapt to indirect fire threats. In fact, a degree of complacency often settles in once troops develop a sort of sixth sense to judge the immediacy of an artillery threat. This sort of acclimatization to danger is harder to achieve in a drone war, as the author has personally experienced. Whereas there are rote, muscle-memory actions that improve one's chances of surviving an artillery barrage, a drone attack is more like single combat. It requires soldiers to outperform the human operator at the controls of the drone that's trying to kill them. It feels like you're being hunted.

The airspace saturated with small UAS threats is not uniform throughout the Ukrainian war zone, but it generally extends at least 10 miles from the line of contact. In this kill zone, the drone threat is constant and unforgiving. Consequently, the density of troops has decreased and mounted movement is limited, forcing soldiers to move on foot, in smaller groups, and often at night. Unable to safely evacuate, wounded soldiers on both sides regularly succumb to survivable wounds, even when they're only a few kilometers away from the nearest casualty stabilization point. To deal with these challenges, Ukrainians now have specialized troops whose specialty is to escort their comrades to and from the contact line. "Guides" are the pathfinders. "Stalkers" are the drone hunters; their task is to use shotguns and machine guns to protect ground units from unmanned aerial threats.

In a recent interview, Lt. Col. Yevhen Bespalov, the commander of Ukraine's 38th Marine Brigade, said that in his area of operation the Russian drone threat penetrated some 20 to 25 km (about 12 to 16 miles) beyond the line of contact, turning lines of communication into suicide runs during daytime. Bespalov said his unit's supply deliveries were exclusively done by ground and air drones, and that soldiers must walk 25 km to their front-line positions. "They choose the right time, the right weather," Bespalov said. "It takes three days, sometimes a week for the infantry to get there."

The proliferation of tethered, fiber-optic FPVs — effectively immune to jamming and other electronic defenses — has made movement to and from the front lines exceptionally hazardous. In some cases, Ukrainian troops have been trapped at their front-line positions for more than 100 days. Unmanned ground vehicles (UGVs) are now widely used to deliver critical supplies, but the drone threat remains a major limiting factor for both sides, forecasting the contested logistics challenges that the U.S. and its international partners will face in future conflicts.

5. Strategic effects.

Ukraine has also developed an arsenal of long- and medium-range drones that routinely strike operational and strategic targets well beyond the front lines and deep within Russian territory. In March, more than 7,000 of these long-range Ukrainian drones targeted Russian oil refineries and military-industrial infrastructure, spurring a 40% reduction in Russia's oil export capacity by month's end, according to Reuters. The Kyiv Independent reports that Ukraine has also ramped up a "middle strike" campaign against Russian air defense targets, creating gaps in coverage that open up "corridors" through which long-range drones can penetrate Russia territory. "We gradually chip away at the entire rock and try to exhaust their air defense capabilities in order to expand this kill zone for their production facilities, enterprises, equipment, headquarters, and so on," a Ukrainian Unmanned Systems Force commander told the Kyiv Independent, describing the middle strike campaign.

Russia, for its part, regularly employs its arsenal of Geran one-way attack drones — an improved, Russian-made derivative of Iran's Shahed-136 — to target Ukrainian civilian areas and critical infrastructure sites. This past summer, Russia stepped up its strategic air campaign, hitting Ukrainian cities practically every night with waves of one-way attack drones and missiles. On the night of March 23 alone, Russia launched 948 one-way attack drones against Ukraine. As a point of comparison, Russia launched a total of 917 long-range drones against Ukraine during the first six months of 2023.

Russia does not yet possess the manufacturing base to sustain an all-out, unmanned bombing offensive against Ukraine. But it's getting closer. With thousands of drones and missiles already in reserve, Russia is now capable of domestically manufacturing some 5,000 of its Geran (Shahed-type) drones per month, a Ukrainian intelligence official recently said. One aim of Russia's long-range drone strikes is to exhaust and deplete Ukraine's surface-to-air missiles ahead of missile attacks. Recognizing the impracticability of burning through stocks of expensive, high-end air defenses — such as Patriot missile batteries — against relatively low-tech drones, Ukraine has developed a number of creative alternatives. Acoustical devices and other sensors are positioned around the country and connected to an integrated air defense system that alerts mobile interception teams operating a range of platforms, from armed pickup trucks to Yak-52 propellor aircraft. The latest leap in counter-drone technology has been Ukraine's arsenal of interceptor drones.

Ukraine produced roughly 100,000 air-to-air interceptor drones in 2025 and is now capable of producing about 2,000 per day, Zelenskyy said in March. As of April, Ukrainian interceptor drones now account for about 70% of downed Gerans, according to Ukraine's military. With a price tag of about $1,000 to $3,000 per unit, these drones offer a financially sustainable air defense alternative.

Russia is now employing faster, jet-powered versions of the Geran, spurring Ukraine to develop faster interceptors, better terminal guidance, and more reliable performance in bad weather and contested conditions. "The enemy is scaling their use, speed is increasing, and interception is becoming more difficult. Our task is to find a technological solution," Ukraine's Minister of Defense Mykhailo Fedorov said in April.

When employed in irregular ways, small, tactical drones can also achieve strategic effects. During Ukraine's 2025 Operation Spiderweb, covert teams launched more than 100 small drones against five Russian airbases, destroying scores of nuclear-capable bombers as they sat on the tarmac. The Ukrainian operators concealed the drones in wooden cabins placed on the back of semi-trucks, which unsuspecting Russian drivers then drove within striking distance of their targets.

This operation marked a milestone in demonstrating what unmanned technologies can achieve in the hands of skilled and enterprising operators. It also served as a stark bellwether for new threats against the U.S. homeland.

6. Air dominance, re-imagined.

The baseline objective for air power is to clear the way for all levers of military power to operate with "impunity." In this new age of unmanned warfare, this concept needs some re-examining.

While supersonic fighters and stealth bombers remain essential to air power, they aren't enough to defend America's ground forces against small, armed drones, zipping around at treetop levels. Thus, to achieve true air dominance, modern militaries must also dominate the air littoral, that low-altitude airspace where small drones fly.

In future conflicts, forward-deployed U.S. personnel will face persistent, lethal threats from the air — as well as by sea and land — even if they are physically divorced from the forward edge of contact. And when it comes to protecting the U.S. homeland, every foot of airspace, from the ground up, must now be defended.

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