DefenseNews

COUNTER-DRONE DEFENSE:

Engineering the Shield Against UAV Threats

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ARROW

A U.S. Air Force Airman assigned to the 820th Base Defense Group operates a drone at Moody Air Force Base, Georgia, Aug. 5, 2025. The integration of drones allows for real-time surveillance and intelligence gathering, improving mission efficiency and effectiveness.

SENIOR AIRMAN LEONID SOUBBOTINE/ U.S. AIR FORCE; COVER: GETTY IMAGES

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By: Matt McLaughlin

The Emerging Threat of Drone Warfare

Military forces have sought to use unmanned aircraft for warfare for more than a century. The Kettering “Bug,” billed as an aerial torpedo, was tested during World War I but never saw use in battle. In the 100-plus years since, unmanned vehicles have come a long way.

In more recent decades, the deployment of the Global Positioning System and other satellites delivered a much greater ability to control unmanned vehicles, leading to the game-changing power of Predator drones, which provided both surveillance and weapons strike capabilities for U.S. forces in military operations in Afghanistan during the 2000s.

Drones became more important to military operations through the 2010s, as capabilities such as drone swarms, AI-assisted targeting and loitering munitions emerged. While the U.S. maintained drone use for counterterrorism, other nations — including U.S. allies as well adversaries such as China and Russia — developed their own drone fleets.

In recent years, drones have played a major role in conflicts around the globe. The Center for Strategic and International Studies reported that in the Nagorno-Karabakh war between Azerbaijan and Armenia, “Unmanned aerial vehicle (UAV) and loitering munition attacks were able to destroy heavy ground units, including T-72 tanks and advanced S-300 air defenses.” In the war in Ukraine, both sides have made extensive and innovative use of unmanned aerial vehicles for attacks both on the battlefield and well beyond the lines.

Modern militaries use drones for a variety of purposes, including surveillance, strike and logistics missions. A variety of characteristics have made drones a powerful tool for both offensive and defensive efforts. “The impact of the drones has actually changed the whole way that the war has been fought on both sides,” said Bill Ramsdale, Business Development Manager for Aerospace and Defense with Arrow Electronics.

Technological advancements have transformed the role drones play in modern warfare. Improvements in miniaturization, communications, networking, targeting and materials have increased the utility of unmanned

From left, Sgt. Christopher Ferranti, Staff Sgt. First Class Gregory Mannen, and Staff Sgt. Michael Kimmel demonstrate ground control station operations during Small Unmanned Aircraft Systems training at the 249th Regional Training Institute, Rees Training Center, Oregon, Sept. 4, 2025.

MAJ. W. CHRIS CLYNE, OREGON NATIONAL GUARD PUBLIC AFFAIRS/ U.S. ARMY NATIONAL GUARD

vehicles while driving down costs. The commercial production of powerful drones has also made them available to more than just global powers. In fact, more than 100 countries are believed to have military drone capabilities, while non-state actors such as Hezbollah, Hamas, and ISIS have also developed or acquired drones.

In addition to the versatility and powerful capabilities that unmanned vehicles bring to the battlespace, drones also reduce the political costs of military action. By eliminating the risk of pilot casualties, drones alter the calculus of how and where military forces may take action.

As drone warfare has proliferated, it has served to reduce traditional military advantages, such as armored units and air defense systems. Drone strikes in the Ukraine and Nagorno-Karabakh conflicts have destroyed tanks and other weapons that cost millions of dollars using unmanned vehicles that are far less expensive.

The surveillance capabilities of drones also greatly improve battlefield awareness, enabling users to lift the fog or war to get a clear picture of troop concentrations and movements. Further, drones have enabled less advanced militaries to make precision strikes that in decades past would have required a robust air force or powerful artillery weapons. They enable forces to strike targets from great distance with less risk to troops and equipment while also challenging the nature of traditional air superiority.

"In recent years, adversary unmanned systems have evolved rapidly," then-Secretary of Defense Lloyd J. Austin III said in a Sept. 2024 statement. "These cheap systems are increasingly changing the battlefield, threatening U.S. installations, and wounding or killing our troops."

The Ukraine conflict has seen a massive increase in the numbers of drones used for military operations. Both Russian and Ukrainian forces use drones for artillery spotting and targeting as well as kamikaze attacks. They have also used unmanned aerial vehicles to carry out long-distance strategic strikes far from the front lines. For example, a Ukrainian drone attack caused major damage to Russia's largest gas processing plant in October 2025, forcing it to shut down.

As military forces and other actors have taken advantage of powerful new drone technologies and capabilities, the importance of being able to defend against drone attacks has grown significantly.

"If national governments are planning defense, and they are not finding ways to protect their armed forces and their populations against the attack of drones, then they are not going to be successful," Ramsdale said. "The future of warfare is going to have to

have some kind of solution to protect against drones."

The Search for Effective Defense Against Drones

Unmanned vehicles represent a particular problem for the U.S. military. As the leading global superpower, the U.S. can project dominance virtually anywhere in the world. However, drones create an asymmetric threat, as inexpensive and easily accessible unmanned vehicles can be employed by both smaller nation-states and non-state actors to attack U.S. service members. A January 2024 drone attack on Tower 22 base in Jordan that killed three U.S. soldiers demonstrated the vulnerability that even U.S. forces have to drone strikes.

To address the threat of drones, a September 2025 report from the Center for a New American Security (CNAS) recommends that the Department of Defense (DoD) prioritize drone defenses. "There's a lot of investment out there to try to figure out the best way to combat drones," says Michael Wilkens, Director of Sales for Aerospace and Defense with Arrow. "It's likely to be a combination of solutions".

Effective drone defenses first must be able to detect drones, which can be challenging given their small size. C-UAS systems must be able to identify attacks and track threats as they move. While unmanned aerial vehicles don't move with the same speed as most advanced missiles, the same systems can be used to track both threats. Finally, defensive systems must employ some way of neutralizing the drone threat.

The Pentagon is working toward its objective of fielding effective counter-unmanned aircraft systems (C-UAS) in a variety of ways. The DoD is streamlining acquisition pathways for counter-drone systems that will use a variety of approaches. These include:

- Directed-energy weapons such as lasers and high-powered microwaves: Among other benefits, these weapons can provide lower cost per shot for U.S. forces. Additionally, high-powered microwave weapons have demonstrated significant potential to defeat drone swarms and high-volume attacks.

- Electronic warfare systems used for jamming and spoofing drone controls. This approach has been widely used by both sides in the Ukraine conflict.

- Kinetic systems such as guns, guided rockets and interceptor drones.

- A layered defense. Combining multiple modes of defense can greatly improve their overall effectiveness.

Wilkens noted that counter-drone initiatives are also exploring novel concepts to address unmanned threats, such as the use of nets that can snare drones in midair. This approach could reduce the chance of collateral damage that may occur when a kinetic weapon intercepts a drone, potentially causing an explosion and shrapnel.

The U.S. military is also making changes to some of its operational concepts to address the threat of drone warfare. For example, dispersing operations over a wider area can reduce the value of specific targets, while hardening forward bases against drone attacks can limit the vulnerability of troops most in the line of fire. Further, U.S. forces are integrating drone defenses into their standard defensive planning and training forces in drone operations and counter-drone tactics.

The U.S. Defense budget increased funding for counter-UAS capabilities by billions of dollars, and in September 2024, the DOD announced its Replicator-2 initiative, aimed at countering the threat of small unmanned aerial systems. The Pentagon is studying the conduct of drone warfare in Ukraine and incorporating the lessons it is learning to better understand evolving tactics and engineer more effective defenses.

In 2020, DoD established the Joint Counter-Small UAS Office as the lead Army organization tasked with C-UAS efforts. The office coordinates counter-drone efforts across services, attempting to avoid duplication and ensure interoperability.

The Pentagon also is taking steps to work with allies to coordinate drone defenses. Some partners, such as Israel with its Drone Dome system, have demonstrated their own effective C-UAS capabilities.

Ultimately, developing and fielding effective C-UAS capabilities will require collaboration. Among numerous parties, including the military, the private sector and allied partners. The rapid evolution of drone warfare will require flexible, agile, fast-paced initiatives that can adapt to new threats.

"It's about the nature of who your enemy is, and it's very difficult to work out what kind of war the U.S. is going to be presented with in the next several decades, and who the enemy is going to be," Ramsdale said. "This makes it difficult to predict which type of drone they're going to have to defend their forces against."

The Continuing Development of Effective Defense Against Drones

Different types of unmanned vehicles pose varying challenges for drone

defenses. The vast differences in size, speed, altitude and use cases create a need for a variety of countermeasures:

• Micro drones under 2 kilograms are difficult to detect but move more slowly than larger drones and are unable to carry a large payload. They are primarily used for reconnaissance and are often susceptible to electronic warfare defenses.

• Small tactical drones under 25 kg can move at speeds over 100 miles per hour, making early detection essential. These drones can carry enough explosives to disable a vehicle, but small arms fire has proved to be effective against them at close range in Ukraine.

• Midsized drones up to 150 kg such as the Turkish Bayraktar TB2 or the Iranian Shahed-136 present a larger radar signature but can still be difficult to detect. They can operate at higher altitudes than smaller drones — in some cases higher than 20,000 feet. These can be used as loitering munitions to attack troops, vehicles and other targets. Mobile gun systems and shoulder-fired missiles present countermeasures, but larger intercept systems generally are not cost effective against these drones.

• Large drones over 150 kg such as the U.S. MQ-9 Reaper and the Global Hawk can operate above 40,000 feet and at speeds reaching up to 400 mph. These drones can be used offensively for strikes against high-value targets as well as close air support. Traditional missile interceptors such as the Patriot system are cost-effective against these targets.

While the variety of drones and their uses requires varied defenses, the steps in the "kill chain" for counter-drone operations require common capabilities.

U.S. Soldiers assigned to 678th Air Defense Artillery Brigade, 263rd Army Air and Missile Defense Command, South Carolina Army National Guard, conducts Counter-Unmanned Aircraft System(C-UAS) during their culminating training exercise at McCrady Training Center, in Eastover, South Carolina, Aug. 15-17, 2025.

SGT. TIM ANDREWS/ U.S. ARMY NATIONAL GUARD

First, detection capabilities must be able to find the drone. This can be achieved using a variety of radar systems, radio-frequency detectors, visual and thermal imaging cameras and acoustic sensors.

Next, tracking drone attacks requires continuous sensor coverage that can follow a drone's movement, handing off coverage from multiple sensors and systems.

Identification of a drone enables defense systems to determine if it is a friendly or enemy asset. This can be achieved using transponders and cooperative identification system while integrating radar signature libraries of known drone types, behavioral analysis, visual recognition and radio frequency signatures. However, this step often must be done in very short timelines.

The decision stage assesses identification information to determine an appropriate response. Assessment may begin with automated systems and be escalated to humans for a final decision.

Defeating a drone attack my involve hard-kill options such as kinetic or energy attacks, or soft-kill options such as electronic warfare or cyber attacks.

Finally, post-action analysis enables forces to assess their drone defenses and make improvements. This could involve recovering drone wreckage for analysis or identifying gaps in defenses throughout the kill chain.

Perhaps the biggest challenge in drone defense is that drone weapons are extremely agile and flexible. They can move and change directions quickly while operating alone or in swarms, either autonomously or under the control of a remote operator. Further they evolve very rapidly, which can quickly reduce the effectiveness of defenses.

"Drone operators can make pretty

minute changes pretty quickly to address changes in measures and counter measures," Ramsdale said. "That's going to require changes in defenses at the same speed of development. Drone warfare, is evolving very rapidly compared to warfare in general."

The Future of Drone Defense

As the DoD and its partners work to develop effective drone defenses, they must keep a number of factors in mind.

The Counter-Small Unmanned Aircraft Systems Strategy DoD published in 2021 calls for a layered defense architecture. This approach requires redundancy by having each layer serve as a backup to other layers. It also must present diversity, using different sensors and effectors to provide options against varied threats. The layered approach should establish depth by deploying multiple engagement layers as threats approach, so if one layer fails, others provide additional chances. The layers also must overlap so threats can't exploit gaps, and they must be scalable and adaptable to deal with the continuing evolution of threats. This adaptability should include modular design to allow the introduction of new components quickly and easily.

DoD and its partners should also look to balance costs with effectiveness. This could lead to the prioritization of directed energy weapons, which costs less per shot, as the primary effector, with more expensive kinetic systems serving as a backup against large or hardened targets. Ultimately, these systems should have a goal of incurring greater cost on the attacker than the defense.

As new defense capabilities emerge, artificial intelligence will play a key role. In addition to enabling the fusion of sensors to process data from all layers of the defense architecture, AI will allow DoD to automate threat evaluation and weapon assignment faster than humans can. AI will also power massive numbers of low-cost drones to create a defensive swarm.

Ultimately, the C-UAS capabilities that DoD fields will be essential to maintaining U.S. dominance against global adversaries as well as asymmetric threats. These systems must be able to protect personnel and assets against rapidly evolving drone attacks, now and in the future.

"Effective drone defense is going to require a breadth of solutions, including drones themselves, but they must be integrated into a complete solution," Wilkens said. "It's going to have to evolve quickly. A defense that works today might change six months from now." **DN**