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INTEGRATION OF UAV AND ANTI-UAV SYSTEMS IN STATE BORDER PROTECTION: INTERNATIONAL EXPERIENCE AND MODERN APPROACHES

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Abstract

This article examines the role of Unmanned Aerial Vehicles (UAVs) in 21st-century border conflicts and hybrid warfare, highlighting their tactical and strategic advantages as well as the emerging threats they pose to national security. Drawing on the insights and experiences from recent conflicts, such as the Russia-Ukraine war and the Nagorno-Karabakh conflict, the study analyzes how the evolution of drone technology is fundamentally reshaping border defense and protection frameworks.

Keywords: Unmanned Aerial Vehicles (UAV), border security, asymmetric warfare, FPV drones, cyber threats, Electronic Warfare (EW), military logistics, “Smart Border”, anti-UAV.

Introduction

The first quarter of the 21st century has entered human history as a period of profound crisis and restructuring of the international relations system and global security architecture. The international legal mechanisms that emerged after the Second World War, based on the Yalta-Potsdam agreements and reinforced by the outcomes of the Cold War, have significantly lost their functional effectiveness today. The capacity of international institutions such as the United

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Nations (UN) and the OSCE to maintain global and regional stability, and to resolve conflicts between sovereign states through preventive diplomacy, has weakened. Consequently, territorial and geopolitical claims that were considered "frozen" for many years in strategically vital regions of the world have reactivated, triggering a chain reaction in the international security system: multi-layered border conflicts, proxy clashes, and large-scale hybrid wars.

This radical transformation of the global security environment imposes completely new and complex strategic tasks on state border guard and protection systems. Until the late 20th century, the inviolability of a state border was primarily measured by the ability to repel direct (classical) aggression from an enemy's regular army, heavy armored vehicles, and frontal aviation. In the modern era, however, threats have lost their linear character. Today, alongside traditional military risks, digital manifestations of transnational organized crime, uncontrolled migration flows caused by global economic and ecological imbalances, clandestine smuggling of weapons and narcotics, and cyber threats aimed at eroding state sovereignty from within are merging into a single destructive complex. This concept of a "hybrid enemy" necessitates a thorough revision of border defense concepts that rely solely on traditional engineering and fortification barriers.

The state border is one of the core attributes of any country's sovereignty, territorial integrity, and national security. Modern globalization processes, the intensification of international migration flows, and new forms of transnational crime place entirely new demands on the border security system. Traditional border control measures – such as foot patrols, observation towers, and stationary technical equipment – have certain limitations in providing continuous surveillance over vast territories. Securing the border requires massive human and material resources, particularly in mountainous, desert, and infrastructurally underdeveloped regions.

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Consequently, the world's developed nations now widely utilize Unmanned Aerial Vehicles to maintain border security. UAVs expand the capabilities of border troops, elevating surveillance efficiency to a brand-new level.

An Unmanned Aerial Vehicle (UAV) is an aircraft with no pilot on board, operated remotely or flying autonomously based on a pre-programmed flight path. In international practice, they are commonly referred to as drones, UAVs (Unmanned Aerial Vehicles), or UAS (Unmanned Aircraft Systems). UAVs represent a vital direction in modern aviation technology, widely deployed in surveillance, reconnaissance, monitoring, cargo transportation, search and rescue, military operations, agriculture, geodesy, and numerous other fields. Their primary advantage lies in their capacity to operate in complex or dangerous areas without risking human life.

An Unmanned Aerial Vehicle generally consists of the following components:

1. **Flight platform** – fuselage, wings, engine, or rotors;
2. **Control system** – remote control console or automatic navigation software;
3. **Navigation tools** – GPS, GLONASS, or other guidance systems;
4. **Surveillance equipment** – video camera, thermal camera, sensors;
5. **Communication system** – means of signal exchange with the operator;
6. **Power source** – battery, fuel, or hybrid systems.

Based on their core function and structural design, unmanned aircraft are divided into several types:

1. **Quadcopters and multirotors** – capable of vertical takeoff and landing (VTOL), ideal for short-range surveillance;
2. **Fixed-wing drones** – capable of long-range flights, utilized for monitoring vast territories;
3. **Hybrid aircraft** – combine vertical takeoff capabilities with long-range flight endurance;
4. **Military UAVs** – deployed for reconnaissance, target acquisition, and strike missions;

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5. **Civilian drones** – used for photography, videography, agriculture, delivery services, and general monitoring.

Unmanned aerial vehicles are a crucial element of the modern security matrix, minimizing the human factor, maximizing surveillance efficiency, and broadening operational control. Therefore, the role of UAVs in border security, military, and civilian sectors will expand exponentially in the future.

The modern system of state border protection is undergoing significant shifts under the influence of scientific and technological progress, digitalization processes, and escalating transnational security threats. Traditional border control methods based on patrol units, stationary observation posts, vehicles, and visual monitoring are often insufficient to effectively secure expansive border sectors comprising diverse terrains like land, sea, river, mountainous, and desert regions. Under these conditions, Unmanned Aerial Vehicles (UAVs) have emerged as one of the most effective innovative tools for reinforcing border security.

Amid this global geopolitical turbulence and stagnation, military strategy, operational art, and warfare doctrines have entered a revolutionary phase. Large tank divisions, costly heavy artillery systems, and stationary command posts – which formed the bedrock of former military doctrines and demanded massive material-economic resources and the mobilization of thousands of personnel – are failing to deliver expected results in modern asymmetric conflicts. On the contrary, facing modern strike assets integrated with high-precision reconnaissance systems, such heavy, slow-moving military platforms with high thermal or radiation signatures become easy targets. On the battlefield, expensive capital-intensive systems (heavy weapons) are yielding ground to high-tech, highly agile autonomous systems that provide a standoff distance advantage over the enemy and, crucially, are relatively cheap to manufacture.

At the epicenter and acting as the driving force of this military-technical revolution is the technology of Unmanned Aerial Vehicles (UAVs) or drones. Drones have evolved from mere tactical reconnaissance and monitoring tools into

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multifunctional combat systems capable of inflicting irreversible strategic damage on an enemy's economy and infrastructure. The integration of UAV technologies with artificial intelligence, multispectral sensors, and geographic information systems (GIS) mathematically multiplies the efficiency of state border protection while introducing unprecedented vertical and asymmetric threats to the national security framework.

In recent years, border conflicts observed in Central Asia, the Middle East, the Caucasus, Eastern Europe, and Africa have forced states to monitor and protect their borders using modern technologies. In this scenario, UAVs are recognized as one of the most effective instruments for ensuring border security.

Unmanned aerial vehicles have traversed a complex evolutionary path from simple surveillance tools to multi-role combat systems. Today, in terms of their functions and technical capabilities in ensuring and threatening border security, UAVs are categorized into four major strategic groups:

1. **Operational-Strategic Reconnaissance (MALE and HALE classes):** This includes drones like the US MQ-9 Reaper, Turkey's Bayraktar TB2 and Akıncı, and China's Wing Loong. Equipped with powerful optoelectronic, infrared, and radar stations, these assets can monitor deep inside enemy territory up to hundreds of kilometers 24/7 without crossing the state border.
2. **Loitering Munitions (Kamikaze Drones):** Systems such as the Lancet (Russia), Switchblade (USA), and Harop (Israel) operate in a prolonged loitering mode in the air. In border clashes, these drones are the most effective tools to "blind" the enemy's Air Defense (AD) systems and command posts.
3. **Tactical and Micro-Drones (Quadcopters):** Militarized variants of civilian drones like the DJI Mavic. These small, stealthy devices allow every platoon and unit to have its "own eyes" at the tactical level, fundamentally changing the nature of trench warfare.
4. **FPV (First Person View) Strike Drones:** The greatest breakthrough in recent warfare. Through special video goggles, the operator can guide a high-speed

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drone into any target (such as the weakest part of a tank or inside a trench) with surgical precision.

The greatest revolution that UAVs have brought to military science is the radical asymmetric transformation of warfare and defense economics. In classical doctrines of war, achieving victory required a state economy to possess a multi-billion-dollar military-industrial complex. Drone technology has completely shattered this capitalist equilibrium in the military sphere.

Today, a single FPV drone assembled from off-the-shelf components costing around $500 can destroy modern main battle tanks worth over $5 million, provided the operator is highly skilled. Similarly, kamikaze drones worth a few tens of thousands of dollars are capable of completely neutralizing an enemy's strategic radar stations valued at $20 million.

Logistical Convenience

Continuous supply of weapons and ammunition to a traditional artillery division requires tons of cargo trucks and a complex supply chain. UAVs have completely solved this problem: a squad of several strike drones and their ground control stations can be easily transported in a single standard passenger car, completely undetected by the enemy.

However, this asymmetry is also triggering a crisis in state defense budgets. Today, to repel mass attacks by cheap drone swarms whose market price does not exceed $10,000, states are forced to expend their expensive anti-aircraft missiles (Patriot, S-400, etc.) which cost anywhere from $1 million to $3 million per launch. This economic paradox can completely exhaust the material resources of even the most powerful state economy in long-term conflicts.

Previously, state border protection was limited to a linear (two-dimensional) defense system, such as building engineering fortifications and wire fences along a specific line. The mass influx of UAVs has injected a vertical and asymmetric character into border security. Now, threats to national security emerge not only

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from the ground level but penetrate through the micro-level (low altitudes) of airspace.

The most dangerous manifestation of these new-era threats is “Grey Zone” operations and the anonymity of attacks. Drones offer an aggressive party the opportunity for plausible deniability regarding their actions. For instance, if a strategic border facility of a state is bombed from the air by an unidentified aircraft, proving legally and technically in a short timeframe precisely which state or group carried out the attack remains extremely complicated.

Simultaneously, a digital transformation of transnational organized crime is being observed along borders once deemed inviolable. Today, drug cartels and smugglers extensively utilize autonomous drones to bypass ground sensors and patrols in rugged mountainous or desert border areas. Operating based on pre-programmed digital maps and GPS/GNSS coordinates, these devices can fly without operator supervision or radio communication, rendering multi-billion-dollar ground fortification systems of border troops practically obsolete.

Finally, the most terrifying cyber-threat in near-future military strategy is “Swarm Intelligence” driven by artificial intelligence. In this scenario, there is no need for a human operator to issue remote commands; dozens or hundreds of micro-drones communicate with each other via a local network, launching a strike on a strategic target under a unified collective algorithm.

The scale of global threats posed by unmanned aerial vehicles indicates that they cannot be effectively countered using only traditional firearms. In modern conditions, reliable protection of state borders demands the creation of an integrated three-tier anti-UAV (Anti-UAV) ecosystem within the defense framework:

[Stage 1: Early Detection] ⟷ [Stage 2: Electronic Jamming] ⟷ [Stage 3: Kinetic Destruction]

(Doppler Radars, Acoustic/AI Sensors) (EW Systems, GPS-Spoofing Tech) (Laser Weapons, Programmable Shells)

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- **Stage 1: Early detection and multi-spectral surveillance.** Because modern micro and tactical copters are primarily manufactured from plastic, carbon, and other composite materials, large military radars cannot detect them. Therefore, borders must integrate specialized Doppler radars capable of recognizing small-sized targets, acoustic sensors that isolate the noise of drone engines from a distance, and AI-powered optical stations that analyze thermal and visual changes in the air within seconds.
- **Stage 2: Electronic Warfare (EW) and Spoofing technologies.** Instead of physically destroying the drone in the air, this method directly impacts its digital "brain" and navigation system. Modern anti-drone weapons (drone-rifles) block the radio frequency channels linking the device to the operator as well as satellite navigation signals (GPS, GLONASS, BeiDou). The most advanced direction in this field is GPS-spoofing, where false geographical coordinates are transmitted to the enemy's unmanned vehicle, causing the drone to lose its orientation, crash to the ground, or lose control and return to the aggressor's own base.
- **Stage 3: Kinetic and laser physical destruction.** If an enemy drone is programmed in a fully autonomous mode and does not respond to electronic signals at all, EW tools lose their effectiveness. In such situations, next-generation kinetic and thermal weapons are deployed:
  - **Directed energy (laser) weapons:** Burn out the delicate optical sensors and cameras of a flying drone within fractions of a second, completely blinding it.
  - **Programmable automated platforms:** High-speed projectiles that calculate the exact coordinates of an aerial target and detonate right in front of it, creating an impassable cloud of shrapnel fragments.
  - **"Hunter drones":** An unconventional tactical solution that fires a special, high-strength net over the enemy drone to lock its propellers and force it to crash to the ground.

To elevate the modern security level of states, military practice worldwide is transitioning toward the "Smart Border" concept. Within this framework, UAVs,

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video surveillance systems, radar complexes, ground sensors, artificial intelligence platforms, and geographic information systems (GIS) operate in an integrated manner as a single cohesive ecosystem.

In the context of 21st-century military-political conflicts and hybrid threats, unmanned aerial vehicles have evolved from a mere auxiliary technical tool into the primary factor deciding the fate of the battlefield and strategic borders. The rapid evolution of UAVs has fundamentally disrupted traditional warfare tactics and state border defense frameworks.

The biggest revolution triggered by drones is the asymmetry in the economics of war. The capability of a simple device costing a few hundred dollars to destroy heavy armored vehicles or radar systems worth millions of dollars has completely shifted the strategic balance. At the same time, the risk of anonymity in **"Grey Zone"** operations, transnational criminal groups moving their smuggling routes into the air, and the looming threat of AI-driven "drone swarms" demand a completely new approach from national security systems.

To mitigate the risks associated with UAV usage, the following measures are essential:

1. Enhancing technical reliability through regular maintenance and strict quality standards.
2. Strengthening cybersecurity through encryption, protected communications, and anti-jamming technologies.
3. Adopting clear legislation regarding privacy and data protection.
4. Establishing national UAV regulations and a licensing system for operators.
5. Training operators and developing comprehensive emergency response plans.
6. Implementing geofencing and collision-avoidance technologies.
7. Creating anti-drone systems to counter criminal exploitation.
8. Strengthening ethical control mechanisms in surveillance and military applications.

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Unmanned aerial vehicles have increased efficiency, safety, and convenience across many sectors. However, they also introduce negative factors such as technical malfunctions, cyber risks, privacy violations, legal ambiguity, criminal abuse, and environmental issues. These challenges indicate a need not to abandon UAV technology, but to manage it responsibly, establish modern legislation, and develop secure technologies. A balanced approach will allow society to reap the benefits of UAV capabilities while minimizing their harmful impacts.

The experience of utilizing unmanned aerial vehicles (UAVs) in the operations of foreign border services demonstrates that these technologies are widely deployed as effective tools in safeguarding state borders and countering illegal migration, smuggling, trafficking of weapons and narcotics, terrorist threats, and other transnational risks. In particular, the experience of the United States, Turkey, Israel, and the European Union shows that the speed, accuracy, and coverage of border control have increased significantly through the use of drones. The most effective methods of utilizing UAVs in border security include continuous aerial patrolling, real-time video surveillance, night thermal monitoring, the integration of drones with ground patrols, comprehensive management using camera and sensor systems, automated object detection driven by artificial intelligence, mobile command vehicles, and swarm application techniques. These approaches yield high results in monitoring vast territories within short periods, conserving human resources, and preventing violations.

Simultaneously, the widespread proliferation of unmanned aerial vehicles has given rise to new threats. Incidents of illicit drones being used for smuggling, espionage, transporting prohibited cargo, conducting surveillance, or damaging strategic assets are on the rise. Consequently, many states are deploying anti-drone (Counter-UAS) systems. These systems rely on a multi-layered defense model consisting of radars, radio frequency detection tools, optical and thermal surveillance cameras, signal jamming, GPS blocking, safe landing protocols, and laser-based neutralization assets.

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The most effective counter-measures consist of:

1. Establishing early-warning anti-drone monitoring systems in border zones.
2. Setting up a unified center for drone detection, tracking, and identification.
3. Implementing rapid information exchange networks between border troops and other security agencies.
4. Deploying electronic warfare assets and lawful neutralization methods.
5. Providing specialized training for operators and technical specialists.
6. Improving national legislation and tightening liability for illegal drone flights.

In general, ensuring border security under modern conditions requires not only the utilization of drones but also the parallel development of counter-drone systems. The future effective model of a border service is an integrated security framework based on the combination of **"drone + artificial intelligence + sensor + ground patrol + anti-drone protection."**

In conclusion, it must be emphasized that today, the territorial integrity of states and the inviolability of borders depend not merely on their manpower or classical military strength, but on the degree of digital control they can establish over the micro-level of their airspace. Modern border defense cannot restrict itself to merely possessing a fleet of drones; it must actively implement a three-tiered anti-UAV ecosystem that encompasses multi-spectral early detection, electronic warfare (EW) jamming, cyber interception, and next-generation laser-kinetic weapons. The security of the future is decided in the laboratories of intellectual defense and high technology; therefore, achieving digital supremacy on this front is a vital necessity for every sovereign state.

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