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THE REVOLUTIONARY IMPACT OF UNMANNED AERIAL SYSTEMS ON MODERN WARFARE: AN ANALYSIS OF UKRAINIAN STRATEGIC AND TACTICAL INNOVATIONS

The use of unmanned aerial systems (UAVs) in Ukraine has acquired a revolutionary character, fundamentally changing the art of war. The purpose of this article is to analyze the key technological, institutional, and doctrinal innovations adopted by the Defense Forces of Ukraine (DFU). This study analyzes the revolutionary and strategic role of Unmanned Aerial Vehicles (UAVs) in the Russo-Ukrainian war, which have fundamentally transformed modern warfare. The use of UAVs has become systematic and is responsible for approximately 80% of tactical damage, evolving from a mere reconnaissance aid into the primary means of fire damage, compensating for the shortage of classic artillery ammunition. The article highlights institutional and technological innovations implemented by Ukraine to achieve technological superiority. Key steps include the creation of the Unmanned Systems Forces and the launch of the "Drone Line" project, designed to scale UAV effectiveness. Particular attention is given to the unique capability of the Defense Forces of Ukraine (DFU) to execute asymmetric Deep Strike operations against critical military-economic assets in the aggressor's deep rear (e.g., oil refineries, airfields). The "Spiderweb" Case is detailed as a classic example of asymmetric action, demonstrating the use of the "Trojan Horse" concept, swarm attacks, and elements of Artificial Intelligence (AI) to inflict irreversible damage on strategic assets with minimal resources. Institutional support is also examined, specifically the role of the Brave1 defense technology cluster in accelerating technology from R&D to mass procurement, and the digitalization of logistics via the DOT-Chain Defense platform. The importance of global partnerships—such as the Drone Coalition (with commitments of €2.75 billion), the "Drone Deal" with the US, and the localization of Baykar Makina's production—is underscored as guaranteeing long-term technological support. In conclusion, the integration of technology, decisive asymmetric actions, and international support provides Ukraine with strategic resilience and serves as a decisive lesson for all modern armies on the future of warfare

Keywords: *Unmanned Aerial Vehicle (UAV); Unmanned Systems Forces (USF); modern warfare; Deep Strike; Operation Spiderweb; defense technology.*

Introduction

The use of unmanned aerial systems (UAVs) by the Defense Forces of Ukraine (DFU) has become a decisive and revolutionary factor in modern warfare, fundamentally transforming the art of war. What began as a supplementary tool for reconnaissance has evolved into the primary means of fire damage? This qualitative leap is quantified by the fact that drones are now responsible for approximately 80% of all damage inflicted at the tactical level [1].

This transformation was not accidental but an asymmetric response to battlefield conditions, specifically the shortage of classic artillery ammunition. This necessity forced a doctrinal shift, effectively leveling the enemy's superiority in heavy weapons. The critical importance of this shift is emphasized by the state, including the President and the Ministry of Defense, who have prioritized the development of domestic defense-tech and a massive increase in production capacity.

Ukraine has become a global testing ground for unmanned innovations, leading to new military doctrines and striking organizational steps, such as the creation of the Unmanned Systems Forces [2] and the "Drone Line" project [3].

The purpose of this article is to analyze the advanced technologies and innovative concepts implemented by the DFU. The analysis is structured into five key areas:

1. Innovation in production and scaling of best practices.
2. Inflicting damage on enemy objects in the deep rear (Deep Strike).
3. Institutional and financial innovations.

4. Countering enemy UAVs (C-UAS) and the development of interceptor drones.

5. International cooperation in the field of UAVs.

The central thesis of this work is that this comprehensive and rapid integration of technology, decisive institutional action, and international support has provided Ukraine with strategic resilience and a technological superiority that serves as a lesson for all modern armies.

Materials and methods

This article employs a qualitative research methodology, specifically a descriptive and analytical review of documented strategic, tactical, and institutional innovations in the use of unmanned aerial systems by the DFU. The methodology follows an analytical synthesis approach, structuring the findings to assess the revolutionary impact of UAVs on modern warfare.

The materials for this analysis are drawn from open-source data provided in the source document, including official government communications, project websites, and summaries of operational results. The article adheres to the IMRAD (Introduction, Materials and methods, Results, Discussion) structure as recommended for scientific publications.

The scope of the analysis is defined by the five key areas of innovation listed in the introduction. The research method includes a specific case study of "Operation Spiderweb", which is used as a prime methodological example to illustrate the practical application of asymmetric action, technological ingenuity, and intellectual superiority.

Results

The results of the analysis demonstrate a multi-faceted and highly adaptive ecosystem for UAV warfare. This ecosystem is built upon rapid domestic production, advanced strategic strike capabilities, and agile institutional frameworks.

Innovation in Production and Scaling: The Brave1 Cluster

A cornerstone of Ukraine's technological acceleration is the Brave1 Defense Technology Cluster, established in 2023 [4]. It functions as the only state coordination platform designed to critically accelerate the path of military technology from an innovative idea (R&D) to mass state procurement and effective application at the front. It achieves this by consolidating the efforts of developers, the military, the government, and investors.

The key mechanisms of the cluster include:

• Stimulating Innovation: The Brave1 platform has registered over 2000 developments, with more than 20% in the field of UAVs. This portfolio covers a wide spectrum, from FPV drones and bombers to reconnaissance systems and C-UAS interceptor drones.

• Funding and Codification: Brave1 provides grant support for promising projects (up to UAH 150 million). More critically, it ensures their codification (admission to operation). This is a critical stage that allows the state to purchase already proven and standardized technologies, bypassing traditional bureaucratic bottlenecks.

• Direct Integration with Troops: The Brave1 Market serves as a direct-action marketplace, or a catalog of innovative defense technologies. This allows military units to directly order UAVs, ground robots, EW assets, and AI modules from Ukrainian manufacturers.

Brave1 serves as the institutional engine that ensures Ukrainian technological leadership is quickly transformed into a tangible combat advantage at the front.

Strategic Deep Strike Capabilities

A primary result of this innovation is the DFU's acquired and unique capability to plan and conduct operations to destroy high-value targets in the deep rear of the Russian Federation. These consistent and effective measures are aimed at a single strategic logic: to degrade the military-economic potential of the aggressor.

Targets are not tactical, but strategic nodes that support the war:

Oil Refining Infrastructure: Strikes focus on critical primary processing units, disabling significant capacity;

Military Airfields and Arsenals: Targeting strategic aviation bases and ammunition depots;

Logistics and Production: Damaging military factories and critical infrastructure hundreds of kilometers from the front line.

This capability is enabled by two technological pillars:

1. Domestic Long-Range UAVs: Ukraine shifted from standard commercial drones to developing and scaling its own fixed-wing, aircraft-type UAVs. Examples include the "Beaver," "UJ-22 Airborne," and "AQ-400 Scythe" series, all capable of covering distances greater than 1000 km. (see Fig. 1).

2. Hybrid Guidance Systems: To overcome powerful enemy electronic warfare and GPS jamming, these UAVs utilize hybrid navigation. They rely on inertial navigation systems (INS) and alternative methods, such as navigation by digital terrain map, to minimize reliance on GPS, especially in the final phase of the mission. This makes them significantly less vulnerable to enemy EW.

Case Study: Operation "Spiderweb"

Operation "Spiderweb" (see Fig. 2) has become a classic precedent in modern military history, demonstrating the DFU's unique asymmetric capabilities. This operation, conducted on June 1, 2025, destroyed a significant portion of Russia's combat-ready strategic aviation and illustrates key innovations that are already being included in military textbooks.

Operational-Tactical Innovations (Asymmetry):

"Trojan Horse" Concept: The key asymmetric advantage was the method of strike. Instead of launching drones from Ukraine, the SSU smuggled dozens of attack UAVs deep into the Russian Federation. They were hidden in special containers

disguised as commercial cargo (sections of modular houses) and transported on ordinary trucks;

Figure 1. Long-range UAVs made in Ukraine. [5]

Proximity Launch: The drones took off directly near the target airfields. This minimized the reaction time of Russian air defense, which was postured to detect long-range, high-altitude targets, not small drones appearing kilometers away;

Coordinated Swarm Strike: The operation employed the principle of "swarm warfare". Over 100 small drones, mainly FPVs, were used simultaneously against four strategic air bases. The number, low cost, and minimal radar visibility of these small drones completely overloaded traditional air defense systems;

Efficiency: The ratio of damage caused to resources used was impressive. With cheap drones and intelligent logistics, aviation assets worth billions of US dollars were destroyed or damaged.

Technological Ingenuity:

Autonomy: The drone swarms were controlled remotely using the open-source ArduPilot autopilot system. This allowed for autonomous flight to pre-set GPS coordinates, minimizing the impact of EW.

AI Guidance: According to reports, drone algorithms were trained on bomber images to autonomously recognize and aim at the most vulnerable points, such as fuel tanks in the wings. This provided high accuracy and maximum destructive power.

Network Exploitation: The drones were coordinated through conventional Russian telecommunications networks (mobile communications), exploiting a vulnerability created by security services not disconnecting communications at secret military facilities.

The strategic impact of "Spiderweb" was profound. It caused irreversible damage to Russian long-range aviation, as the destroyed bombers (Tu-95MS, Tu-22M3) have not been mass-produced for decades. It demonstrated that swarms of cheap UAVs can effectively neutralize expensive, manned strategic aviation, forcing a global reassessment of strategic asset protection.

Institutional and Financial Innovations

The effectiveness of these drones is supported by deep institutional and financial reforms aimed at maximizing supply speed and supporting domestic producers.

The "Drone Line" Project:

Initiated by the President, this project is a revolutionary step aimed at scaling the most effective unmanned systems. Its key tasks are:

1. Creation of a "Killzone": To form a continuous "killzone" 10-15 km deep, making it impossible for the enemy to advance without significant losses.
2. Infantry Air Escort: To provide units with constant air reconnaissance and fire cover to destroy targets before they reach friendly positions.
3. Scaling Experience: To identify and scale the unique combat experience of the best drone units across all branches of the military.

A key innovation in this project is simplified recruiting. The Ministry of Digital Transformation [7] launched the "Drone Line" service in the Diia application, allowing candidates to apply directly to top units without queues or paperwork.

Priority Funding and Procurement:

The government has confirmed the financial priority of technological weapons. As of July 2025, the Defense Procurement Agency had state contracts for unmanned systems valued at UAH 99.3 billion. In the first seven months of 2025, the Agency contracted three times more UAVs than in all of 2024. Critically, more than 95% of these contracted UAVs are Ukrainian-made [8].

Digitalization of Procurement (DOT-Chain Defense) [9]:

To eliminate bureaucratic obstacles, the innovative digital platform DOT-Chain Defense was launched. This system works as a modern "weapons marketplace". Its unique feature is a rating system, where military personnel can evaluate ordered drones and leave feedback on their combat use. This provides direct feedback to manufacturers, helps units make informed choices, and gives the state a clear view of real frontline needs.

Simplified Logistics:

A key achievement was the simplification of internal military procedures. UAVs, systems, and ammunition for them are now written off only under the act of write-off as a result of launch. This eliminates the need for extensive paper documents and frees operator time for combat missions [10].

Countering Enemy UAVs (C-UAS)

In response to enemy drone threats, Ukraine is actively developing its own interceptor drones, forming a new type of troops in the Air Force for unmanned air defense. This development has progressed through stages:

Stage 1: FPV kamikaze drones, used to destroy enemy reconnaissance and strike drones at short distances.

Stage 2: Aircraft-type interceptor drones, which have longer range and speed.

Stage 3: Specialized interceptors, developed specifically to counter loitering munitions like the Shahed-type.

These interceptor drones (see Fig. 3) use diverse technologies, including: physical damage (ramming or dropping nets), kinetic ammunition (such as the Ukrainian Drone Hunter equipped with two 12-caliber barrels), electronic counteraction to "jam" the control signal, and AI integration for autonomous detection, capture, and tracking.

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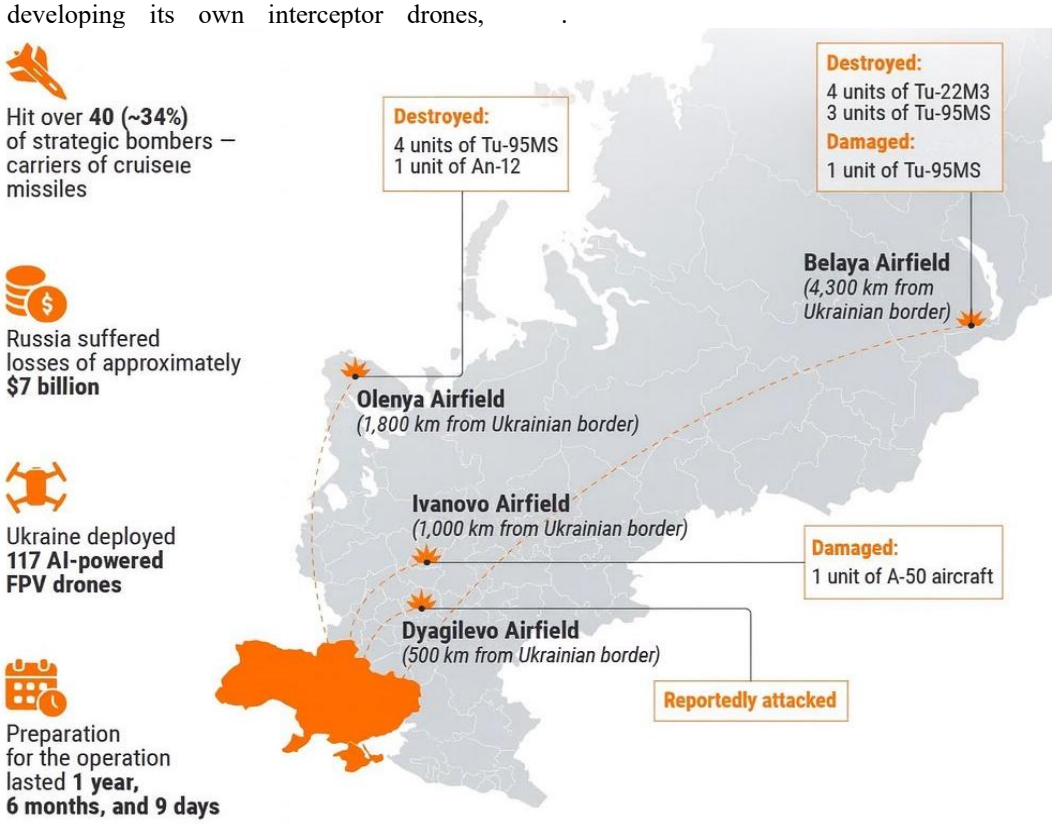

Figure 2. Results of "Spiderweb" Operation [6]

International Cooperation

Ukraine's domestic innovation is amplified by active international cooperation focused on joint production, funding, and technology exchange.

Multilateral Drone Coalition:

This is one of the most important initiatives launched within the "Ramstein format". Led by Latvia and the United Kingdom, it unites about 20 partner countries (including Australia, Canada, Germany, Sweden) [12]. The coalition's strategic goal is the large-scale supply of UAVs. Participating countries have committed at least €2.75 billion to support this effort during 2025. This includes the planned supply of approximately 35,000 interceptor drones to combat Russian Shaheds.

Strategic Bilateral Partnerships and Localization:

Ukraine has moved beyond simple procurement to joint production and technology localization:

United States: A long-term "Drone Deal" [13] is being negotiated. This 5-year agreement concerns the purchase of Ukrainian drones and the possibility of joint production of a number of Ukrainian UAVs;

Turkey: The Turkish company Baykar Makina is implementing a project to build a plant in Ukraine for the production and maintenance of UAVs like the Bayraktar TB2 and Akinci [14];

Figure 3. Different types of interceptor drones [11].

Netherlands: Through the "Build with Ukraine" initiative, €110 million in investments will be used to launch joint production of deep-strike UAVs [15];

United Kingdom: The LYRA program establishes cooperation in the development and scaling of defense technologies, including bombs and interceptor drones [16];

Specialized Localization: Cooperation extends to maritime systems, with Norway's Kongsberg opening an office in Kyiv for the joint production of unmanned surface vehicles (marine drones). An agreement was also signed with the American company AeroVironment for the phased localization of Switchblade 600 kamikaze drones.

Discussion

The results presented confirm that UAVs have become a revolutionary and decisive factor in modern warfare. The discussion of these results can be framed by the three key lessons Ukraine's experience offers to the world.

Lesson 1: Doctrinal and Budgetary Transformation.

The "80% rule" is not just a statistic; it signifies a complete doctrinal shift. Drones have become an asymmetric replacement for expensive artillery. This implies that the traditional NATO funding priority, focused on expensive, low-volume platforms, is outdated. The new doctrine requires a "junk layer" of cheap, mass-produced, and expendable UAVs.

Furthermore, the success of Ukrainian deep-strike drones proves that the "safe zone" or deep rear has disappeared. Not a single fixed, high-value infrastructure asset (air base, port, logistics hub) is secure. This demands a complete reassessment of physical and electronic security for all strategic objects.

Finally, the traditional bureaucratic procurement cycle (5-10 years) is incompatible with the pace of technological warfare, where changes occur every 3-6 months. The success of Brave1 shows that NATO countries must establish similar mechanisms to rapidly codify and integrate commercial, AI-driven solutions within months, not years.

Lesson 2: Technological Imperatives – Autonomy and C-UAS.

The results show that the modern frontline is a "GPS-Free War". The heavy use of EW means that no GPS-dependent UAV can survive. The only path to successful deep strikes is through autonomy, specifically inertial navigation systems (INS) and onboard artificial intelligence (computer vision). This implies that investment in Lethal Autonomous Weapons Systems (LAWS) is no longer a future concept but a present-day necessity.

Conversely, a critical gap in C-UAS has been exposed. Expensive anti-aircraft missile systems are economically unprofitable and technically ineffective against swarms of cheap FPV drones. The priority for all modern armies must be the creation of a Multi-Level C-UAS System, combining short-range (trench) EW, laser/kinetic systems for swarms, and micro-air defense systems using interceptor drones.

Lesson 3: Institutional Adaptation.

The "Spiderweb" case and the creation of the USF prove that technological ingenuity and intellectual superiority are decisive. This requires institutional adaptation. The creation of a separate branch of forces – the Unmanned Systems Forces – is a necessary organizational innovation. It ensures centralized doctrine, development, and lobbying for technological needs.

Logistics must also be digitized. Bureaucracy and long supply chains are an advantage for the enemy. Ukraine's response launching DOT-Chain Defense and simplifying write-off procedures is a model for all allies. A digitized "Markeplace Model" with a feedback/rating system is critical to reduce delivery times and integrate real combat lessons.

Conclusions

UAVs have become a key factor in Ukraine's strategic resilience and have fundamentally reshaped the modern art of war. The set of measures taken by the Defense Forces of Ukraine has provided technological superiority and strategic resilience.

The conclusions of this analysis are threefold:

1. Tactical and Operational Dominance: Drones have become the main means of fire damage (~80% of hits), providing an asymmetric response to ammunition shortages. The creation of the Unmanned Systems Force and the "Drone Line" project consolidates this new doctrine and scales best practices.

2. Strategic Asymmetric Influence: The DFU has acquired a unique Deep Strike capability to destroy strategic targets in the enemy's deep rear (refineries, airfields). The "Spiderweb" case became a classic precedent for how technological ingenuity (swarm strikes, AI, "Trojan Horse" logistics) can achieve maximum effect with minimal forces, causing irreversible damage to strategic assets.

3. Institutional and International Support: The Brave1 technology accelerator has streamlined the path from R&D to mass procurement. Digital platforms like DOT-Chain Defense provide transparent financing and rapid delivery. This domestic success is guaranteed long-term support by the global Drone Coalition (€2.75 billion) and strategic joint-production agreements with the US ("Drone Deal"), UK (LYRA), and Turkey (Baykar).

Thus, UAVs are not just a type of weapon, but a key tool shaping the new world order in the military sphere. The Ukrainian integration of technology, decisive action, and international support provides a lesson in resilience and effective resistance for all modern armies.

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РЕВОЛЮЦІЙНИЙ ВПЛИВ БЕЗПІЛОТНИХ АВІАЦІЙНИХ СИСТЕМ НА СУЧАСНУ ВІЙНУ: АНАЛІЗ СТРАТЕГІЧНИХ ТА ТАКТИЧНИХ ІННОВАЦІЙ УКРАЇНИ

Це дослідження аналізує революційну роль безпілотних авіаційних систем (БАС) у російсько-українській війні, які набули стратегічного та систематичного характеру та докорінно змінили сучасне воєнне мистецтво. Встановлено, що на тактичному рівні дрони відповідають приблизно за 80% вогневого ураження, перетворившись з допоміжного засобу розвідки на головний інструмент завдавання вогневих ударів в умовах дефіциту класичних боєприпасів. У статті висвітлено інституційні та технологічні інновації України, спрямовані на досягнення технологічної переваги. Серед ключових кроків — створення Сил безпілотних систем та запуск проєкту «Армія дронів», що масштабує ефективність БАС. Особливу увагу приділено унікальній здатності Сил оборони України (СОУ) завдавати асиметричних ударів у глибокому тилу противника (Deep Strike), спрямованих на підрив його військово-економічного потенціалу (нафтопереробні заводи, аеродроми). Як класичний приклад такої асиметрії детально розглянуто операцію «Павутина» (Spiderweb), що продемонструвала застосування концепції «Троянського коня», ройових атак та елементів штучного інтелекту для ураження стратегічної авіації. Досліджено інституційну підтримку, зокрема роль кластера Brave1 у прискореному доведенні технологій від ідеї до масової закупівлі, а також цифровізацію закупівель через платформу DOT-Chain Defense. Підкреслено важливість міжнародного співробітництва (Коаліція дронів, «Drone Deal» зі США, локалізація виробництва Baykar Makina), яке забезпечує довгострокову підтримку та інтеграцію українського Defense Tech у глобальний оборонний ланцюг. У висновках наголошується, що інтеграція технологій, рішучі асиметричні дії та міжнародна підтримка забезпечують Україні стійкість і слугують ключовим уроком для усіх сучасних армій.

Ключові слова: *Безпілотний літальний апарат (БпЛА); Сили безпілотних систем (СБС); сучасна війна; глибинне ураження; Операція "Павутина"; оборонні технології.*

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