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Evolution of Unmanned Systems Capabilities in the Armed Forces of Ukraine during the War: Historical Overview and Practical Experience

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Abstract. Modern armed conflicts are increasingly dependent on technologies that can significantly increase the effectiveness of firepower and reconnaissance. The introduction of the latest technologies in unmanned systems (unmanned aerial vehicles, unmanned maritime systems, unmanned ground systems) is increasingly playing a key role.

Ukraine's experience is unique in that the country, being at war with a numerically superior enemy, not only adapted existing technologies but also created a new kind of troops - the Unmanned Systems Forces. This step was a response to the challenges of war and an example of an innovative approach to military affairs.

The relevance of the topic is due to the fact that Ukraine's experience can serve as a model for other states seeking to modernise their armed forces in the case of limited resources and high-intensity hostilities. Currently, the literature lacks a comprehensive historical analysis of the evolution of unmanned systems in the Armed Forces of Ukraine in 2022-2024, considering both organisational and technological changes. Most studies focus on individual aspects, such as tactics or specific models of unmanned systems. In this article, the authors aim to combine individual elements into a coherent picture, supplementing it with practical examples and development prospects.

Thus, the article presents the results of a retrospective analysis of the evolution of the capabilities of unmanned systems in the Armed Forces of Ukraine during the war (2022-2024) by such key components as: development of the command and control bodies of the Unmanned Systems Forces of the Armed Forces of Ukraine, military formations of unmanned systems and innovative technologies of unmanned systems.

Keywords: evolution, technology, unmanned systems, unmanned aircraft systems, unmanned ground systems, maritime (water) unmanned systems, Russian-Ukrainian war.

Introduction

Modern armed conflicts are increasingly dependent on technologies that can significantly increase the effectiveness of firepower and reconnaissance. The introduction of the latest communication technologies, remote control, and object recognition algorithms in unmanned systems (unmanned aerial vehicles (UAVs), maritime unmanned systems (MUS), and unmanned ground systems (UGS)) play a key role. Russia's full-scale invasion of Ukraine 24 February 2022 was a catalyst for the rapid development of these technologies in the Armed Forces of Ukraine (AFU). Initially used for basic reconnaissance, UAVs have evolved into multifunctional systems capable of performing a wide range of tasks, from adjusting artillery fire to destroying enemy

strategic targets at distances of up to 2,000 km.

Ukraine's experience is unique in that the country, being at war with a numerically superior enemy, not only adapted existing technologies but also created a new kind of troops - the Unmanned Systems Forces (USF). This step was a response to the challenges of war and an example of an innovative approach to military affairs. The relevance of the topic is enhanced by the fact that Ukraine's experience can serve as a model for other states seeking to modernise their armed forces in the case of limited resources and high intensity combat. Furthermore, the evolution of the Unmanned Systems (USs) in the AFU reflects broader global trends towards technology-oriented warfare, where the advantage depends not only on the number of troops, but also on innovation, its scaling and integration into military strategy.

Research on the role of UAVs in the Russian-Ukrainian war was actively conducted in 2022-2024 by both Ukrainian and international experts. A November 2024 report by the Centre for Strategic and International Studies (CSIS) stated that Ukraine had integrated more than 170 types of USs into its army, an unprecedented example of real-time technological adaptation. In their reports, analysts from the Institute for the Study of War (ISW) highlighted how the massive use of FPV UAVs has changed the tactics of close combat, allowing the AFU to compensate for the lack of heavy equipment.

Ukrainian sources, such as Militarnyi, Ukrainska Pravda and Defence Express, covered the stages of the Unmanned Systems Forces (USsF) development in detail, focusing on key figures involved. In addition, professional institutions in Ukraine, such as the Kharkiv National Air Force University, have repeatedly studied the technical aspects of USs development. International platforms such as ResearchGate and JSTOR published articles comparing the Ukrainian experience with the conflicts in Nagorno-Karabakh, but noted that the scale and systematic use of the USs in Ukraine is unparalleled.

At the same time, the literature lacks a comprehensive historical analysis of the evolution of USs in the AFU in 2022-2024, taking into account both organisational and technological changes. Most studies focus on individual aspects, such as tactics or specific USs models, while in this article, the authors aim to combine these elements into a holistic picture, supplementing it with practical examples and development prospects.

USs of various types (air, ground, maritime) are modern weapons systems that have become game changers in the Russian-Ukrainian war and have forced a change in the way warfare is conducted. Their widespread use has provided troops with new capabilities to:

round-the-clock online monitoring of the area of responsibility, which ensures an unprecedented level of situational awareness of all levels command and control (C2) commanders;

conducting reconnaissance (both overview and detailed) and fire damage to the enemy in tactical and operational depth;

adjustment of strike and firepower;

logistics and advanced medical evacuation;

combating enemy UAVs;

remote mining (demining) of areas;

fire support for combined arms units (subunits);

electronic warfare;

mining (de-mining) of waters and attacks on military surface ships and underwater facilities.

And most importantly, the use of USs makes it possible to reduce the number of personnel in the most dangerous areas of the front by replacing them with USs.

The experience of using USs in the Russian-Ukrainian war has proved their high efficiency, which has now created the conditions for scaling up the positive solutions. The scaling up takes place both through the further introduction of various USs into existing military formations and

through the creation of new formations focused on the use of mainly USs of various functional purposes to support the conduct of military operations of groups of troops (forces) of the AFU from the air, sea and land.

First, this is due to the fact that in a modern war the use of weapons and military equipment available to the AFU to support the actions of troops (forces) directly on or near the line of contact is associated with a significant risk of their being hit by enemy firepower and, accordingly, the loss of their crews.

In view of the above, in order to identify the main trends in development and problems that may be faced by the military units and subunits of the USs in the AFU and the USs themselves as a weapon system in the future, it is advisable to conduct a retrospective analysis of the evolution of their capabilities, starting from the moment of their practical absence (2022) to the present, when these capabilities have become quite significant. This is the reason for the relevance of the topic of this article.

Methodological Framework

The article uses the following as the main tools for studying the evolution of the development of USs capabilities in the AFU:

the method of retrospective analysis, methods of system analysis and synthesis, methods of management theory - in determining the main stages of development of the capabilities of the USs, analysis of the evolution of the structures of C2 bodies of the USs military units (subunits);

methods of the theory of mathematical statistics - in the analysis of statistics on the use of USs in the AFU.

Results

At the beginning of Russia's full-scale aggression against Ukraine, there was a chaotic use of various UAVs privately owned by both individuals and commercial companies, which on their own initiative began to form crews and approach the military with proposals to engage them in combat missions for aerial reconnaissance and artillery fire adjustment in the interests of the defence forces.

UAVs were used without identification of “friend or enemy” and without coordination, which led to the loss of a significant number of their UAVs due to friendly fire and electronic warfare. This situation required immediate resolution.

In view of the above and in order to organise interaction and coordination of UAVs of various types and structures, the Coordination Centre for Civil-Military Interaction of UAV complexes (UAVCes) of the Kyiv Defence Forces (Centre) was launched in the interests of the defence of Kyiv in accordance with the order of the Commander of the Land Forces of the AFU No. 116/7/2/4288 of 15 March 2022.

Later, an experimental crew of UAVs was added to the Centre.

The main tasks of the Centre were defined:

creating a database and assessing the capabilities of existing organisations and types of UAVs that can perform species surveillance tasks;

organising interaction with organisations that will be involved in the implementation of species monitoring tasks;

organisation of interaction with the units of electronic warfare, electronic intelligence of the AFU and other components of the security and defence forces to ensure the quality of surveillance tasks;

assistance in the execution of tasks on the use of forces and means and analysis of the type of information received from UAVs of various types and structures;

studying the experience of work and improving the system of coordination of obtaining

species information from the UAVCes;

development of proposals for planning the enhancement of the capabilities of the UAVCes capability set;

organisation of cooperation in processing information materials based on the results of UAV flights and intelligence information from space reconnaissance assets.

Subsequently, based on the analysis of the work carried out and the decision of the Commander-in-Chief of the Armed Forces of Ukraine, mobile groups were formed on the basis of the Centre to exchange experience in military C2 bodies and headquarters of units of operational and strategic military groups.

The Centre has been established over the years:

civil-military interaction in the interests of the use of UAVCes units by the Defence Forces, which played an important role during the active phase of defence of the capital of Ukraine;

interaction between charitable organisations (volunteers) and units of the AFU and other components of the Defence Forces on the provision of micro (tactical) and mini (tactical battlefield) reconnaissance UAVCes (reconnaissance and fire control), and training of their crews.

In response to threats, in 2022-2023, the optimal structure of the AFU was sought, including the creation of an effective C2 vertical of the USs.

Thus, taking into account the leading role of missile and artillery troops on the battlefield, the Commander-in-Chief of the AFU decided to establish the Missile and Artillery Command of the AFU with the UAV Aviation Directorate within its structure, which was subsequently reorganised into the Main Directorate of Combat Strike Systems of the General Staff (GS) of the AFU (AFU GS MDCSS) with the UAV Directorate within its structure. Subsequently, the AFU GS MDCSS was reorganised into the Main Directorate of the-Missile and Artillery and USs of the GS of the AFU with USs Directorate within its structure.

The analysis of the use of the USs in the first year of the full-scale war, as well as the approaches to the management of USs units (subunits) that existed at that time, revealed a number of complex problems regarding;

vertical C2 of units (subunits) of ground, air and maritime unmanned systems at all levels of military command;

the procedure for training operators for the needs of troops (forces);

the procedure for providing troops (forces) with USs;

approaches to the development of the USs;

automation of the processes of managing the use of USs and their security.

The identified problems and awareness of the importance of a systematic approach to the development and use of USs units led to the establishment of the Central Directorate of Unmanned Systems of the GS of the AFU (AFU GS CDUSs), which was the first step towards institutionalising the work on the development of the USs.

The main tasks of the AFU GS CDUSs were:

coordination of the actions of units using UAVs;

analysis of combat experience and development of a concept for the use of USs;

interacting with volunteers, manufacturers and international partners to provide the AFU with USs.

The creation of this directorate allowed for a shift from the chaotic use of UAVs to a more structured approach. For example, in 2023, the AFU began forming specialised UAVCes military units, which became the basis for practising tactics for complex operations using UAVCes of various types and levels - from tactical multi-rotor FPV systems to strategic aircraft models.

In September 2023, the AFU GS CDUSs was reorganised as the Main Directorate of Unmanned Systems of the GS of the AFU (AFU GS MDUSs). This step was due to the fact that the

existing staff of the AFU GS CDUSs was unable to perform the full range of tasks that this C2 body had to perform. This once again underlined the growing role of the USs in the war and the need for their further development.

At the same time, preparations were underway to create a separate kind of force - the Unmanned Systems Forces of the AFU (AFU USsF).

Presidential Decree No. 51/2024 of 6 February 2024 became a historic document that instructed the Cabinet of Ministers and the AFU GS to work on the issue of creating the Unmanned Systems Forces of the AFU (AFU USs). This decree was a response to the successful use of the USs in air, land and maritime operations in 2022-2024, in particular in operations against the Russian Black Sea Fleet and strikes against enemy targets in the deep rear.

The process of creating the AFU USs was completed in the summer of 2024. On 11 June 2024, the USs Forces were officially presented in Kyiv as a separate branch of the of the AFU. The symbol of the new type of troops is a steel swallow, a sign of speed, manoeuvrability and accuracy.

On 25 June 2024 the National Security and Defence Council of Ukraine approved the decision to establish the AFU USs, which was enacted by Presidential Decree No. 382/2024. On 3 September 2024 the Verkhovna Rada adopted Law No. 11507, which amended the Law of Ukraine "On the Armed Forces of Ukraine", officially establishing the AFU USs as a separate branch of the armed forces.

On 16 September 2024 the President of Ukraine signed amendments to this law, completing the process of institutionalising the work of the USs.

The main tasks of the AFU USsF are defined:

provision of supplies and technical support to USs units;

training of operators and specialists (15 training centres were set up in 2024);

planning of operations using UAVCes, UGSs, MUSs;

cooperation with manufacturers (at the time of the establishment of the AFU USsF cooperation was established with 90% of domestic companies).

Creating the AFU USsF Ukraine became the first country in the world which had such a force. This step reflects the evolution of USs capabilities from spontaneous use of UAVs to their integration into the system of employment of the AFU in three domains: air, land and sea. During the two years of war (2022-2024) Ukraine not only adapted commercial solutions but also developed hundreds of its own models.

In addition to C2 bordies USs military units have also undergone evolution. The first units to appear in the AFU were UAV crews, which performed mainly air reconnaissance and artillery fire control tasks. They were usually a part of artillery units. The effectiveness of their use led to the formation of UAV platoons as part of combined arms units and subunits, which evolved into companies of striking UAVs. Thus, in total, about a hundred Companies of Strike UAVs were created in 2023.

The next stage in the development of the USs military formations can be considered further saturation of the combined arms brigades with USs units. Thus, already in 2024, battalions of the Strike UAVs and, as an experiment, first platoons and then companies of the UGSs began to be formed in the combined arms brigades.

The third, revolutionary, stage in the evolution of the USs military formations in the AFU can be considered the transformation of the most effective UAVCes battalions into separate USs regiments and brigades, which began in late 2024 and continues to this day. These military units of USs include the separate USs brigade "Birds of Magyars", separate USs regiments of the "Hawks", "Nemesis", "Achilles", "K-2", "Rarog", "Phoenix", etc.

The President of Ukraine launched the "Drone Line" project to unite the efforts of the USs units and scale up best practices. The main tasks of the project are defined:

creating a killzone 10-15 km deep, where the enemy will not be able to move without losses;
providing infantrymen with constant air support and cover;
detecting and destroying targets before they get close to our positions.

Currently, the capabilities of the USsF are being enhanced by incorporating separate USs brigades, regiments and battalions (air, ground and marine).

As for the Air Forces of the AFU, they continue to take organisational measures to implement the decision of the AFU Commander-in-Chief to transform manned aircraft into unmanned aircraft.

As for the AFU Navy, it should be noted that it continues to build up the capabilities of the Marine Corps and a separate brigade of special-purpose MUSs by adding personnel and more modern MUSs.

USs have also actively developed in the Air Assault Forces, the Special Operations Forces, the Support Forces, the Logistics Forces and the Medical Forces of the AFU.

The evolution of the C2 bodies and military formations of the USs in the AFU, discussed above, was primarily due to the rapid development of USs technologies during the of the Ukrainian-Russian war.

Such technologies were the basis of the USs that were actively used both at the beginning of the war and continue to be used in domestic and foreign UAVCes (such as “PD-1”, “Furia”, “Spectator M”, “Mara2P”, “DJI Mavic”, “Fly Eye”, “Raven”, “Spy Arrow”, etc.) They have provided and continue to provide prompt information about the enemy, which allows for a timely response to changes in the situation.

The optoelectronic and radar equipment installed on reconnaissance UAVs effectively detects and transmits images of enemy objects to the C2 points of troops (forces). The usage of USs to adjust artillery fire ensured rapid detection and identification of targets, transmission of coordinates to artillery units and monitoring of the results of the destruction, which significantly increased the accuracy of target destruction, reducing the risk of civilian casualties and damage to infrastructure.

The high efficiency of aircraft-type reconnaissance UAVs in performing enemy reconnaissance tasks at operational depth in difficult terrain, forested or urbanised areas has contributed to the introduction of new ways of using them. For example, reconnaissance UAV crews began to use other UAVs as repeaters of control radio signals to reconnoiter the enemy beyond the radio range between the ground control point and the UAVs, and to overcome the enemy's electronic reconnaissance zone, they began to use radio silence or interference-proof satellite communication channels. In turn, the advantage of multicopter reconnaissance UAVs is their small size, which allows them to perform reconnaissance tasks even in the face of active opposition from enemy air defence systems.

The shortage of destruction means, in particular precision weapons, encourages the development and use of strike UAVCes. At present, reconnaissance and strike UAVCes are being developed (“Bayraktar TB2”) are being developed, but the enemy’s strengthening of air defence reduces the effectiveness of their use and requires to search for alternatives.

Naval operations and the dominance of the Russian fleet in the Black and Azov Seas have given rise to the development and use of maritime unmanned complexes (MUCs). Since 2023, Ukraine’s Defence Forces have been building up their capabilities to use MUCs (Sea Baby, Magura), which allow them to achieve parity at sea, successfully destroy the enemy fleet and systematically attack its naval bases.

The next step in the development of USs the use of UAVs with FPV (First Person Vision) technology. The so-called FPV drones significantly increased the ability of units to destroy military equipment and later became widespread in the fight against enemy infantry.

Their low cost, availability of production and modularity ensured their widespread use. In the early stages of their use, they were used to “drop” ammunition, and later, given their relatively low

cost and the ability to use a variety of ammunition, they were developed into “kamikaze drones”. Having proved their effectiveness in tactical combat, the Ukrainian Defence Forces began to use aircraft-type “kamikaze drones” to destroy enemy targets deeply in the enemy’s territory (DeepStrike). This allowed them to partially compensate for the lack of aviation and long-range firepower.

In 2024, wheeled and tracked UGSs were developed. Their appearance is aimed at performing certain tasks of logistical support of troops, evacuation of the killed in actions (KIA) and wounded personnel from the battlefield, and mining (demining) of territories. The modular approach to their construction makes it possible to deploy a variety of firepower: heavy machine guns, mortars, grenade launchers, etc. Examples of such UGSs are: “Volia-E M2/MK19”, “D21/11”, “Wolly”, “Rage”, etc. In addition to the UGSs (“Termite”, “Targan”, “Storm”, “Snake”), UAVs (“Vampire”) and MUSs (“Stalker”) are used to perform cargo transportation tasks.

At the same time, in the context of a complex electronic environment and active counteraction of the enemy to the USs, the issues of increasing the stability of control and efficiency of performing USs tasks are becoming relevant. The main directions of solving the problematic issues mentioned in are the introduction of artificial intelligence technologies (use of drone swarms, autonomous navigation, target recognition and detection, search for optimal routes and obstacle avoidance, etc.)

Given that the use of UAVs is carried out in the face of adversary air defence and electronic warfare (EW), there is an urgent need to minimise the impact of radio interference on the channels of information exchange between the Ground Control Centre (GCC) and the UAV, as well as to reduce the visibility of the UAV itself. As a result, to counteract the enemy’s EW and air defence systems, comprehensive methods of increasing the interference immunity of radio control channels were introduced, namely:

use of a special channel for information transmission that is inert to active interference (fibre-optic cable for FPV drones);

adaptive change of the control signal power depending on the UAV's distance to the GCC;

use of a network of repeaters to increase the range of tasks;

use of antennas with a narrowly focused radiation pattern;

real-time monitoring of the electronic situation on board the UAV.

In the absence of the possibility of implementing these methods, we used non-energy methods, which, by promptly changing the type of signal and its parameters, allow us to adapt to the conditions of the interference situation. The use of these methods has solved a set of problems aimed at improving the interference immunity of radio control channels. The main ones are:

ensuring adaptation to the interference situation by changing the parameters of signals and their types based on the results of the analysis of the types of radio interference used by the enemy in close to real time;

increasing the secrecy of information exchange between UAVs and GCC in order to complicate enemy electronic reconnaissance, assessing the parameters of the signal and the fact of its emission through the use of new generation systems in the field of UAV radio communication, command and control, based on the use of extended spectrum signals;

integration of artificial intelligence technologies and machine learning algorithms in the course of performing tasks for early detection (analysis of the electronic environment, establishing the fact of operation of EW means and identification of their type by radio emission), adaptation to the electronic environment (automatic change of control channel parameters, optimisation of the flight route), data analysis (detection of patterns and prediction of EW means), participation in the final stages (homing of FPV drones on the target's own radiation or its silhouette, mapping of already processed intelligence in real time, return of the UAV);

minimisation of control signal generation and processing devices due to the software and hardware control method.

The evolution of the USs capabilities in the Armed Forces of Ukraine from 2022 to 2025 is shown in Fig. 1.

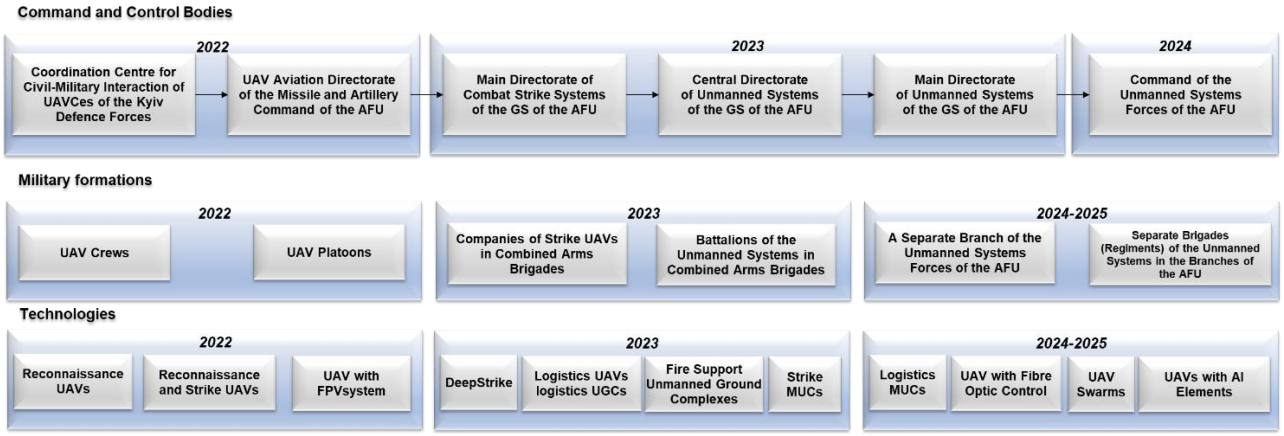


Figure 1. Evolution of the USs capabilities in the Armed Forces of Ukraine from 2022 to 2025

Discussions

Analysing the latest publications in the field of capability development of USs military units in the AFU, it is necessary to note the key ones, such as:

The Doctrine of the Usage of USs in the Defence Forces of Ukraine, 2023;

Principles of Development of Robotic Systems in the AFU, Semenenko O. M. and others. 2023;

projects:

“Strategy for the development of the USs Forces of the AFU and military units (subunits) of USs of the types (separate branches of troops (forces)) of the AFU”, 2024;

Concept for the development of UGCs (systems) in the AFU, 2024;

Concept for the usage of a separate assault brigade of USs, 2024;

Concept for the usage of a separate brigade of USs, 2024;

Concept for the usage of airborne assault troops with USs units, 2024;

Concept for the use of Marine Corps units with USs, 2024;

Classification of UGS in the AFU, 2024;

Classification of UAVs as part of UAVCes in the AFU, 2024.

These documents were developed by working groups consisting of representatives of structural subdivisions of the AFU GS, branches (separate branches of troops (forces)) of the AFU, higher military educational institutions and research institutions of the Ministry of Defence of Ukraine and the AFU, which demonstrates a balanced approach to the development of doctrinal and conceptual documents aimed at the development and application of the USs.

The analysis of the documents shows that they are devoted not only to determining the main directions of development of innovative technologies for the creation of the USs, but also to the development of new forms and methods of using military units of the USs.

Conclusion

Thus, the article presents the results of a retrospective analysis of the evolution of the USs capabilities in the AFU during the war (2022-2024) in terms of the following main components:

development of the C2 bodies of the USs Forces of the AFU, USs military units and innovative technologies. Thus, it can be argued that the history of the evolution of the USs C2 bodies in Ukraine from the UAV Directorate within the Missile and Artillery Command of the AFU to the Command of the USs Forces of the AFU, the evolution of military formations from UAV crews to separate regiments and brigades of the USs, and the evolution of technology from toy multicopters to USs with artificial intelligence is an example of how combat experience and technological ingenuity can transform the army in a time of war. This process has not only strengthened the country's defence capabilities, but also laid the groundwork for its leadership in the field of unmanned technologies in the future.

Recommendations

The results of a retrospective analysis of the evolution of the capabilities of the USs in the AFU during the war for Ukraine's independence can be used to determine further trends in the development of the USs in the future, both in terms of weapons systems and USs military units, as well as to prevent the occurrence of mistakes that occurred at the stages of formation of the USs Forces in the AFU.

In addition, the materials of the article can be used by military authorities, research institutions and higher military educational institutions in the development of doctrinal (conceptual) documents in the field of USs.

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