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CHAPTER 3

DEVELOPMENT OF INNOVATIONS IN THE FIELD OF MILITARY COMBAT AT SEA

ABSTRACT

The relevance of the issues highlighted in this section is primarily related to the insufficiency of research on the development of asymmetric means of combat at sea in the conditions of overwhelming enemy forces, first of all, maritime unmanned systems (apparatus) and unmanned aircraft systems, as well as peculiarities of managing their creation and development.

The experience of combat operations at sea during the Russian-Ukrainian war proved that thanks to the use of modern technologies, Ukraine was able to turn the tide of the war in the Black Sea and dislodge the Russian Black Sea Fleet from the occupied Crimea. Using maritime unmanned systems (apparatus) and unmanned aircraft systems in the strike version, the Defense Forces of Ukraine destroyed or damaged about three dozen enemy ships and boats, as well as damaged a number of port facilities.

At the same time, before the beginning of the full-scale aggression of the Russian Federation against Ukraine, the development of unmanned maritime systems (apparatus) was not foreseen at all. The first samples of these complexes were created only in the summer of 2022 on an initiative basis, and already in November of the same year, the creation of the world's first "fleet of maritime (sea) drones" was announced. And if at the initial stage their development took place decentralized, by the efforts of various departments, in the version of "unmanned brander", then in the future complexes with various weapons (reactive volley fire systems, sea mines, etc.) were developed, and the range of their tasks expanded significantly. Therefore, for the more effective development and use of maritime unmanned systems (apparatus), there was a need to create a separate type of troops within the Armed Forces of Ukraine with corresponding functions – the Forces of unmanned systems.

The object of research is maritime robotic systems. The subject of research is the development of maritime robotic systems in the interests of performing tasks with the Defense Forces of Ukraine. The results of analytical research on the development of maritime robotic systems, primarily maritime unmanned systems (apparatus), are highlighted, which made it possible to identify trends and directions for their further development, as well as to identify the peculiarities of managing their creation and development.

KEYWORDS

Maritime robotic system, situational awareness and intelligence system, maritime unmanned complex, unmanned surface vehicle (USV), unmanned aircraft complex, development, combat at sea, asymmetric actions at sea.

As it is known, achieving success in the fight against the enemy largely depends on the chosen strategy and available forces and means. In the conditions of the Russian-Ukrainian war at sea, taking into account the significant advantage of the enemy in general military capabilities, an important factor is the use of asymmetric methods and means of influence. One of these tools is, of course, robotic, autonomously operating, unmanned aerial systems (UASs) and unmanned surface and subsurface systems (complexes).

In the conditions of the armed aggression of the Russian Federation (RF) against Ukraine, the conduct of asymmetric actions at sea has acquired diversity in the application of both technical means and specific forms of application.

At the same time, the analysis of the conduct of combat operations at sea during the full-scale armed aggression of the Russian Federation against Ukraine indicates that the use of classic forms of employment of ships of the Navy of the Armed Forces (AF) of Ukraine led to losses among personnel and ships. In the course of hostilities in 2022, the enemy destroyed the "Slovyansk" patrol boat, amphibious assault boat "Stanislav", the minesweeper "Genichesk" [1–3]. This led to the maximum limitation of the ships employment in the future during combat operations at sea.

A person, his/her life and health, honor and dignity, inviolability and security are the highest social value in Ukraine. Implementation of this norm of the Constitution of Ukraine is the main goal of the national security policy [4].

In the conditions of the unprecedented spread of information and robotic technologies in the world, it was Ukraine in the conditions of the Russian-Ukrainian war that achieved intellectual superiority (intellectual leadership) over the enemy, which ensured the success of operations at sea.

One of the ways to implement the main goal of the state policy of national security in the war at sea is the use of unmanned surface vehicles (USV), which allows personnel to be in places protected from enemy attacks, thereby not risking their own lives and health during hostilities.

Therefore, the issue of preserving the life and health of servicemen of the Defense Forces of Ukraine (DFU) in confrontation with the enemy through the USV, which allows to prevent losses among personnel during the armed struggle at sea and inflict maximum losses on the enemy, is relevant.

3.1 ANALYSIS OF REGULATORY ACTS ON THE DEVELOPMENT OF THE NAVY OF THE ARMED FORCES OF UKRAINE IN THE PART RELATED TO MARITIME ROBOTIC SYSTEMS

As a result of the occupation of the Crimean Peninsula in the spring of 2014, the Navy of the Armed Forces of Ukraine lost more than 80 % of their assets and capabilities. In the future,

the Armed Forces of the Russian Federation continued to conduct actions at sea aimed at causing economic damage to Ukraine by hindering its maritime activities. Thus, in March 2014, units of the Armed Forces of the Russian Federation established control over Ukrainian gas production facilities on the shelf of the Black and Azov Seas, and in 2018, the Russian Federation began conducting actions to obstruct commercial shipping to Ukrainian ports of the Sea of Azov. The need to counter the armed aggression of the Russian Federation from the sea, to return control over the captured territories and water areas, to ensure the protection of the state's national interests at sea required the restoration of the relevant naval capabilities of the Navy of the Armed Forces of Ukraine in the shortest possible time. At the same time, Ukraine did not have the appropriate financial resources to create in the short- and medium-term perspective a fleet comparable in terms of quantity and quality to the Black Sea Fleet of the Russian Federation. The aforementioned required finding ways to achieve parity at sea with the enemy by adopting samples of weapons and military equipment within the framework of the allocated financial resource for the development of the Navy of the Armed Forces of Ukraine to conduct asymmetric operations, including maritime robotic systems (MRS). The analysis of the directions of development of samples of naval weapons of the leading maritime countries shows that in the specified period there was an active development of the above-mentioned systems [5–14]. As the subsequent experience of the Russian-Ukrainian war at sea in 2022–2024 proved, they became one of the most effective means for conducting asymmetric actions at sea.

In order to study the trends in the development of innovations in the field of military combat at sea after the beginning of the armed aggression of the Russian Federation against Ukraine in 2014, in particular, in relation to the creation of the Armed Forces of Ukraine, an analysis of the relevant regulatory and legal acts on the development of the Armed Forces of Ukraine that were developed (existing , in which changes were made), in the chronological sequence of their development (clarification).

One of the first documents that determined the views on the development of the Navy of the Armed Forces of Ukraine after the beginning of the armed aggression of the Russian Federation against Ukraine for the long term was the "Strategy of the Naval Forces of the Armed Forces of Ukraine 2035" [15]. According to the specified document, in the period up to 2035, a gradual (in three stages) expansion of the naval capabilities of the Navy of the Armed Forces of Ukraine is planned, taking into account forecasted threats, economic opportunities and development priorities. At the first stage (until 2025), the development of capabilities to ensure control over the territorial waters of the state and beyond them (up to 40 nautical miles from the coast) is envisaged. At this stage, the main priority was the creation of a situation awareness system in the near sea zone with the aim of timely detection of the enemy and its intentions, providing information on a real time scale to all components of the defense and security forces of the state, ensuring the mutual exchange of information with NATO member countries and other partner countries, the second priority is the formation of the ability to prevent enemy actions in the near sea zone, the third is the acquisition of the ability to effectively control coastal waters, rivers and protect the

state's ports. At the second stage (from 2025 to 2030), the development of capabilities to ensure the protection of Ukraine's national interests at sea within the Exclusive Economic Zone of Ukraine is envisaged. At this stage, the main priority remains the system of situational awareness and intelligence, the second priority is the provision of effective control of the water area in the air, surface and underwater areas within the exclusive (sea) economic zone of Ukraine for a specified period of time, the third is the formation of capabilities for the destruction of objects enemy at long range. In the third stage (from 2030 to 2035), the further development of the capabilities acquired during the first and second stages, their expansion to protect the national interests of Ukraine in the world ocean is foreseen. At this stage, the main priority is the acquisition of the ability to ensure the effective control of a certain area of sea water in the zone of interests of Ukraine together with the naval forces of NATO member countries and partner countries, the second priority is building up the ability to inflict a given degree of damage on enemy objects as at sea as well as on land, the third is the formation of capabilities to limit any actions of the enemy, including the prevention of the possibility of deploying its forces to carry out an act of aggression from the sea direction. At the same time, in equipping the Navy of the Armed Forces of Ukraine with weapons and military equipment, priority was supposed to be given to surface forces, which should be able to perform tasks of controlling the water area, and the execution of tasks to destroy enemy objects was supposed to be carried out using high-precision weapons (anti-ship missile systems) of ship-based, coast-based and air-based [15]. Acceptance of MRS into the Navy of the Armed Forces of Ukraine was not considered by the specified document.

The next normative legal act, which determined the directions of the development of the naval potential, was the Resolution of the Cabinet of Ministers of Ukraine dated December 18, 2018 No. 1108 "On Amendments to the Naval Doctrine of Ukraine for the Period Until 2035" [16]. Thus, the main directions of its development in the part related to the adoption of samples of weapons and military equipment into the combat composition of the Navy of the Armed Forces of Ukraine included the construction of modern ships (boats), aircraft of naval aviation, anti-ship complexes of sea, air and coast bases. At the same time, one of the directions of strengthening the forces and means of the Navy of the Armed Forces of Ukraine and the Costal Guard of the State Border Service of Ukraine in the Sea of Azov is defined as the creation of the necessary military potential in peacetime and a special period, including at the expense of multi-purpose small-sized surface platforms, in particular unmanned surface and aerial vehicles.

Another document that defines promising ways of development of the Navy of the Armed Forces of Ukraine is the "Doctrine of the Naval Forces of the Armed Forces of Ukraine" [17]. This document envisages the development of the Naval Forces of the Armed Forces of Ukraine in accordance with the stages and priorities defined in [15]. At the same time, promising directions for the development of weapons and military equipment were determined:

– maritime component – building up the ship fleet by building (purchasing): multi-purpose ships of the "corvette" class, missile boats, landing ships, patrol ships and boats, unmanned subsurface vehicles (USSV) of various purposes, auxiliary vessels of various purposes, carrying out

modernization and planned repairs warships, boats, and auxiliary vessels of the Navy of the Armed Forces of Ukraine and other components of the security and defense sector; revival of underwater and minesweeping forces; creation of the Unified situation awareness system at sea;

– coastal component – equipping coastal military units (subunits) with the latest weapons, in particular – coastal antiship missile complexes;

– aviation component – ensuring airworthiness and modernization of the existing fleet of naval aviation aircraft; development of a patrol aircraft; purchase of specialized helicopters; equipping military units (subunits) with reconnaissance unmanned aerial systems [17].

Thus, this document provided for the construction (procurement) of a number of MRS for the needs of the Navy of the Armed Forces of Ukraine, namely, USVs, USSVs for various purposes, as well as unmanned aerial systems (UAVs) in the reconnaissance version.

The next legal act that determined the ways of development of the Defense Forces of Ukraine, including the Navy, was the "Military Security Strategy of Ukraine" approved by the Decree of the President of Ukraine dated March 25, 2021 No. 121/2021 [18]. This document provides for the use of the DFU in the course of ensuring the military security of the state of the latest high-tech and highly effective means of armed struggle, in particular, the production and equipping of the DFU with modern weapons, military and special equipment, provision of means of attack, including unmanned and robotic ones.

Approaches to the MRS development at sea changed radically only after the full-scale armed aggression of the Russian Federation against Ukraine and the successful experience of their use against enemy forces in the Black Sea. Thus, at the beginning of 2023, the Decree of the President of Ukraine dated 06.02.2023 No. 51/2024 was issued regarding the creation of the Forces of Unmanned Systems within the structure of the Armed Forces of Ukraine as a separate type of forces [19] with the aim of increasing their capabilities in relation to the use of unmanned and robotic air, sea and land systems, ensuring readiness for use of such systems as intended. At the same time, according to information from open sources, it is known that in August 2023, a separate brigade for the USV employment was created within the Navy of the Armed Forces of Ukraine [20]. The foreseen organizational measures in the Armed Forces of Ukraine, which are aimed at improving the functions of generation and employment of units of unmanned and robotic air, sea and ground systems, testify to the understanding of the leadership of the state and the DFU of the role of the need to implement innovations in the field of military combat at sea, in particular, regarding the development and build-up MRS capabilities.

Separately, it should be noted that currently in Ukraine there is no legal framework regulating the production, certification, licensing, operation and application of MRS.

The analysis of the normative legal acts on the development of the Navy of the Armed Forces of Ukraine in the part that concerns the MRS shows that they take into account global trends regarding the use of the latest high-tech means of conducting armed combat at sea. However, the specified documents, developed (refined) before the beginning of the full-scale armed aggression of the Russian Federation against Ukraine, were mostly declarative in nature, without disclosing

the role and place of the MRS in achieving the goals of the DFU use at sea, specifying the tasks that they can rely on, etc. At the same time, as a result of the successful use of unmanned naval and unmanned aerial systems against ships (boats), as well as enemy infrastructure facilities in the Black Sea, these issues were reflected in the relevant legal acts, which had a positive impact on the MRS development.

3.2 THE INFLUENCE OF THE THEATER (AREA) OF MILITARY OPERATIONS ON THE DEVELOPMENT OF MARITIME ROBOTIC SYSTEMS

The characteristics of the theater (area) of military operations are of great importance for the use of any forces and means, including USV. During the research of the characteristics of the theater (area) of military operations, this study examines the set of natural characteristics of the water area where the USV is used by the Defense Forces of Ukraine, namely the Black Sea.

Considered:

– general physical and geographical conditions (parameters of the theater, nature of the shores, topography of the bottom, straits, bays, and others);

– hydrometeorological conditions, which consist of meteorological (types of weather; air temperature and humidity; winds; fogs; visibility; radar observability; cloudiness and precipitation; local weather features; special meteorological phenomena) and hydrological (fluctuations in the water level) that vary in time and space and currents; water temperature and density; ice regime of ships [21].

The dimensions of the theater of war allow effective USV use.

The USV has a tactical range of up to 500 miles, which allows it to carry out the task of damaging on enemy surface targets in the Black Sea.

The low, flat shores in the northwestern part of the Black Sea allow choosing up to 30 accessible places for launching USV into the water with the help of special equipment.

The shallow, flat relief of the bottom in the northwestern part of the sea allows the use of sea mines of various types in this area, setting them with the USV help.

Low temperatures in the northwestern part of the sea in the period December-March cause ice formation, which excludes the USV use in the coastal strip and especially in estuaries and rivers in case of their freezing, at the same time, such phenomena are observed quite rarely.

A change in temperature, high humidity causes condensation, which in turn causes fogging and corrosion.

Cloudiness, precipitation, fog also have a significant impact on the USV use, as they limit the operation of communication and video surveillance systems.

The high clearness of the atmosphere determines that visibility usually reaches the maximum natural limits (10–12 miles) [22]. This confirms the need to apply USV in the dark. The duration of the dark time is 7–14 hours.The nature of winds and waves have a distinct seasonal character.

In winter, strong (4–7 points) and stormy (over 6 points) weather prevails, which prevents the USV use.

Great depths and small dismemberment of the shores with such winds cause strong agitation, both in open parts of the sea and in coastal areas.

Excitement above 3 points, which excludes the USV use, which can be expected in winter with a probability of up to 40 %.

In summer, the average wind speed does not exceed 3–4 points. The probability of storms does not exceed 10 %.

The nature of changes in water temperature and sound speed, water transparency, salinity and water density do not significantly affect the USV application.

In general, the physical and geographical conditions of the Black Sea favor the use of existing USV types by the Defense Forces of Ukraine. The exception is the winter period, due to excitement and the effect of low temperatures. This requires further improvement of their tactical and technical characteristics for the possibility of use in difficult weather conditions.

3.3 EXPERIENCE OF MARITIME ROBOTIC SYSTEMS EMPLOYMENT DURING MILITARY OPERATIONS AT SEA

The experience of using unmanned systems (aviation, surface, ground) in real combat conditions is taken into account, and the results of the application analysis are implemented, both to improve the technical characteristics of the specified systems, and to improve the control system of unmanned systems. The development of modern unmanned aerial and surface systems was significantly influenced by the experience of their use during the armed aggression of the Russian Federation against Ukraine. From the first days of the full-scale invasion, the existing "Bayraktar TB-2" UAV were actively used to repel armed aggression, including in the Black Sea. In modern conditions, the successful combat experience of this complex was gained by Azeybardzhan during its military campaign in Nagorno-Karabakh [24]. In the sea direction, these complexes were mostly used for conducting reconnaissance and damage small-sized ships and boats that do not have their own complexes and air detection means targets and air defense. For ships of the class of frigates, corvettes and those of their size, equipped with modern means of detecting and destroying air targets, the "Bayraktar TB-2 UAV" became an easy target when entering the affected zone. Therefore, their use was limited to the task of highlighting the situation in certain areas. The need for a further struggle for the sea and the lack of ships in Ukraine equivalent in class to the fleet of the Russian Federation in the Black Sea required an asymmetric response. In an initiative manner, several power structures began to develop and, most importantly, immediately implement USV projects that would be able to solve important tasks, namely, to end the dominance of the Black Sea Fleet of the Russian Federation in the Black Sea, or at least in its northwestern part. USV not an invention of the Ukrainian military and extremely complex engineering structures and are used all over the

world: both in the military and in civilians, in particular for research purposes. In the fall of 2016, the private shipbuilding company "Unik Yachts" in the city of Mykolaiv presented the "Shadow" project USV, which according to the development strategy of the State Border Service of Ukraine as of 2020 was supposed to be in its arsenal for patrolling the coast [25].

Many countries use USV on water for patrolling, reconnaissance and mine clearance tasks. It's cheap and safe. For the first time, USV was used against a large warship by the Yemeni Houthi rebels, so in January 2017, the frigate of the Saudi Arabian Navy "Al-Madinah" was unexpectedly attacked by USV in the open sea. As a result of the incident, the ship was damaged, two sailors died. But the superiority in the use of USV in the Black Sea as a shock weapon in modern conditions belongs to the DFU. On October 29, 2022, in the Sevastopol Bay, the "Admiral Makarov" frigate and the "Ivan Golubets" minesweeper were successfully attacked by unmanned surface attack systems. There were probably attempts to use similar complexes earlier, because according to the Russian occupation authorities, on September 21, 2022, an unidentified USV was found on the coast of the city of Sevastopol, which was towed into the sea and destroyed by detonation by the forces of the Black Sea Fleet of the Russian Federation.

Taking into account the first success in the USV employment and their obvious cheapness compared to the targets they are capable of hitting, already in November 2022 the state leadership announced its intention to create a fleet of Ukrainian-made USV. However, a centralized management system for the creation, testing and application of unmanned surface systems and unmanned systems in general, such as the Defense Advanced Research Projects Agency (DARPA) in the US Department of Defense or the State Administration of Defense Science, Technology and Industry (SASTING), as in China, has not been established. Each structure followed its own path and obtained results in the struggle for the sea, creating units and a system for managing this process independently.

The Navy of the Armed Forces of Ukraine, which at the end of 2021 received the "Bayraktar TB-2" UAV, actively used them at the beginning of the full-scale invasion and, according to information from open sources, using this complex, they attacked and destroyed or damaged seven Russian boats in the Black Sea. In particular, there are four patrol boats of project 03160 "Raptor", one patrol boat of type KS-701 "Tunets", one landing boat of project 02510 "BK-16", one landing boat of project 11770 "Serna" with an anti-aircraft missile system on board. Undoubtedly, the "Bayraktar TB-2" UAV was and is involved in carrying out the tasks of covering the situation on the Black Sea, but there are no open data on the number of objects detected with their help, and even more so on the damage inflicted. Nevertheless, these are the first unmanned systems that came to the defense of the Black Sea with the beginning of the military aggression of the Russian Federation against Ukraine [23].

The next step in the application of unmanned systems at sea was the USV creation. Thus, the Security Service of Ukraine (SSU) together with the Navy of the Armed Forces of Ukraine and private companies worked on the USV creation in the summer of 2022. Later, the SSU made public information about the independent creation of the "Sea Baby" USV. With great probability,

it can be stated that according to the USV, the Sevastopol Bay was attacked in November 2022 and three vessels of the Black Sea Fleet of the Russian Federation were damaged. In 2023, "Sea Baby" USV was transformed into a universal platform with various functions. They successfully attacked the Crimean Bridge in July 2023, destroying one span and damaging the bridge pillar, as well as nine more ships and vessels of the Black Sea Fleet of the Russian Federation during 2023. In May 2023, the medium reconnaissance ship of project 18280 "Ivan Khurs" was attacked and damaged in the Black Sea, in August 2023 – the large amphibious ship of project 775 "Olenegorsky Gornyak", the anti-sabotage boat of project 21980 "Grachonok" near the Novorossiysk naval base, and in the Kerch Strait – Project 52 "Sig" oil tanker. Near the city of Sevastopol, in the sea, a small project 1239 "Samum" hovercraft and a project 22160 "Serhiy Kotov" patrol ship were attacked and damaged in September, and in October – the SB-565 "Professor Mykola Muru" rescue tugboat, patrol the ship of the project 22160 "Pavlo Derzhavin" and the hydrographic boat of the project 23040 "Volodymyr Kozytskyi", which performed the task of searching for mines near the city of Sevastopol. In this way, the units of the Security Service of Ukraine, following their own path, created USV, improved and successfully implemented their application in the Black Sea.

The Main Intelligence Directorate (MID) of the Ministry of Defense of Ukraine (MDU) followed a similar path, albeit with a slight delay in time. The creation of "MAGURA V5" USV became known during its demonstration at the International Defense and Industrial Exhibition, which was held in the city of Istanbul in July 2023. However, we had to wait a few more months for confirmation that this was indeed an active USV. The combat use of "MAGURA V5" became known in November 2023, when two Russian amphibious boats stationed at the Black Sea base of the temporarily occupied territory of the Autonomous Republic of Crimea were attacked and destroyed. It was one landing craft of project 11770 "Serna" with an armored personnel carrier on board and landing craft of project 1176 "Akula". Already in January 2024, the missile boat of the project 1241.1 "Ivanovets" was hit by the MID using the "MAGURA V5" USV and sank as a result. The next target of "MAGURA V5" USV in February of the same year was the large amphibious ship of project 775 "Cesar Kunikov" near the city of Alupka, as a result of which it sank. In March, the patrol ship of project 22160 "Serhiy Kotov", which was on patrol in the Kerch Strait, was sunk. Attacks on Vuzka Bay in Crimea and the Crimean Bridge area in May and June 2024 destroyed two patrol boats of the KS-701 "Tunets" type, the project 12150 patrol boat "Mongoose" and the project 498 tugboat "Saturn" [26].

Therefore, from the beginning of the armed aggression due to the threat of attacks by the USV, the fleet of the Russian Federation in the northwestern part of the Black Sea was forced to stop combat activities such as patrolling, sea transportation, significantly reduced the conduct of reconnaissance with the use of ships, and was also forced to relocate the main forces of the fleet to the Novorossiysk naval base and build a new base in Ochamchira (Abkhazia). A positive consequence for Ukraine was the restoration and increase of sea transportation in the Black Sea from the ports of Odesa.

Out of all the destroyed and damaged ships, boats and vessels of the Russian Federation, and this number is 60 units, USV accounted for half of them, while it should be noted that the greatest successes in destroying enemy watercraft were achieved by "MAGURA V5" USV. This is confirmed by the statement of the deputy commander of the NATO Joint Forces Command, Rear Admiral Timothy Henry, in his interview on June 29, 2024. After all, if to compare the technical characteristics, from open sources, of USV, then with almost the same dimensions, both complexes have a length of about 5.5 meters, and a width of 1.5 meters, but the larger warhead of the "Sea Baby" is from 450 to 850 kilograms compared to "MAGURA V5" – up to 320 kilograms, then the mass of the warhead is not a decisive factor when the ship is destroyed. It is logical to assume that such a factor is the number of USV involved in the attack, or the choice of the place of damage to the ship [27–30].

In addition to the above-mentioned USVs, the power structures of Ukraine, together with the enterprises of the defense-industrial complex (DIC), carry out the development and production of about eighteen UAVs, three USVs In addition to the already known "Sea Baby" and "MAGURA V5", in 2024 the Navy of the Armed Forces of Ukraine in the city of Odesa at the security forum in the Black Sea region "Black Sea Security Forum 2024" presented a new development, namely USV, which was named "Stalker 5". The cost of this project is 60 thousand EUR, USV, which has a range of up to 600 kilometers, a gasoline engine allows to develop a speed of about 75 kilometers per hour, a length of 5 meters and a width of 1.2 meters. The warhead has a mass of 150 kilograms. And the complex itself is a platform that can be used both in the strike version and for the performance of other tasks: logistics, reconnaissance, patrolling [27].

At the same time, at the conference on the defense cluster "Brave1", USV of three models were presented: "Toloka TLK150", "Toloka TLK 400", "Toloka TLK 1000". It is obvious that this development will increase the capabilities of the DFU in the Black Sea to attack surface ships of the Russian Federation, and possibly submarines.

Such a number of unmanned systems definitely requires their systematization. First of all, it is necessary to summarize the experience of their creation and development, the experience of application and also the development of directions for further development. It is necessary to understand that the enemy does not stand still. In addition to creating its USV, it is creating and improving a defense system against attacks from the sea. It is necessary to take this into account in the further development of unmanned systems and to improve not only their technical component, but also the methods of application. Such a complex issue can be solved only by combining the efforts of various structures that participate in the process of creating and using unmanned systems under a single leadership. Expanding the functionality of unmanned systems only pushed the country's leadership to create a new type of forces in the structure of the Armed Forces of Ukraine – the Forces of Unmanned Systems. The creation of such a command made it possible to turn the "Army of Drones" project into a state institution that will deal with its implementation. In essence, this command must accumulate all experience, as well as establish a system of obtaining experience directly from the battlefield for a timely response to both technological changes and the tactics of using robotic systems.

It will definitely be interesting for further development to take into account the experience of the world's leading countries in applying USV. For example, the US is already deploying unmanned boats to monitor the enemy's actions at sea. So, for example, in October 2023, USV took part in an operation to track Iranian warships in the Strait of Hormuz.

China developed the USV of the L30 project, which it demonstrated in 2022. The Chinese army used this boat several times during landing exercises, when approaching the landing beachhead, the amphibious assault ships launched USV, which followed the shore, identified and destroyed obstacles, thus clearing the way for the ships.

In 2017, the Israeli Navy deployed the Seagull project USV to intercept enemy boats and protect its coastline.

Thus, today there is a tendency to create USV-based universal platforms that are capable of performing the entire range of tasks that rely on surface and underwater ships and boats.

3.4 DEVELOPMENT OF MARITIME ROBOTIC SYSTEMS BASED ON THE EXPERIENCE OF THE RUSSIAN-UKRAINIAN WAR AT SEA

The experience of the Russian-Ukrainian war at sea showed that the USV due to the ease of manufacture, low cost compared to warships and boats and, as a result, the possibility of their mass production, have now taken a dominant position in the fight against enemy surface ships. As mentioned above, the defense-industrial complex of the state in the interests of the Defense Forces of Ukraine has developed and continues to develop samples of maritime robotic systems in recent years.

The development of maritime robotic systems developed for the needs of the Defense Forces of Ukraine during the Russian-Ukrainian war is considered below, and the main trends in their development are determined.

Ukraine uses a rather innovative approach in the application of maritime robotic systems, in particular, USV. Most of the countries of the world currently use these devices for reconnaissance and search purposes, but it was Ukraine that used USV equipped with an explosive substance to damage enemy warships and support vessels, as well as sea and coastal facilities of its infrastructure.

The first recorded case of the USV use by Ukraine was its detection by the enemy on one of the beaches of the city of Sevastopol on September 21, 2022. At the time of discovery, it was unknown who owned this device, who was its manufacturer and its purpose. It was equipped with a Starlink antenna, a camera on the stern, as well as other sensors and lighting devices. It has been speculated that this is a semi-submarine that can submerge and stay under water for some time. It has been assumed that this is a reconnaissance USV, but with the possibility of being equipped with ammunition and using it as a floating bomb. Some experts suggested that the sensors on the front of the ship could be used as a laser target detection system. It has been also suggested that this USV is one of the coast guard systems that the USA handed over to Ukraine in April 2022 [31].

The main components of USV discovered in the city of Sevastopol (**Fig. 3.1**).

At the same time, the reason why the USV attack on the ship of the Black Sea Fleet of the Russian Federation on September 21, 2022 was foiled was the shutdown of the Starlink satellite system, which was used to control the device, on the instructions of the owner of the said satellite system, Elon Musk. The reason for which he gave the instruction to stop the operation of the satellite communication was the fear of retaliatory actions of the Russian Federation. Because of this, USV suddenly lost contact when approaching the coast of Crimea and was thrown onto the coast [32].

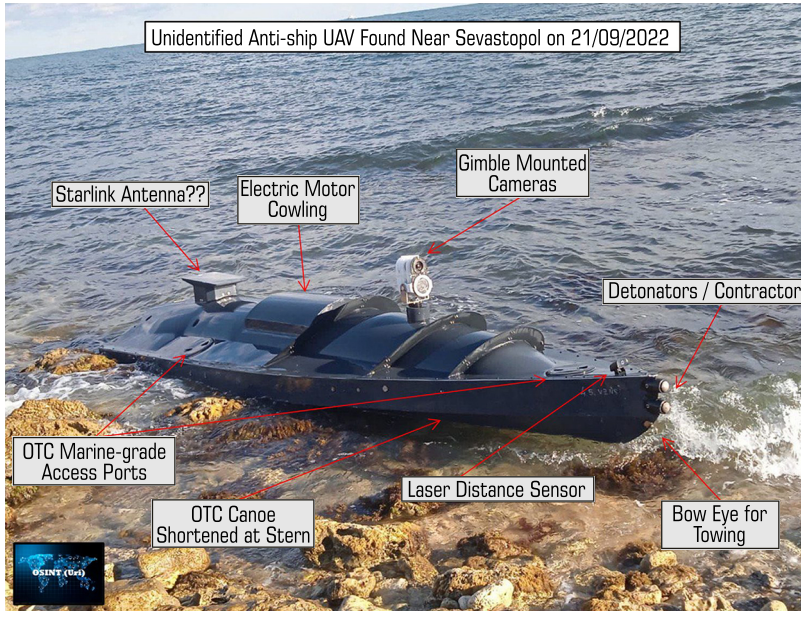

Fig. 3.1 The main components of USV discovered in the city of Sevastopol
Source: [31]

There is no information in open sources regarding the USV control scheme during application. But it roughly looks like this (**Fig. 3.2**).

The first successful case of defeating ships of the Black Sea Fleet of the Russian Federation using USV occurred on October 29, 2022, when the Defense Forces of Ukraine carried out a combined attack on the enemy's naval base in the city of Sevastopol with sea and air drones. At the same time, 9 maritime unmanned surface and 7 unmanned aerial vehicles were used [33]. It should be noted that such a large-scale operation took place for the first time in world history.

According to the Ministry of Defense of the Russian Federation, the attack was repelled and only one ship ("Ivan Golubets" sea minesweeper) was "insignificantly damaged", but according to military experts and OSINT analysts, the consequences of this attack were more significant. It was reported that several more ships were damaged, in particular the frigate "Admiral Makarov", which is the carrier of the Kalibr sea-based cruise missiles and which, after the destruction of the "Moskva" cruiser, is considered the flagship of the Black Sea Fleet of the Russian Federation. It is likely that the attack on Russian ships in Sevastopol on October 29, 2022 was carried out using USV of the same type that was discovered on September 21 in the city of Sevastopol.

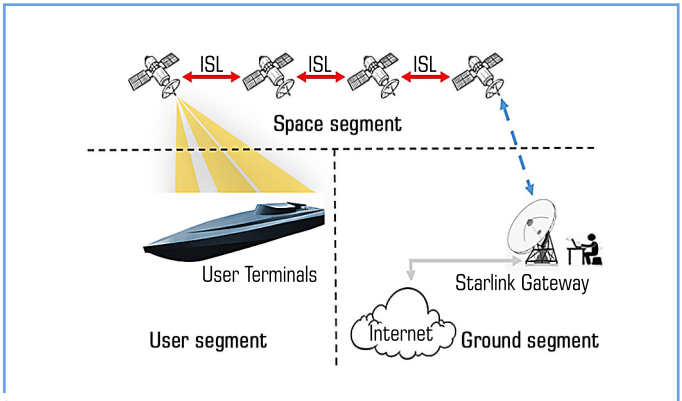

Fig. 3.2 Approximate scheme of the control system of the first USV samples

The next stage in the development of domestic USV was the development of the Magura V5 (Maritime Autonomous Guard Unmanned Robotic Apparatus V-type) device by the Ukrainian state enterprise "Spetstechnoekport" – this is a Ukrainian multi-purpose maritime unmanned device developed for the MID of the Ministry of Defense of Ukraine (**Fig. 3.3**). It can perform surveillance, reconnaissance, patrolling, search and rescue operations, mine warfare, fleet protection and combat missions. The possibility of using "Magura V5" as part of several drones (swarm) is not excluded [34]. The hydrodynamic body and smooth profile allows this device to move stealthily, and also ensures its maneuverability. At the same time, the advantage of "Magura V5" is that no complex infrastructure is required for their launch, no special platforms (slips) are required for launching the device.

Also, according to data from open sources, it is known about the installation of P-73 air-to-air anti-aircraft missiles at the indicated USV (**Fig. 3.4**) [35].

The need to equip USV with means of combating enemy aircraft is connected with the experience of their use during the Russian-Ukrainian war. Taking into account that aviation is a sufficiently effective means of detecting and destroying USV on sea crossings, there is a need to install

appropriate means of destruction on them, primarily anti-aircraft missile systems, which was implemented on the "Magura V5" USV.

Fig. 3.3 "Magura V5" USV appearance
Source: [34]

Fig. 3.4 "Magura V5" USV appearance with installed P-73 air-to-air missiles
Source: [35]

A comparative analysis of the tactical and technical characteristics of the specified domestic USV is given in **Table 3.1** [34, 36].

Another domestic development of USV is "Sea Baby" (**Fig. 3.5**). According to the leadership of the SSU, this device is the result of many months of development, which began after the full-scale

invasion of the Russian Federation into Ukraine. It is exclusively developed by the SSU, no private firm was involved in its development.

Table 3.1 Comparative analysis of tactical and technical characteristics of USV of the 1st generation and "Magura V5"

No.	Characteristic	Type of unmanned surface vehicle	
		Unmanned surface vehicles of the 1st generation	"Magura V5"
1	Length	5.5 m	5.5 m
2	Operational radius of action	up to 400 km	up to 416 km
3	Range of travel	430 miles (800 km)	450 miles (833 km)
4	Combat load	up to 200 kg	320 kg
5	Maximum speed	43 knots (80 km/h)	42 knots (78 km/h)
6	Ways of navigation	automatic GNSS, inertial, visual	satellite communication/radio network

Fig. 3.5 "Sea Baby" USV appearance
Source: [37]

Models of the specified USV at the end of 2023 already had several redundant communication systems, were made of low-visibility materials and had warheads of up to 850 kg, compared to 108 kg in the first versions. In the last months of 2023, Sea Baby has transformed from a kamikaze to a multi-purpose platform that can perform various tasks and is constantly being improved. Thus, in January 2024, the SSU presented the "Sea Baby", equipped with 2–6 jet flamethrowers similar to the RPV-16, and in May of the same year, guides for launching 122-mm rockets of the "Grad" system were installed on the "Sea Baby" (**Fig. 3.6**).

Fig. 3.6 "SeaBaby" USV appearance with guides for the use of 122-mm shells
Source: [38]

Comparative characteristics of "Magura V5" and "Sea Baby" USVs are shown in **Table 3.2**.

Table 3.2 Comparative characteristics of "Magura V5" and "Sea Baby" USVs

No.	Technical characteristics and combat capabilities	"Magura V5"	"Sea Baby"
1	Length, m	5.5	7.0
	Width, m	1.5	2.0
	Height above the waterline, m	0.5	0.7
	Speed:		
	cruiser, knots	22	22
	maximum, nodes	42	42
	Range, miles	More than 500	Up to 450
	Carrying capacity, kg	Up to 320	Up to 850
2	Conducting intelligence	+	+
	Coverage of the surface situation, classification of targets	+	+
	Damage to surface ships (boats), other surface targets, surfaced submarines, hydraulic structures, etc.	+	+
	Search, detection, identification of mine-explosive, combined and non-explosive barriers	–	–
	Breakthrough of the enemy's barrage and network barriers in the places of basing and anchorages of ships and vessels	–	–
	Ensuring covert delivery of ammunition, weapons, and special means to the area of use with return to the specified area (to the return point)	+	+
	Support of search and rescue operations at sea	–	–

It should be noted that not only surface USV, but also underwater ones are being developed for the DFU needs. Thus, Ukrainian volunteers are developing the "Marichka" (**Fig. 3.7**) UUS, which has a declared range of more than 1,000 km. The main task of this device is to destroy bridges, coastal structures, submarines, and ships. If necessary, it is also capable of conducting reconnaissance and transporting cargo.

Fig. 3.7 "Marichka" UUV appearance

The organization "AMMO UKRAINE" is engaged in the development of "Marichka" UUV. It has protection against the effects of radio electronic warfare systems of the Russian Federation, in addition, it cannot be pinpointed by most radars, scanners and echo sounders. Some of the specifications of the mentioned device have been made public along with video recordings of its tests, but the manufacturer is not disclosing its other specifications for security reasons. In its own videos, the developer talks about the use of the device and its advantages: it is invisible to many radars, scanners and echo sounders, has a standby mode, can be turned on by a timer or by a signal, and due to its size, it can carry a powerful ammunition or other payload. Currently, it is known that the length is 6 meters, the width is 1 meter, and the range is 1000 km.

The next UUV sample developed for the DFU needs is the "Toloka TLK-1000" (**Fig. 3.8**) – an autonomous UUV manufactured by LLC "Intelli" (Ukraine) with a range of up to 2000 km, automatic target search and capture, which can carry up to 5 tones of the explosive substance. It was developed in order to solve a complex strategic problem – the destruction of large-scale objects, such as the Crimean bridge, as well as other significant military, infrastructural and naval targets.

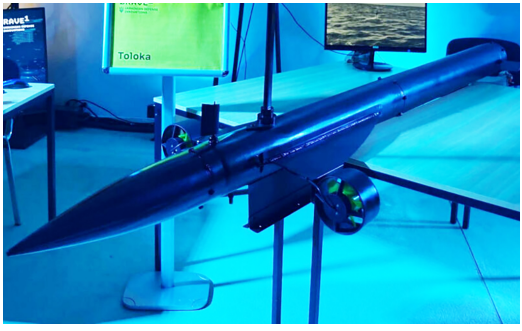

Fig. 3.8 "Toloka TLK-1000" UUV appearance

"Toloka TLK-1000" can destroy hydrotechnical structures and ships of any size in its path, which allows it to perform various military tasks. With its ability to destroy large ships, it can be used to block enemy sea lanes. Also, "Toloka TLK-1000" can continue the mission in autonomous mode when it goes out of range of telemetry, which allows it to perform missions at a long distance from the base.

Comparative characteristics of "Marichka" and "Toloka TLK-1000" UUVs are shown in **Table 3.3**.

Table 3.3 Comparative characteristics of "Marichka" and "Toloka TLK-1000" UUVs

The name of the unmanned subsurface vehicle	"Toloka TLK-1000"	"Marichka"
Range, nautical miles	650	540
The time of autonomous operation, days	90	–
Length, m	12	6
Diameter, mm	1000	1000
Battery capacity, kW	300	–
Hybrid power plant	+	–
Nominal speed, knots	4	–
Maximum speed, knots	5	–

CONCLUSIONS

The analysis of the development of the domestic MRS showed that their most intensive development took place precisely during the Russian-Ukrainian war at sea. Early planning to equip the Defense Forces of Ukraine with maritime robotic systems before the start of full-scale armed aggression of the Russian Federation against Ukraine, although it took into account the experience of the world's leading countries in the development and use of the latest high-tech means of conducting armed warfare at sea, did not allow determining priorities in their purpose and the necessary number for effective performing tasks at sea. It was after the full-scale invasion of the Russian Federation into Ukraine and the beginning of hostilities at sea that the specific tasks that the MRS are capable of performing were determined, the corresponding models were developed and tested in practice. The actual result of their application, taking into account changes in the composition and position of the enemy's forces and countermeasures against these systems had the greatest influence on the MRS development.

The conducted analysis of the management of the MRS development allows to conclude that at the initial stage of the Russian-Ukrainian war at sea, their creation and development took place decentralized, by individual components of the Defense Forces of Ukraine (the Security Service, the

Main Intelligence Directorate of the Ministry of Defense, the Armed Forces of Ukraine) in accordance with the tasks, they which were carried out. This led to the appearance of a significant number of MRS samples, including for the performance of the same tasks. As a result, there was a need to centralize not only the use of these systems, but also the management of their development. In the future, this will make it possible to unify MRS samples in accordance with their purpose and tasks, reduce costs for their production, operation and time for training personnel for their maintenance.

Also, based on the results of the conducted research, the main trends in the development of domestic MRSs since the beginning of the military aggression of the Russian Federation against Ukraine were determined, which include:

– the use of remotely controlled USV in order to prevent losses of personnel;

– gradual expansion of the range of weapons and technical means installed at USV;

– further increase in accuracy and range of attack means based on USV, achieving such a scale of impact on the enemy, which is comparable to the effect of missile weapons;

– need to develop both surface and underwater USV;

– expansion of the range of tasks that USV is capable of performing, in particular, with regard to inflicting damage on enemy warships and support vessels, sea and shore facilities of its infrastructure, conducting reconnaissance, monitoring enemy forces and means, issuing target designations, executing hidden mine laying, in including active ones, combating enemy air attack means, conducting demonstration actions, searching for and destroying sea mines, etc.;

– wide use of UAVs of various purposes (reconnaissance, reconnaissance-strike, strike), which allows to significantly expand the capabilities of detecting and inflicting damage on enemy forces and assets;

– the transition of unmanned vehicles to a new technological base, in particular, the use of satellite communication systems for their management.

REFERENCES

1. V khodi boiu zatonuv patrulnyi kater "Sloviansk" (2022). Available at: https://mil.in.ua/uk/news/v-hodi-boyu-zatonuv-patrulnyj-kater-slov-yansk/
2. Freik, N. (2024). VMS VSU poteriali na voine kater "Slaviansk" i tralshchik "Genichesk". Za nikh "uzhe otomstili". Available at: https://news.liga.net/all/news/vms-vsu-poteryali-na-voyne-kater-slavyansk-i-tralschik-genichesk-za-nih-uje-otomstili
3. Tarash, N. (2023). Znykli bezvisty 16 moriakiv: kudy podilysia viiskovi z zatonulykh kateriv "Slov'iansk" i "Stanislav". Available at: https://mipl.org.ua/znykli-bezvisti-16-moryakiv-kudy-podilysya-vijskovi-z-zatonulyh-kateriv-slov%CA%BCyansk-i-stanislav/
4. Pro rishennia Rady natsionalnoi bezpeky i oborony Ukrainy vid 14 veresnia 2020 roku "Pro Stratehiiu natsionalnoi bezpeky Ukrainy" (2020). Ukaz Prezydenta Ukrainy No. 392/2020. 14.09.2020. Available at: https://zakon.rada.gov.ua/laws/show/392/2020#Text

5. Manley, J. E. (2016). Unmanned Maritime Vehicles, 20 years of commercial and technical evolution. OCEANS 2016 MTS/IEEE Monterey. https://doi.org/10.1109/oceans.2016.7761377
6. Yan, R., Pang, S., Sun, H., Pang, Y. (2010). Development and missions of unmanned surface vehicle. Journal of Marine Science and Application, 9 (4), 451–457. https://doi.org/10.1007/s11804-010-1033-2
7. Corfield, S. J., Young, J. M. (2006). Unmanned surface vehicles – game changing technology for naval operations. Advances in Unmanned Marine Vehicles, 311–328. https://doi.org/10.1049/pbce069e_ch15
8. Heo, J., Kim, J., Kwon, Y. (2017). Technology Development of Unmanned Underwater Vehicles (UUVs). Journal of Computer and Communications, 5 (7), 28–35. https://doi.org/10.4236/jcc.2017.57003
9. Heo, J., Kim, J., Kwon, Y. (2017). Analysis of Design Directions for Unmanned Surface Vehicles (USVs). Journal of Computer and Communications, 5 (7), 92–100. https://doi.org/10.4236/jcc.2017.57010
10. Choe, J., Kim, C., Kim, D. (2012) Trends of Military Unmanned Underwater Vehicle (UUV). Defense and Technology, 396, 52–69.
11. Terracciano, D. S., Manzari, V., Stifani, M., Allotta, B., Caiti, A., Casalino, G. (2019). SEALab current research trends: Maritime Unmanned Systems for dual-use applications. Proceedings of 2019 IMEKO TC-19 International Workshop on Metrology for the Sea. Genoa, 303–308.
12. Remote Defence, unmanned and autonomous systems take hold in military toolboxes (2018). European Defence Agency. Available at: https://www.eda.europa.eu/docs/default-source/eda-magazine/edm16
13. Allison, G. (2020). Royal Marines test unmanned craft in Norway. Available at: https://ukdefencejournal.org.uk/royal-marines-test-unmanned-craft-in-norway/
14. National Research Council, Division on Engineering and Physical Sciences (2005). Autonomous Vehicles in Support of Naval Operations. National Academies Press.
15. Strategy of the Naval Forces of the Armed Forces of Ukraine 2035 (2019). Available at: https://navy.mil.gov.ua/en/strategiya-vijskovo-morskyh-syl-zbrojnyh-syl-ukrayiny-2035/
16. Pro vnesennia zmin do Morskoi doktryny Ukrainy na period do 2035 roku (2018). Postanova Kabinety Ministriv Ukrainy No. 1108. 18.12.2018. Available at: https://zakon.rada.gov.ua/laws/show/1108-2018-%D0%BF#n2
17. Doktryna_Viiskovo-Morski Syly Zbroinykh Syl Ukrainy (2021). Available at: https://ivms.mil.gov.ua/wp-content/uploads/2021/12/doktryna_vijskovo-morski-syly-zbrojnyh-syl-ukrayiny.pdf
18. Pro rishennia Rady natsionalnoi bezpeky i oborony Ukrainy vid 25 bereznia 2021 roku "Pro Stratehiiu voiennoi bezpeky Ukrainy" (2021). Ukaz Prezydenta Ukrainy No. 121/2021. 25.03.2021. Available at: https://www.president.gov.ua/documents/1212021-37661
19. Pro naroshchuvannia spromozhnostei syl oborony (2024). Ukaz Prezydenta Ukrainy No. 51/2024. 06.02.2024. Available at: https://www.president.gov.ua/documents/512024-49625

20. Ukrainian Navy creates a brigade of naval drones (2023). Available at: https://mil.in.ua/en/news/ukrainian-navy-creates-a-brigade-of-naval-drones/
21. Yakymiak, S. V. (Ed.) (2013). Voienno-heohrafichni umovy zastosuvannia syl (viisk) Viisko-vo-Morskykh Syl. Kyiv: NUOU im. Ivana Cherniakhovskoho, 164.
22. The Black Sea and Azov seas to the waters of Ukraine (2004). Kyiv: Ministry of Transport of Ukraine, Department of Sea and River Transport, State Institution "State Hydrography", 292.
23. Azerbaidzhanski BPLA u viini za Nahirnyi Karabakh (2021). Available at: defence-ua.com/weapon_and_tech/azerbajdzhanski_bpla_v_operatsiji_zaliznij_kulak_ch1-4922.html
24. Mykolaivska firma rozrobliaie bezpilotni katery dlia Odeskoho zahonu Morskoi okhorony (2016). Available at: news.pn/uk/messages/168938
25. VMS Ukrainy otrymaly pershyi kompleks Bayraktar TB2 (2021). Available at: defence-ua.com/army_and_war/vms_ukrajini_otrimali_pershij_kompleks_bayraktar_tb2-4225.html
26. Spysok vtrat korabliv pid chas rosiisko-ukrainskoi viiny. Available at: https://uk.wikipedia.org/wiki/Список_втрат_кораблів_під_час_російсько-української_війни
27. V Ukraini stvoryly novyi morskyi dron pid rizni zavdannia – vid kamikadze do rozvidky ta lohistyky (2024). Available at: defence-ua.com/news/v_ukrajini_stvorili_novij_morskij_dron_pid_rizni_zavdannja_vid_kamikadze_do_rozvidki_ta_logistiki-15690.html
28. V Ukraini rozrobyly morskyi dron MAGURA V5 (2023). Available at: https://mil.in.ua/uk/news/v-ukrayini-rozrobyly-morskyj-dron-magura-v5/#google_vignette
29. Romaniuk, R. (2024). Vodni drony, Ilon Mask ta vysokotochni rakety: yak Ukraina vidvoiuvala Chorne more. Ukrainska pravda. Available at: https://www.pravda.com.ua/articles/2024/01/1/7435326/
30. Bezpilotni nadvodni aparaty-kamikadze klasu Sea Baby. Available at: https://shipshub.com/uk/classes/289-2.html#google_vignette
31. Gault, M. (2022). Mysterious Sea Drone Surfaces in Crimea. Available at: https://www.vice.com/en/article/xgy4q7/mysterious-sea-drone-surfaces-in-crimea
32. Ilon Mask taiemno vidkliuchav Starlink mynuloho roku i zirvav ataku Ukrainy morskymy dronamy na flot VMS RF (2023). Available at: https://enovosty.com/uk/news-ukr/news_technology-ukr/full/0709-ilon-mask-tayemno-vidklyuchav-starlink-minulogo-roku-i-zirvav-ataku-ukraini-morskimi-dronami-na-flot-vms-rf-cnn
33. Sutton, H. I. (2022). Why Ukraine's Remarkable Attack On Sevastopol Will Go Down In History. Available at: https://www.navalnews.com/naval-news/2022/11/why-ukraines-remarkable-attack-on-sevastopol-will-go-down-in-history/
34. Chernysh, O. (2023). Mahura. Shcho vidomo pro morski drony, yakymy Ukraina mozhe atakuvaty Rosiiu. Available at: https://www.bbc.com/ukrainian/articles/clew6ee5nx8o
35. Pro shcho hovoryt Magura V5 z R-73, yakyi peretvoryly na morskyi dron-ZRK (2024). Available at: https://defence-ua.com/weapon_and_tech/pro_scho_govorit_magura_v5_z_r_73_jakij_peretvorili_na_morskij_dron_zrk-15254.html

36. A fundraiser that will become a game-changer. Join the formation of the world's first Naval Fleet of Drones. Available at: https://u24.gov.ua/navaldrones
37. "Morskyi maliuk". Shcho vidomo pro dron, yakym SBU bie po Krymskomu mostu i flotu. Available at: https://www.bbc.com/ukrainian/news-66518479
38. Morskym dronam Ukrainy nadaly zmohu zapuskaty snariady "Hrada". Available at: https://mil.in.ua/uk/news/morskym-dronam-ukrayiny-nadaly-zmogu-zapuskaty-snaryady-gradu/