UNMANNED UNDERWATER SYSTEMS – A FORCE MULTIPLIER TOOL FROM OPERATIONAL PERSPECTIVE

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Abstract: *The accelerated development of autonomous systems within the defense industry raises a series of legal, ethical, political, operational and technological challenges. The concept of autonomy applied to military equipment and systems is fundamentally reflected in the options for complementarities between human operators and autonomous systems, on the one hand, but also on the diversity of existing military capabilities, depending on the specific technological development stages.*

Keywords: development, autonomous systems, challenges, military capabilities.

Introduction

The increasingly important role of artificial intelligence and the concept of autonomy in the design and realization of new military capabilities lead us to the need to adapt and reconfigure military operations at the doctrinal level. As intelligent robotic technologies and processing algorithms will increasingly occupy the field of military engagement, and network warfare begins to become a constant aspect of current conflicts, military decision-makers will need to be prepared to act and make decisions in a completely changed operational environment as compared to 15-20 years ago. Computational engineering and software solutions will offer customized action variants to the military, with a much reduced response time, simplifying decision-making and providing an accelerated response to the opponent's initiatives. In addition, autonomous systems will be able to perform missions and tasks with greater accuracy and efficiency, while at the same time reducing the risks to military personnel.

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These trends, regarding the development of intelligent unmanned systems within the military organization, offer both opportunities and challenges for combat forces, but also for military theory specialists. From a certain point of view, these equipments have the potential to be more precise, less risky and obvious than the use of troops in the field from a traditional perspective. The autonomy of robotic systems offers the operational advantage of actions in a hostile territory, where communications can be intercepted or intentionally cut off. As unmanned vehicles will have increased autonomy, human operators will have to move from an operator control model to an architecture based on the multi-control concept of several robotic systems[1]. The result of this paradigm shift at the conceptual and operational level will allow the military organization to deploy a greater number of military equipment in a high risk operations area but with superior destructive power. The transfer of military decision-making sequences from the human operator to the autonomous systems will progressively lead to a higher spatial-temporal coordination, a larger amount of data processed in a very short time, a much greater reaction speed and an optimization of decision cycles.

The concept of autonomy is analyzed in this research paper only from operational perspective, but moral and ethical considerations are not subject within this scientific article. The analysis of the concept of autonomy in this article rules out the aspect of morality or legality in connection with the use of robotic systems.

1. Development of maritime autonomous systems as multiplier factor and functioning of operational profile in the naval doctrine

We believe that information technology has a considerable impact on the planning and management of military operations at sea. This phenomenon is very visible when we analyze the concept of sea control. In this case, in the era of information, efforts to achieve sea control must be concerted from the beginning with actions to obtain informational superiority or block access to information for the opponent. Thus, this phase

[1] ALEOTTI J., CASELLI S., REGGIANI M., *Leveraging on a Virtual Environment for Robot Programming by Demonstration*, Robotics and Autonomous Systems 47/2 (2004), p.153.

becomes an integral part of the operational concept of obtaining or maintaining control of the sea. Maritime autonomous systems allow us to achieve informational superiority through the ability of this equipment to process data and provide action options, offering technical capabilities of collecting, processing and dissemination in a constant flow while at the same time redeeming enemy vulnerabilities or blocking access to critical information. From a certain perspective, we can make an analogy between getting control of the sea and controlling the information space.

One of the main objectives of this scientific approach is to identify the proper means on how the capabilities of autonomous underwater systems can contribute to the definition and comprehension of a flexible, adaptable and mission-oriented structure of the Romanian Naval Forces for a near future time horizon. The approach we propose from this perspective starts from the realities of the Romanian Armed Forces structure at this moment, but also from the vision that we bring to interest on the complementary character of the new technologies, and for a more remote perspective the approach of the systems- of-systems (multi-level forces and means built into the concept of network-based warfare)[2].

The lethal armament systems are relatively simple to define and are widespread and known both from a theoretical and practical point of view. The addition of a supplementary component, autonomy, significantly complicates the way in which the issue of the use of autonomous military systems in the armed conflicts will be addressed in the future. From the point of view of the moral component of the war, the concept of autonomy applied to combat systems introduces two important components, namely: its own decision for military equipment and the ethical component, notions that did not exist until now. For a specialist in the automated robotic industry, the concept of autonomy refers to the delegation of some decision-making sequences to robotic equipment that has been pre-programmed by the human operator. The autonomy of military systems for the execution of lethal actions refers to "*the ability of systems to perform the attack on*

[2] SEA-17B, *Advanced Undersea Warfare Systems*, Systems Engineering Analysis Capstone Report, June 2011. Naval Postgraduate School, pp.40-43

selected targets without being initiated or confirmed by the human operator, both for the target selection situation and for the execution of the attack"[3].

Current and future information management technologies will set footprint and cover not only the space of employment, physical (land, air or maritime), but also the information space - *cyberspace*. The existence and growth of the importance of the fourth dimension of the space will cause the conceptual boundaries of war to become blurred and unstable within a short period of time. As a consequence of this we will be able to see a condensation of the time factor in the future. This effect will occur as a result of the ability of robotic systems to collect, evaluate, use, transmit, and multimodal transfer large amounts of information at higher speeds and to multiple users. Underwater autonomous vehicles can develop multiple functionalities, being assimilated as diverse sources of information, but linked to each other and organized into ISR (*Intelligence, Surveillance and Reconnaissance*) architecture in support of Naval Task Force (TF) or Naval Task Group (TG). Finality is a much faster response time and a dynamic decision-making cycle tailored to the needs of the mission. The doctrinal transformations that autonomous robotic systems will impose on time and space will accelerate the rhythm of combat at sea. The forces that will win the fight in time and get the information superiority, as well as control over the opponent's reactions, will be in a position to execute the surprise of the enemy and therefore to have the initiative. From our perspective, information superiority will be one of the main operational level goals to gain the advantage of the battle rhythm and the freedom of maneuver in the engagement space.

The technologies introduced by the autonomous systems and information technology will lead to a drastic reduction of the time allocated to the planning, preparation and conduct of military actions at sea or in joint operations. The information that commanders will have at their disposal for the management of naval battle groups at sea will be disseminated to subordinate units quickly and with greater accuracy and will be displayed using digital technology - via encrypted and video data transmissions. This

[3] FOSS, Michael,*What are Autonomous Weapon Systems and What Ethical Issues do they Raise,*2008, Conference Towards Autonomous Robotic Systems. Springer Berlin Heidelberg, p.3

information support will make available to naval task groups commanders the tools through which they can visualize the situation in the operating area and can process and transmit critical information in video format. The commander will have the ability to convey in an explicit manner his intention and CONOPS to all command levels. In our view, the application of the concept of war based on the network in the naval field has a number of advantages, the most important being the multiplication of the fighting power of our own forces.

This power derives from superior processing of information, easy user access and dissemination speed, unlike the industrial era where combat power was given by the number of combatants and combat equipment. If the traditional elements of combat power, such as fire power or troop mobility, can be readily quantifiable, it is difficult to achieve in the determination of measurable indicators of combat power in the information spectrum. The problem of real determination of the fighting power is given by the existence of multiple immaterial factors, which cannot make it possible to be determined by measurement. In network-based warfare, excessive centralization leads to a reduction in the multiplier effect induced by information technology. In fact, the use of autonomous systems within a network-based architecture starts from the principle of multipolarity and decentralization of decision. Other factors that diminish the success of network operations in which we use autonomous underwater vehicles and information technology are the low level of training and understanding of the complex hiring environment by operators, the low level of competence of commanders in adapting to new specific conceptual developments of the IT field, as well as the reduced adaptation of the state to the rapid pace of processing and dissemination of information products.

Planning and execution of anti-submarine warfare actions in the shallow waters, the situation specific to the area of responsibility of the Romanian Naval Forces at the Black Sea, should focus on two main elements: deterrence and neutralization of the diesel-electric submarines of the enemy on the transit routes, while protecting HVU's own, such as logistic support vessels, commercial ships or allied amphibious forces. Navy forces are conducting military actions at sea, in the area of responsibility, to ensure freedom of navigation and access to international waters and to discourage any threat to sea lines of communications (SLOC). From the perspective of ASW's challenge of fighting in the narrow seas, it becomes a critical and immediate need to build and maintain effective ASW capabilities either by upgrading or replacing existing ones, or by building a hybrid between existing platforms (ships, aircrafts) and modern, autonomous or semi-autonomous means (underwater vehicles, fast surface vessels, etc.). These actions allow the Naval Forces to further ensure success in protecting their own forces and maintain SLOC free and safe for navigation.

In our view, autonomous systems will not be able to replace traditional naval platforms over a time horizon of 10-15 years. As we have seen in the evolution of military technology, the emergence of equipment such as airplanes, tanks, or steam-powered combat ships did not replace combat forces, but reconfigured military actions and subsequent strategies, doctrines and tactics to develop military action. In a globalized world where technological achievements in the civil sphere have a higher velocity of development than those in the military industry, characterized by bureaucracy and a chronophagous decision-making cycle, military specialists responsible for the procurement of military equipment will have to make quick decisions from the point of view of the adaptability and compatibility of robotic systems in the civilian-military field.

2. The operational design of using autonomous underwater vehicles in support of antisubmarine warfare for shallow waters

Worldwide, among countries with maritime military capabilities, there is a particular interest in reducing the costs associated with underwater warfare in the two main directions: anti-submarine warfare (ASW) and the naval mine warfare (MW). Lately, the concept of using unmanned underwater vehicles (UUVs) for both domains, ASW and MW, marks an accelerated development both at conceptual and practically-applicative level.

For a long time, the missions of searching, discovering, identifying, classifying and neutralizing enemy submarines consisted of routine, laborious, long-term actions, and with a very high effort on the part of specialized vessels and aircraft, with a high rate of crew exhaustion, especially due to the large amount of information to be processed, of the limited information processing equipment, correlated with the rapid data outer limits.

The framework of the antisubmarine actions manages to best encompass both the operational art and the scientific side of the problem. It is science because ASW is structured, systematically, based on scientific research and validated theories, and is largely accomplished by repetitive and iterative actions. In addition, the amount of knowledge, equipment and level of training required to conduct activities in the underwater environment must be taken into account. Equally, the ASW field is also characterized by military operational art because, despite the existence of numerous sets of procedures, techniques and fighting tactics, the issue of antisubmarine warfare can also be seen as an unexpected play, in addition to the unpredictability of factors environment.

Autonomous systems, whose rapid development and widespread use, both in the military and in the civil spheres, have been able to bring added efficiency and make the issue of the fight against the submarine a less dangerous and less redundant for human operators. Within this scientific approach, we believe that it is necessary to develop conceptually a model for the organization and use of autonomous underwater systems that respond to the following set of requirements:

• *How can we integrate the UUV architecture concept into the organic of a surface task group (TF or TG) and what are the principles under which we can ensure its antisubmarine protection by reducing the human operator's effort?*

• *For what assignments can we exclusively allocate UUV equipment, and what is the degree of autonomy in their decision-making process, so that we are more efficient compared to human operators?*

• *How can we determine and quantify the superior characteristics of robotic systems as compared to classical ones?*

The concept of architecture refers to the structure and components that make up a system, the relationships of interdependence between the structural elements, but also the principles and rules governing their design and the operation of the system as a whole in time. The necessity of defining an architectural concept of UUV use is to develop and use the network centric warfare, the use of military equipment with a high level of information technology, the need to interconnect systems used in combat, interoperability and functional optimization to carry out the missions. For these reasons, we appreciate that the war of the future will be one of the integrated military systems, and the operational architecture will have an increasingly important role, which is the key to success in terms of integration and interoperability.

In any architectural design we design the use of UUV, it will have to follow the C4ISR typology. Starting from the capacity of underwater autonomous systems to be versatile, these equipments can be autonomous mini-submarines, explosive cargo carriers and underwater transport or immersion robots. Concurrently with the development of artificial intelligence and technology, UUVs will have an increasingly important role in maritime operations and will act as a multiplier of maritime forces.

From an operational perspective, the representation of the TU-UUV concept includes the combat missions, the combat environment and the capabilities necessary to achieve the military purpose and objectives.

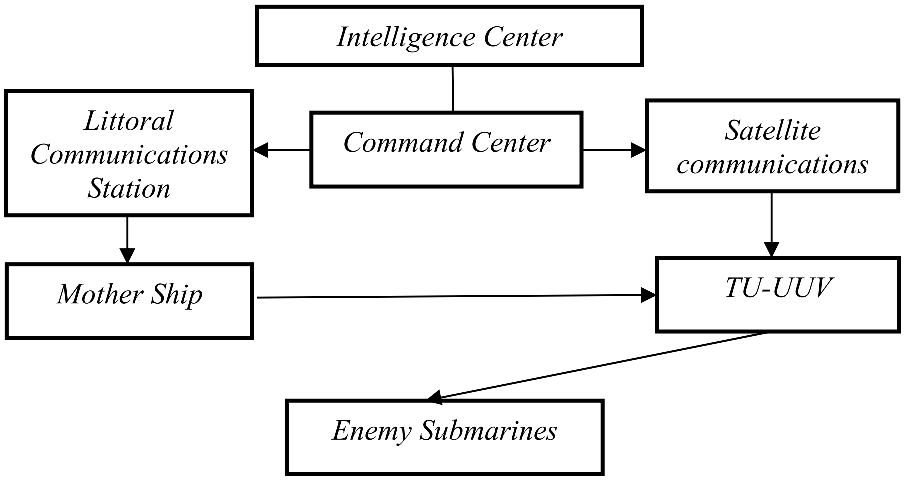

Figure 1. Conceptual operational level representation

The main objective of the antisubmarine warfare is to prevent and prohibit the use of enemy submarines in the maritime area of interest. Antisubmarine Warfare (ASW) is a component of underwater warfare and includes a mix of platforms such as surface ships, helicopters, patrol marine aviation, and submarines. All these means have the mission of discovering, pursuing, classifying, neutralizing or destroying the enemy's submarines. The principal development direction in this area is the increasing use of autonomous underwater systems. In order to understand the advantages of UUV use and proposed models, it is important to understand the character of the antisubmarine actions. For this, we have analyzed the main concepts, processes, platforms and environmental factors that fundamentally determine the ASW directions in shallow waters areas.

The anti-submarine warfare in the littoral waters is complex and can be hampered by high commercial traffic, but also by environmental factors specific to shallow water area. Banning the intrusion of the enemy's submarines and neutralizing the secret of their insidious actions is difficult to accomplish, compared with the anti-submarine missions in the blue water areas. From the perspective of the complexity and the lack of predictability of the environmental factors in the coastal zones as well as the high level of the acoustic signals in the littoral areas, the ASW-specific classical methods and procedures are not very effective for the shallow waters. High acoustic interference and low acoustic wave propagation in seaside waters affect the efficiency of underwater acoustic sensors. Therefore, from the analysis of the specificity of the environmental factors, it is necessary to identify and use complementary ASW capabilities. The introduction of autonomous underwater systems and a new technology for antisubmarine warfare leads to an integrated and comprehensive approach to the maritime combat area[4].

The capabilities and requirements for UUV use in combat are analyzed from a dual perspective, the functional approach and the one resulting from the specifications of the operational requirements, the point of interest being the identification of an optimum on the needs of this complex analytical framework. From the analysis of operational requirements, we identified the following indicators on the efficiency of UUV use: Ability to cause damages; Ability to act in a hostile environment; Availability; Efficiency of sensors; Mobility; Autonomy; Interoperability; Transport capacity; Possibility of redistribution.

Modeling through the symbolic representation of redefining reality corresponds symbolically to a concise formula of relevant or critical

[4] Naval Doctrine Command, *Littoral anti-submarine warfare concept*, Norfolk, VA, 1998. [Online], available at: http://fas.org/man/dod-101/sys/ship/docs/aswcncpt.htm#Littoral. Accesed on 24.12. 2018.

elements for a particular process or system. The military system, and more specifically the field of planning and conducting military operations, is a real system but cannot be represented by equations, mathematical formulas, laws of physics, etc., characterized by complex dynamic actions, and the simulated model is invariant an artificial one. Typically, such models bear the name of generative systems, and are based on the use of artificial agents in the virtual environment of the computer[5]. Modeling and agent-based simulation is a new way to implement concepts within complex systems, such as military operations. These simulations are critical in assuring decision makers' support in CONOPS validation or for different sequences in the planning process. Following these modeling, the optimal structure of forces, the efficient use of sensors and weapons, the validation of new doctrinal concepts or the introduction of new combat tactics can be determined. In this area, the most known and applied tools include computational mathematical systems such as: MATLAB, PYTHON, AnyLogic, NetLogo, Pythagoras and MANA (*Map Aware Non-Uniform Automata*)[6].

Autonomy and operational profile play an important role in configuring autonomous systems and provide support for modeling the interaction between the multiple factors under consideration. Modeling and simulating program is particularly useful because it operates with critical indicators for combat actions such as the ability to act in secret, the characteristics of the sensors and weapon systems, the possibilities offered by the communication systems. Another important aspect of this software is the modeling ability according to the intentions and tactical profile of the operator. This aspect is relevant from the point of view of introducing elements related to the development of fighting actions and the way of moving from a static tactical situation to a dynamic one. The simulation of

[5] AXTELL, R.., *Why Agents? On the Varied Motivations for Agent Computing in the Social Sciences*, Center on Social and Economic Dynamics, Working Paper No. 17, 2000, pp. 88-91.

[6] MACALAND, C. and NORTH, M., *Tutorial on agent-based modelling and simulation*, *J. Simulation*, vol. 4, no. 3, 2010, pp. 151–158.

combat forces cannot be modeled in a fully predictable manner. The operational situation and the tactical conditions will always require the movement and the action of the forces at sea, so that the success or failure of the simulation will have to be taken under the specter of reserve on the particular evolution of certain parameters.

From the point of view of the warfare actions, we can integrate how the relationships between input and output data are interdependent with the structure of the TU-UUV concept.

As a result, we believe that the use of the TU-UUV concept for the accomplishment of the ASW missions has to comply with the above-mentioned typology, having as its core the principle of design centered on data and information. At this stage, we appreciate that the presented architectural models can achieve the collaborative and comprehensive ASW function, thus providing the best premises for operating autonomous systems. The entry into operation of autonomous underwater vehicles brings important changes to the concepts, principles and doctrines of the naval warfare. Developing a concept of using autonomous systems creates for the Navy the prerequisites for diversifying the capabilities available as well as extending the range of missions that can be executed. Planning and conducting the antisubmarine warfare with modern capabilities should start from the analysis of the challenges of the future and the understanding of the operational limitations of the classical systems.

From the perspective of the challenges faced by the Romanian Navy, regarding the need for modernization and adaptation to the new technologies in the field of naval warfare, we consider that a complex system analysis is required, starting from the correlation of the fundamental aim, the detailed objectives and tasks specific to the missions defined by the national military strategy and the doctrine of the Naval Forces. All this must be in line with the current level of military capabilities development, but also with the prospect of assimilating new technologies from an integrated and collaborative vision at the level of the North Atlantic Alliance.

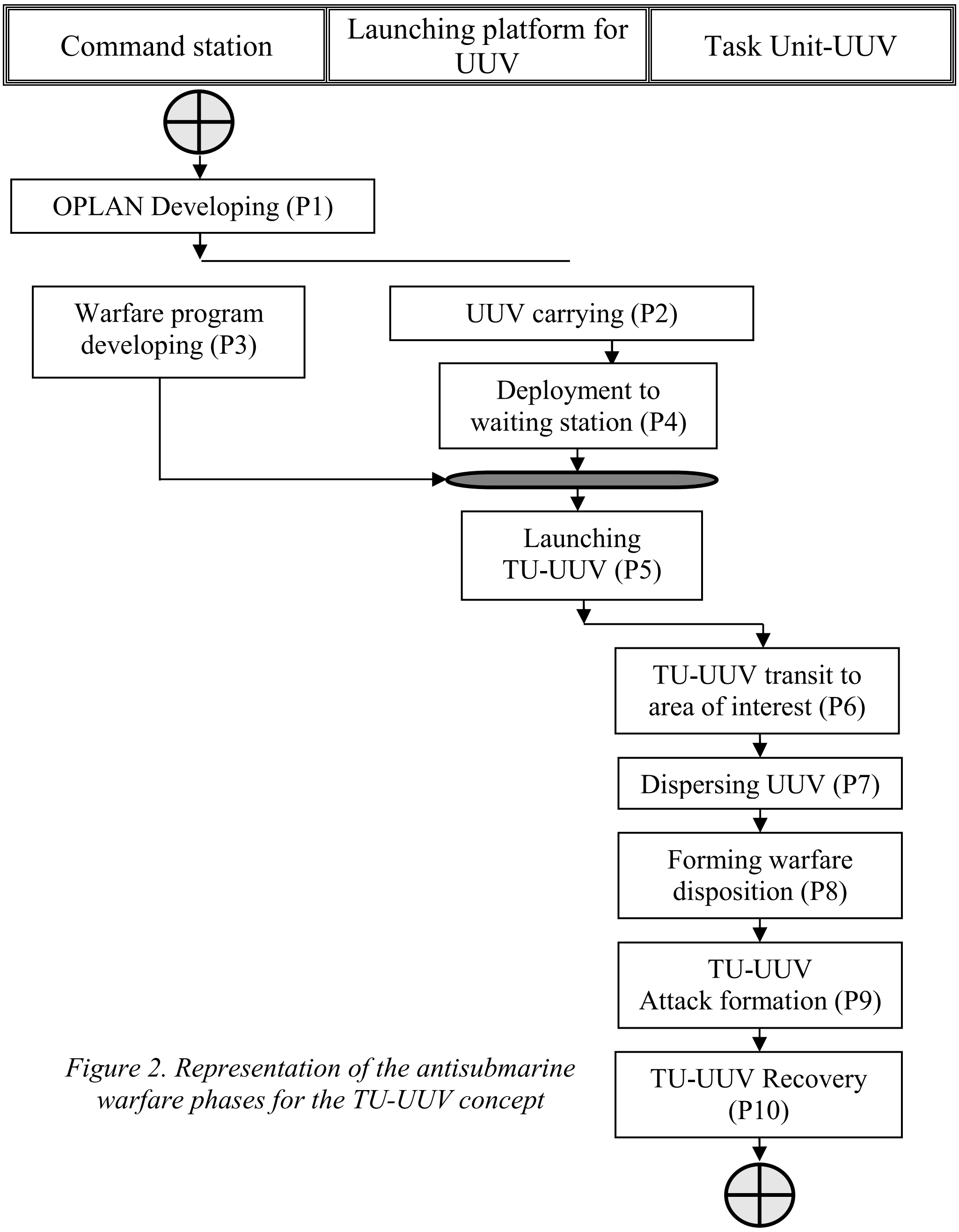

Figure 2. Representation of the antisubmarine warfare phases for the TU-UUV concept

From the analysis of the multiple organizational transformations of military systems within NATO, as well as from the study of the mechanisms for substantiating the processes of endowment of allied naval forces, we can state that the entire procurement cycle is designed to facilitate a much faster refurbishment of existing capabilities. Achieving a modular design on the architecture of the mission-operational-research, development-production and acquisition profile is the foundation of a new approach to the strategy for defining military equipment needs.

In our view, for a medium time horizon (10-15 years), it is difficult to achieve a total replacement of existing capabilities at the moment in the Naval Forces or to carry out upgrade work on existing ships and to considerably improve performance, taking into account constructive and design constraints and limitations. We therefore propose to increase the interoperability of existing platforms and to carry out the missions undertaken by them by developing the concept of complementarities of the autonomous systems. The proposed concept for analysis and implementation aims at capitalizing the technological advances of robotic systems and easy operation on board ships, aircrafts or land, for a huge number of missions and environments of the tactical field.

From our point of view, the main arguments for using autonomous underwater systems in the area of operations should become a priority axis of interest for the Romanian Navy, including the following:

I.The character of the force multiplier factor.

The use of autonomous robotic systems in military actions has the effect of reducing the human force involvement for the same types of missions, but also the possibility that a single human operator can execute through the autonomous systems of previously executed actions by a larger number of operators or combatants. Multiplier factor includes a series of quantifiable, measurable elements that refer to:

• Extending the operational range of surface vessels or submarines using unmanned underwater systems for the antisubmarine warfare specific field;

• Ability of autonomous systems to be more robust and reliable in the underwater environment influenced by sea level, visibility, density, salinity, water temperature;

• High endurance threshold compared to human operators in terms of factors such as fatigue, routine, formalism of performing operations, lack of orientation in the underwater environment,

• Ability of autonomous systems to move and act secretly at great distances from the launch platform and to collect and transmit information from maritime areas where surface ships or own submarines cannot act;

• A group of autonomous undersea units can achieve a more efficient execution of mine counter measures missions, for instance, it can cover much better and in a much shorter time an area for the mines search. Realizing cooperation between unmanned vehicles means requires a flexible vision and good coordination, reorganization according to mission specific and dynamic positions, with a minimal incidence of the human factor, but at the same time able to respond to the environmental challenges of the maritime area changes or changes resulting from adjustments to the objectives of the mission. This capability is strictly limited by the operating conditions of the communications systems in the submarine environment (characterized by factors such as acoustic wave dispersion, attenuation and bandwidth).

II. Reduction of the risks to the life of combatants by introducing autonomous robotic systems into the operating area;

III. Autonomous underwater vehicles (AUVs) have the potential to improve the performance of existing capabilities in the area of anti-submarine combat in shallow waters area. These systems have also been used in World War II military operations, but this equipment has recently shown a particular interest from several countries in terms of superior operational capabilities compared to traditional naval platforms.

Conclusions

Considering the directions studied, the arguments, the observations and the conclusions drawn of this article, we consider to issue a series of proposals regarding the reconfiguration of the military actions of the Naval Forces through the use of autonomous underwater systems. We can say that technological progress has changed the paradigm of warfare. The way we understand maximizing technological evolution at one point gives us the strategic ability to plan victories.

Another proposal would be for the Romanian Navy to focus on adapting existing capabilities to meet new challenges or to develop new capabilities to meet the full range of specific missions, given the challenges of the future in terms of space underwater warfare. The new concept of using underwater autonomous equipment should be conceived on a modular approach and multi-mission theory, in close correlation with the threats in the area of responsibility – naval mines, force protection, anti-terrorist actions, maritime surveillance, surface combat actions, or anti-submarine warfare in areas with shallow waters (as the case is with the Romanian littoral area).

This article has identified the concepts and tools by which the Romanian Navy can improve its maritime activities for the execution of specific missions by using autonomous systems with implications in the underwater environment, the sea surface and the airspace adjacent to the area of responsibility. Practically, we have tried to emphasize the role of the force multiplier that these systems can provide.

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