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THE TIMELINESS OF AN UNDERWATER SENSOR SYSTEM

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Abstract:
In this article, we intend to bring in mind the importance of submarine surveillance systems in terms of information support and the creation of a fully recognized maritime image. The importance of information to strengthen the maritime power of a state with access to the sea calls for the identification of effective adaptive solutions that minimize effort and costs. Due to the diversity of underwater vectors, the need arised to identify them in the sea areas of interest or in maritime operation areas, where their presence endangers the safety of naval forces or coastal objectives. We believe that a system of submarine sensors is an efficient and effective solution for obtaining information that contributes to the realization of the recognized image in the overall maritime environment under the responsibility of the Romanian Navy.
Keywords: underwater sensors; hydrolocator; maritime surveillance; underwater surveillance systems.

The motivation for choosing the topic resulted from the personal consideration of promoting a desideratum for the development of conceptual solutions for the development of a defensive system for the surveillance of the submarine environment with a network of sensors at the littoral. Even though the existence of such a system is tributary to Cold War conceptions, the development of a modern system would meet current technological requirements, as well as a concept adapted to it. In essence, the purpose of this article is to identify a maritime image enhancement solution recognized by the use of a submarine surveillance system to provide information on the presence of submarine vectors falling within the area of responsibility of the Romanian Navy, with the role of discovery, localization, identification and early warning.

The topicality of the theme derives from the dangers generated by the diversity of underwater vectors, in line with the technology that has outgrown all security measures. The development of such vectors has become a concern of maritime powers wishing to gain control of the entire spectrum of the aerial, surface, underwater and cybernetic mediums. Unmanned submersible vehicles have become underwater vectors that have changed the status of the maritime spectrum in which the submarines have held an important place. At the heart of our approach is the hypothesis that underlines the fact that there is a link between the evolution of underwater detection systems and the possibilities of fighting underwater, i.e. the leap created by the technological development of the vectors exceeds the capabilities of some detection systems. Therefore, we believe that the return to the basic principles of defense, detection and localization underwater, using classical sensors, mainly passive, hard or almost undetectable, is a solution that can be reversed. Based on this hypothesis, we believe that it is possible to design a reliable system of submarine sensors to neutralize the gap between submarine vector technology and the physiognomy of military action in relation to the battlefield.

In order to achieve the purpose of this article and validate the above mentioned working hypothesis, we will focus on three research objectives that underpin the initiated approach. The first objective is the conceptual delimitation of the role of a coastal submarine surveillance system which contributes to the accomplishment of a RMP that complements the need for information on the underwater situation near the littoral. The second objective considers the importance of information to strengthen the maritime power of a country with sea exit such as Romania. Based on these considerations, the third objective will be to make predictions on the trends and

characteristics of developing a submarine surveillance system. Achieving these goals will allow us to conduct a descriptive analysis of a coastal submarine surveillance system that integrates sensors and responds to new trends in submarine vector evolution.

We believe that the achievement of these proposed objectives will lead to the achievement of a product that will be a milestone which will contribute to the consolidation of the solutions for improvement of the maritime situation, especially the submarine image, which the Romanian Naval Forces could benefit from in the optimal decision making process to an imminent threat.

The Maritime Spatial Surveillance is a permanent main mission of the Naval Forces, so the submarine space as an integral part of it is an area of interest requiring specific capabilities that are capable of providing the information needed to capture the underwater image to complete the RMP. From this point of view, the underwater space is a vulnerability of the entire maritime space that needs to be minimized. Such vulnerability generates risks and threats to the safety of the submarine environment.

A vulnerable environment diminishes the ability of a surveillance system to discover and respond to the emergence of a risk. In order to decrease the potential risks, submarine space surveillance must be performed by hydro-acoustic means, by observing electromagnetic anomalies or identifying other detection underwater means.

We believe that the existence of a sensor system, located in a network that covers the information nedeed to create the complete RMP, is a top priority. The most current means of discovery are hydrolocators, which are often placed on board surface vessels or submarines. Thus, in order to optimize effort and maximize product, in this case the underwater image, sensors of active or passive hydrolocators type placed in a monitored system would be a handy solution.

A system[1] is a concept that defines an ensemble of dependent elements that form an organized whole, which makes the activity carried out to function according to the intended purpose.[2] A system addresses globally the relationships between its components, capitalizing on their synergy, which, taken individually, does not present entities with special attributes but individual characteristics that differentiate them. From a hierarchical point of view, the main component within a submarine sensor system is the hydrolocator. From the point of view of the system resolution, which means the degree of hierarchy and the relations between the component elements, a subsystem of sensors allows the hydrolocator to be valued by the analyst's ability to make predictions and control the system.

Prediction is the property of the sensor system to assess the evolution of the system's operation and to contribute to an objective analysis of the submarine environment. Control is the monitoring of the action of sensors or other elements of the submarine sensor system on their quantitative and qualitative parameters and the identification of optimal operating solutions using other routes of the system itself so that the role of the system is achieved. The main functions of a hydroacoustic sensor system are submarine surveillance and research, which contribute to enhancing the security of the marine environment by obtaining and providing information. Below we will briefly describe the conceptual meaning of these functions.

Submarine Surveillance, an important component of maritime surveillance, is the set of actions and measures prepared and deployed by naval, surface and submarine forces designed to systematically monitor the area of submarine responsibility, providing the information needed to complete and produce the recognized Maritime Image (RMP) a maritime area of interest or a maritime operations area.

Hydrolocation research of submarine space is the set of actions and measures organized and deployed by forces and specialized means to obtain information on the underwater assets in the area of responsibility of maritime surveillance systems, the determination of position and movement elements, mutual information and disseminating the information necessary to make the decision for the planning, organization, preparation and deployment of maritime operations.

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[1] From the Latin "sistema", in the sense of crowd, reunion, assembly, a.n.

[2] DEX, Dictionary of the Romanian Language, Univers Enciclopedic Publishing House, Bucharest, 1998, p. 993

The Surveillance and Research Submarine Area is the maritime space under the responsibility of a specialized force in which it defers its assigned mission, the discovery and determination of geographic coordinates and the motion characteristics of a submarine vector.

The security of the maritime environment thus acquires a new component, the size of its security being added to the size of the submarine space security, an aspect that increases the risks and threats by widening the spectrum of vulnerabilities.

The hostile information actions of submarine vehicles, submarines and unmanned submarine vehicles of potential enemies pose a threat to maritime security, especially if it is intended to develop a maritime image in its own area of interest in order to influence the actions of the Naval Forces. Some forms of threat to maritime security are actions against port infrastructure, important coastal objectives; actions against surface ships or submarines, actions on shipping vessels, maritime communications, actions on oil platforms and other littoral facilities.

In order to manage the risks and threats to the safety of the submarine environment, the existence of a plan to ensure good management of coastal surveillance systems must be a short-term objective of the Navy. Under this plan, a system of submarine sensors covers the need for information that contributes to the realization of the recognized image across the marine environment.

Current military actions have a multidimensional character generated by the multitude of environments in which they are deployed, the submarine environment being one of the least controlled; so, if properly exploited, the risk of changing the ratio of forces to the benefit of the controlling person increases. Surprise is also a risk assumed in the event of technological gaps, which are still the basis for competition between actors. The need to avoid surprise has the effect of developing modern systems of early research, detection, observation and early warning. We believe that eliminating this gap can also be achieved through simple solutions. Returning to classic is not a solution to be avoided. In the case of underwater warfare, the simplest submarine detection system is the hydrolocator which in the passive mode presents minimal risks of detection.

The emergence of modern technologies calls for an adequate modification of operational concepts, the structural adaptation of naval forces to the realities of the maritime battlefield, and the full exploitation of the opportunities offered by it. The information dimension of military actions is based on the processing of information provided by sensors that offer advantages to an opponent. Thus, the underwater environment, through its vulnerabilities, represents an environment that can be exploited by a potential adversary.

Having presented the main conceptual elements and the role of a submarine surveillance system at the littoral, we believe that we have achieved the first objective proposed in this approach. In what follows, we propose to analyze how to conduct the information process specific to a submarine sensor system and its role in providing information to strengthen the maritime power of a seaside state.

The information[3] in its quantitative sense is an aspect that emphasizes the relationship between the transmitter and the receiver, a relationship that eliminates the undetermined character of an event that has a degree of certainty or probability. At a high probability of an event, the information is small enough, but the ratio changes if the event is low, then we need much more information. [4]

The quality of the information provided by a sensor system is characterized by the frequency of information, its content and its importance. Frequency of information is a time dimension that refers to the amount of information, timeliness and relevance of the source, relative to a planned unit of time for the gathering of information. The content of the information is a quantitative dimension that refers to the relevance, accuracy, precision, attributes that give it

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[3] From the Latin "informatio", with the sense of communication, news, be aware of a situation, according to DEX, Dictionary of the Romanian Language, Univers Enciclopedic Publishing House, Bucharest, 1998, p. 491

[4] Pătru Pîrjol, Doctoral thesis, „*Arhitectura sistemului de supraveghere a spaţiului aerian naţional pentru sprijinul combaterii ameninţărilor specifice operaţiilor aeriene*”, Ed. UNAp, Bucharest, 2018, subcap. 2.2.1, Theory of Information, p. 68

importance. The importance of information relates both to the form and to the necessity of the information, attributes that allow its presentation, understanding, use or capitalization in a timely manner.

Considering the main dimensions of information, qualitative and quantitative, it is noted that these are not sufficiently highlighted if the information does not manifest its active dimension, which finalizes the role for which the information has been obtained. We mention that information has a shelf life, given its usefulness. The life cycle of information has basically five stages, collecting, transmitting, processing, using and storing. Information thus obtained can become a finished product if it goes through an information process of collection, processing, presentation and storage.

Within a submarine sensor system, the information process comprises an operational system, a computer system and a decision system, content elements specific to an information system. Such a process should enable decision makers to identify possible courses of action in line with the real situation. The operational system provides information processing, monitoring, control and registration. The IT system is an assembly of interconnected elements with the automation tasks of the data collection and processing process. Practically, this information system includes the technical means of processing data and providing information. In essence, the decision-making system is represented by information management by the decision-maker, whereby the decision-maker decides how to act based on the actual information obtained from the information process.

The location and role of a sensor in this information process is paramount, since it is the first element of this system that provides primary information, raw information on the presence of a submarine vector. The information thus obtained passes through an information flow, it is transmitted within the information system to the operational system, it is transformed into processed data about its source and its certainty. It is subsequently taken over by the computer system which after processing provides data on the motion and position elements of the detected vector. Furthermore, a performing system can also provide data on vector classification, identity, and other elements. The information flow ends after a decision by the decision-maker on how to use it in the decision-making process. Practically, this information circuit is the route the information flows from the sensor to the storage and processing environment.

If, within an information system, a sensor is a transmitter, from the point of view of place within a submarine sensor system, it may be a transmitter / receiver and technically it may be active or passive. The location of a sensor within such a system is not independent, because all the sensors form a network of sensors. A network is an assembly of sensors interconnected by means of communication media. The role of the network is to provide the possibility of accurately receiving the signal emitted by a submarine vector and transmitting it to the operational system receivers so as to identify the elements necessary for the processing.

The components of a network are connected in different ways, which can be independent, just to give system stability. Mapping the components of the sensor network is the aspect we want to highlight and in the literature it is called topology, which can be physical and logical. The physical topology refers to the spatial layout of elements of the submarine sensor network. The logic topology refers to how data is transmitted from sensors to component systems. The implementation of today's communications and information technologies contributes actively to the development of a submarine sensor system by integrating a sensor network capable of processing a large number of information to enable a three-dimensional image of the submarine space.

Below we will present the role of a sensor within a three-dimensional subsurface sensors system that responds to the purpose of this article. Theoretically, a sensor is a device capable of sensing and responding to the action of a stimulus, being able, with the aid of some electronic components, to attribute that value to a stimulus following a measurement. A submarine sensor is designed to transform a certain type of energy emitted by a submarine vector into a certain type of energy that represents the primary information. The existence of a diversity in terms of operating principles of underwater sensors, as well as a variety of ways to implement these principles through technical solutions, results in the emergence of a variety of criteria for the classification of

sensors. In principle, a sensor contains a sensitive element that allows data collection. The geographic layout and connection of several sensors creates a three-dimensional network that, together with the processing and interpretation systems, forms a sensory system. In the marine field, the most common type of underwater sensor is the hydrolocator, which can be classified according to the operating principle, hydroacoustic, hydrodynamic, magnetoacoustic, etc.

The layout of the waterworks in a network allows continuous surveillance of the maritime area of interest and the provision of data necessary for the realization of a three-dimensional image of the submarine environment. The principle behind the discovery, identification and localization of vectors is remote sensing. This allows obtaining information about vectors and phenomena remotely. The remote sensing in the submarine environment is based on the principle of propagating waves of different types through the liquid medium. The sensor systems formed from hydrolocators use the principle of passive or active detection as the main method of collecting information based on the signal characteristics of the detected vector. The passive remote sensing consists of receiving signals transmitted in a medium, emitted in various spectra. The active remote sensing consists in the emission and reception of signals that are emitted and received by the same sensor or different sensors within the same system.

We note that, based on simple principles, applicable through theories, namely the information theory, by adapting classical systems to modern technologies, information superiority can be achieved, complementing the recognized maritime image and supporting decision-making on how to respond to the threat to maritime security.

The permanent improvement and advancement of military technologies is a determinant factor that influences the operational possibilities of force genres. The process of adapting to these changes determines the need to find appropriate technical solutions, including by replacing these systems and improving the staff that serves it, generating additional costs. Obtaining maritime space control is dependent on these adaptations to new technologies. From this point of view, Naval Forces are determined to identify those solutions that meet the needs of obtaining, processing and disseminating information that contributes to the realization of the fully recognized maritime image.

We believe that the constituent elements of the maritime power of a littoral state are usually: the naval forces and means of the military fleet, including those of the border police, maritime aviation and marine infantry; merchant fleet; infrastructure and logistics resources, including bases, ports, supply points and warehouses, shipyards, repair shops, airports; consciousness and maritim tradition; maritime educational system.

The main indicators of FNR that contribute to the consolidation of Romania's naval power are: the personnel of the naval, maritime and river forces; the combat and support units; the number and quality of naval platforms; the ship types; the marine aviation in organic; marine infantry; the number and quality of communication and information systems; the observation system; the diversity and quality of infrastructure elements; the resources and other elements. We must not neglect the terrestrial and airborne components of Romania's military power, which can complement the naval power in expedition or force projection operations by maritime operations.

Information is an enhancing factor for achieving the maritime power that the Naval Forces can contribute directly. Practically, The Navy contributes to the management of an information war, permanent concern, in peace times, crisis or war, offering new dimensions to the battlefield. This concern has led to the cybernetics of the battlefield, the emergence of an infrastructure vulnerability that a submarine sensor system is part of.

In this direction, we believe that adaptation to information technology must be achieved through the adoption of methodologies for the management of military actions in the maritime environment that produce effects at the level of specific procedures for the planning, management and deployment of maritime operations. The risk that can arise during an information warfare, when using a submarine sensor system is the capacity offered by the level of information technology owned by an opponent, which through certain threats specific to the marine environment, spying, subversion, surveillance, etc., could counter information supremacy.

Considering the arguments presented, we consider that we have achieved the first two objectives of our approach, so we continue to make some predictions about the trends and

characteristics of the development of a submarine surveillance system that has the primary means of detection, the hydrolocator.

From this perspective, maritime operative art will need to adopt a vision for the Maritime Operational Environment by adapting the missions, organization, planning and deployment of maritime operations. The information actions supported by a submarine sensors system support the conventional actions of surface and submarine forces, providing a tactical advantage in the maritime battlefield.

The necessary information for the deployment of maritime operations can be obtained through different ways and means, but a solution based on a simple principle applicable to the design of a submarine sensor system will add the certainty of the presence of a submarine vector in the area of responsibility of the Navy.

This information can be used at the tactical level to search for, discover, track immediate submarine threats, select and assign targets at the operational level to form the basis informations for analyzing a submarine enemy potential to support decision-making on an optimally course of action. At the strategical level for completing the multilayered image over the area of interest. Eliminating uncertainty about the lack of information about a possible submarine enemy is a gain with effects at all levels of maritime operative art.

Based on our analysis, we believe that the realization of a submarine sensor system will require the identification of technological solutions adapted to the information warfare at which an enemy potential will not have access, discourage it and prevent its use. So the implementation of such a move is a secret objective achieved in a safe and confidential manner. These attributes of such a system will multiply the combat potential of the Navy by increasing the level of maritime space control. Such a system, which responds to the underlined specifications, can be supported by the use of existing complementary systems, naval or aerial platforms, radiohydro-acoustic buoys, and unmanned vehicles.

We could call the sensors used in such a modern system intelligent sensors, due to the amount of data processed, the precision of the products supplied, the speed at which they operate, and other specifications that increase efficiency. The specificity of such a system is mainly to determine the presence of a submarine or underwater vehicle, the determination of position and motion elements, geographic coordinates, depth, speed, road, etc., very important in a process of analysis of a potential enemy in terms of early warning and identifying an optimal response. It will also be able to have other uses for several beneficiaries, such as permanent seabed mapping, identification of underwater anomalies, hydrological predictions, etc. In particular, such a system provides permanent control of the submarine space, being a defender's advantage in the complex battlefield that is the maritime environment.

The future of such a system can address different requirements of the submarine battlefield by using multispectral sensors in the optical spectrum, electromagnetic, radioelectronic or acoustic spectrum.

The surveillance of the submarine environment is at the discretion of a state with maritime interests, since the costs of a sensor system are not exaggerated to the purpose for which it was designed and its maintenance and operation is not an issue that can not be manage by maritime power, any rank[5] would be that.

A submarine surveillance system can be easily integrated into a command and control system, while digitizing information is done at the smallest level of the control chain. A naval, surface or submarine platform is an important vector that can help fill the submarine image with the use of a sensor that can be integrated into such a system. In this situation, we do not refer to an occasional contribution, but we can consider the mobile platform as a complementary means of monitoring the submarine environment that gives the system precision and, at the same time, expanded flexibility in the vicinity of the supervised area.

Essentially, a submarine surveillance system has both advantages and disadvantages that can be identified and monitored during the design stage so that the operation is efficient.

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[5] FN-1, *Doctrina forțelor navale*, București, 2018 (Navy's Doctrine)

Tactical Advantages: Early Warning; increasing military action rhythm, real-time action; secret action, avoiding surprise; surprise the enemy; and so on.

Operational Advantages: extensive submarine space control; permanent oversight; hardly detectable, cannot be jammed; covers a considerable area with minimal operational effort; provides a precise picture of the submarine environment; the operation of the sensor network is not influenced by the failure of a sensor; very good performance; sensors have small dimensions; provides the independent operation of each sensor, but the synergy of the system is the key to its effectiveness; maintenance costs are affordable; multiple uses; intended for more than one beneficiary; is not influenced by weather conditions, seafloor shape or sea currents.

Disadvantages: in active mode you may be discovered; communication nodes with seaside systems are vulnerable; replacing a sensor is a complex operation; incidents may occur in operation; influencing the change in seabed profile and sea water density differences. Even if the disadvantages of such a system are multiple they can be compensated by technical and tactical measures.

The benefits of this sensor system recommend it for use in the maritime surveillance system, with acquisition, maintenance and operation costs being affordable, generating a favorable efficacy report. A notable advantage is presented by the submarine sensor system with anchored hydrolocators stations in a network because such a system ensures the technological advancement of some fleets that can maintain a minimum degree of control of the sea.

The inventor of the hydrolocator was Lewis Nixon, who made a sonar, in fact a 1906 listening device, which he designed to detect the presence of icebergs. Subsequently, it was used for submarine detection. The operating principle was based on the phenomenon of sound propagation in the water and its reflection when encountering a submarine obstacle. However, at present, the hydrolocators are based on other operating principles that increase their range of functions.

In our opinion, a system of submarine sensors will be an important element of the integrated maritime surveillance system with early detection and warning capabilities, increasing the role of a primary source of information from the submarine environment. The complementarity of the system in peacetime will materialize through its use by other beneficiaries, depending on the characteristics with which it has been endowed.

The emergence of new threats to maritime security will lead to the adaptation of the Navy's modalities of action and the identification of new response solutions, so expanding capabilities in the underwater environment is a short-term goal.

From the viewpoint of the place and role of such a system in supporting decision-making during military actions, in times of peace, crisis or war, it is characterized by three dimensions of the action it supports: spacial; temporal and actional. In the spacial dimension, the system covers a considerable area within the technical specifications. In time, the system provides permanent surveillance of the submarine environment. Actional, a submarine sensor system covers the information need during maritime operations, providing a benefit with effects at all levels of military, tactical, operative and strategic actions.

In conclusion, the role of a surveillance system with submarine sensors is given by the advantages it creates, as follows:

- provision of a means of fighting in the information field;
- permanent surveillance of the submarine area;
- timeliness of the system, taking into account that a military action at sea begins and ends with the surveillance of the maritime operations area;
- unitarity through functionality, leadership and exploitation;
- provision of the right information, insofar as it is the only specialized underwater surveillance system that can provide a spatial image.

For this, the density of a sensor network must be designed to meet the purpose for which it was created. We hope that such a system will counteract the versatility of unmanned vectors, provide stability to the seaside surveillance system, reconfigure the existing sensor network, provide time for a timely reaction in the event of an underwater threat. Thus, the development trends of the submarine surveillance system will take into account the range of target sensors, the

development of C4ISR control and control capabilities. Consequently, a surveillance system with submarine sensors is a vector of the maritime power of a state with access to the sea having regional interests. This is, from an operational point of view, a power element, from an action point of view, a security vector. From a structural point of view, it is a component of a system of systems, the product of the military business revolution, a cause of network warfare.

We anticipate a structural adaptation of seafront surveillance systems by implementing such a system of underwater sensors to compensate for the technological leap of fleets using versatile, silent and secret submarine vectors. Structural adaptation must be in line with the evolution of modern military actions. Functional adaptation aims to neutralize system vulnerabilities, technical or tactical. From this point of view, we think that the network can be made in cloth, cord, alignment or circular system. Integration of such a system into a single surveillance site will give the user an edge, and fitting into a command and control architecture will be a considerable leap.

The upward direction of information and communications technology in modern warfare links information and action. In this case, a submarine surveillance system will provide proactive information support from the lowest level, supporting decision-making at higher levels of planning. The development trends of a submarine system must take into account: the possibility of connecting to the existing command and control structure; the possibility of horizontal expansion; the importance of technical parameters; identifying new detection underwater lines; interconnecting all entities with underwater detection capabilities.

Applying the Smart Defence Alliance concept will require the need for an interoperable system with existing systems at the coast of the member countries. The European Pooling and Sharing concept requires interinstitutional and departmental cooperation between EU countries, the integration of such a system at European level will provide stability to the early regional surveillance and early warning system.

In view of the above, we believe that the arguments supporting the opportunity of such a system at the seaside are sufficient, so that we can consider the objectives and purpose of our approach. Consequently, we support the importance of such a system of submarine sensors that contributes to the realization of a complete maritime image that the Naval Forces will be able to access in peacetime along with institutions with maritime interests, and in times of crisis along with the elements of the National Defense System.

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