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CONCEPTUAL MODEL OF PROJECT MANAGEMENT FOR ROBOTIC WATER AREA CLEARING FROM UNDERWATER POTENTIALLY HAZARDOUS OBJECTS

КОНЦЕПТУАЛЬНА МОДЕЛЬ УПРАВЛІННЯ ПРОЕКТАМИ РОБОТИЗОВАНОГО ОЧИЩЕННЯ АКВАТОРІЙ ВІД ПІДВОДНИХ ПОТЕНЦІЙНО НЕБЕЗПЕЧНИХ ОБ'ЄКТІВ

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Abstract. The scientific and applied task of project management for water area clearing from underwater potentially hazardous objects has been formulated. It is proposed to implement the task by the use of marine robotic vehicles. There has been developed a generalized conceptual model of project management for robotic water area clearing based on the common information space of the project. The model has the form of a four-level structure. Each level is realized by the appropriate marine robotic vehicles and connected with other levels through the information exchange system.
Keywords: project management; conceptual model; marine robotics; underwater potentially hazardous object

Анотація. Сформульовано науково-прикладне завдання управління проектами очищення акваторій від підводних потенційно небезпечних об'єктів. Реалізацію завдання пропонується виконувати шляхом застосування засобів морської робототехніки. Розроблено узагальнену концептуальну модель управління проектами роботизованого очищення акваторій на основі єдиного інформаційного простору проекту. Модель створена як чотирьохрівнева структура. Кожний рівень реалізується відповідними засобами морської робототехніки і пов'язаний з іншими за допомогою системи інформаційного обміну.
Ключові слова: управління проектом; концептуальна модель; морська робототехніка; підводний потенційно небезпечний об'єкт.

Аннотация. Сформулирована научно-прикладная задача управления проектами очищения акваторий от подводных потенциально опасных объектов. Реализацию задачи предлагается выполнять путем применения средств морской робототехники. Разработана обобщенная концептуальная модель управления проектами роботизированного очищения акваторий на основе единого информационного пространства проекта. Модель создана как четырёхуровневая структура. Каждый уровень реализуется соответствующими средствами морской робототехники и связан с другими с помощью системы информационного обмена.
Ключевые слова: управление проектом, концептуальная модель, морская робототехника, подводный потенциально опасный предмет.

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Problem statement. At present, water area clearing from explosive objects (mines, shells, missiles and air bombs) is an urgent problem that needs to be solved for many countries of the world. Thus, 78 countries and 8 particular regions have issues related to unexploded mines and artillery shells [1–3]. Moreover, 58 countries and 7 regions record deaths of civilians caused by these issues [3].

In the world practice, conducting operations for the inspection and clearing of land and water areas from explosive objects (humanitarian demining) is one of the top priorities of government action [4–8].

Underwater potentially hazardous objects (UPHO) are explosive items and ammunition from past wars. They threaten the life and health of coastal dwellers and tourists, pose a danger to the marine environment, and complicate the social and economic development of coastal areas, including that related to water transport and tourism [9].

The problem of water area clearing from UPHOs is relevant to Ukraine as well, since it was in the thick of events during the deadliest wars in human history, World War I and II. Ukrainian mine clearance services are removing explosive objects on a daily basis, while random discoveries result in casualties [10].

According to Ukrainian scholars, 1150 ships lie sunken at the bottom of the Black Sea, most of them being located on the continental shelf of the coastal zone [10, 11]. The estimated total weight of ammunition in all the sunken boats and ships exceeds 20 000 tons.

Approximately 100 000 tons of liquid fuel remains in the tanks, compartments and air cushions on most sunken ships, so there is a real danger of fuel leakage due to metal corrosion.

Chemical waste landfills have been formed over a long period of time, chiefly resulting from the activities of the USSR's Black Sea Fleet on the coastal shelf. Mainly associated with the Chersonesus dump, there are 49 containers of chemical waste in the water area adjoining the village of Chornomorsk, 11 containers in the Kerch Strait, 1 container in the Feodosia Gulf, 66 containers near the coast of Alupka, 60 containers near Yalta and the The Swallow's Nest castle, 70 containers near Alushta, 80 containers near Balaklava, and 65 containers around the Cape Lucullus [11].

At the present time, requirements are being put forward for increased productivity and quality of underwater works on water area clearing from remaining weapons and military equipment, for timely detection of new threats occurring within water areas and posing a danger to human life and ship navigation. On top of that, there are certain requirements for reduction of risks to the lives

of the people who are directly involved in emergency response within water areas.

It is apparent that the primary approach for improvement of productivity and safety of the operations dealing with water area protection from emergencies is robot automation of underwater engineering activities and, consequently, modernization of the organizational structure of project management for water area clearing from UPHOs. This approach can be implemented on the basis of proactive management and is a project by definition, as it is characterized with uniqueness (organizational and technical modernization of the operational activities of the State Emergency Service of Ukraine) and effectiveness (increasing productivity and quality of the works).

Latest research and publications analysis. Formation and implementation of the projects and programs on water area clearing from UPHOs are currently governed by a number of legislative and subordinate acts of Ukraine, as well as internationally recognized documents regulating humanitarian demining of land and water areas [2–6, 9, 12–15].

According to these documents, declaration of safety of UPHOs in the inland waters and the territorial sea of the state is mandatory for all owners of these underwater objects. It can be conducted in the form of individual projects in order to provide control over safety measures, assessment of sufficiency and efficiency of the measures on emergency prevention and response in the area of location of the underwater objects.

Execution of the specified set of works calls for creation of a common UPHO data collection in order to identify the main processes of the projects to be implemented. The core data usually include [4–6]:

a) information about the UPHO, its location and ownership at the time of sinking and at the time of drafting the declaration;

b) information on the quantity, type and basic properties of the hazardous substance contained in the UPHO;

c) basic (related to the purposes of declaration) geographic, hydrometeorological, geological, hydrological and ecological characteristics of the location of the UPHO;

d) information on the measures taken for safety provision at the object's sinking, or an indication of the absence of such information;

e) information on the measures (works) taken for emergency prevention having been or being executed on the site after the object's sinking, or an indication of the absence of such information;

f) assessment of the risk of emergencies arising from the state of the UPHO, including analysis of possible causes, circumstances, and consequences;

g) a procedure for warning the population living in the adjoining territory (in the coastal area) and the personnel performing technological works on the underwater object, as well as informing relevant central and local authorities about the threat of occurrence of emergencies arising from the state of the UPHO;

h) a list and a brief description of the measures to be taken to reduce the level of the risk of emergencies arising from the state of the UPHO;

i) a list and a brief description of measures taken to protect the population and territories that need to be conducted in case of an immediate threat or emergency arising from the state of the UPHO;

j) information on the reserves of material and financial resources necessary for the elimination of emergencies arising from the state of the UPHO.

The target program for the protection of the population and territories from man-made and natural emergencies for 2013–2017 provided for implementation of urgent measures taken to protect the population and territories from emergencies in the following areas:

1) engineering protection of land and water areas from emergencies;

2) emergency prevention and recovery on the facilities, land and water areas characterized with an unsatisfactory technogenic and ecological condition;

3) land and water area clearing from explosive objects;

4) rehabilitation of land and water areas contaminated due to military activity;

5) hydrometeorological support of the works;

6) material and technical re-equipment of government bodies and civil defense forces;

7) increasing the efficiency of operational and integrated emergency response.

Along with the available technology of UPHO mapping, identification and disposal, understanding the operational environment is an important prerequisite for developing a safe, efficient and cost-effective project or program.

As shown by the analysis of issues related to management of the projects on water area clearing from UPHOs, including those implementing marine robotic vehicles (MRV), the processes of management of such projects are usually accompanied with systemic conflicts: the lack of comprehensive approaches to robot automation of this type of activity at sea, the lack of a common information space of these projects, and so on. These circumstances highlight the need to develop a conceptual model for the management of project s on robotic water area clearing from UPHOs as the basis for their further structuring and implementation.

THE ARTICLE AIM is to develop a generalized conceptual model for project management of robotic water area clearing from underwater potentially hazardous objects on the basis of a common information space of the project.

Basic material. In general, water area clearing from UPHOs suggests implementation of appropriate projects and programs, which result in the water areas that were contaminated with UPHOs becoming free of them, that is, cleared and ready for dedication to public for use as intended.

Since the specific features of humanitarian demining of water areas presently require engaging up-to-date MRVs, an integral part of the processes in management of such projects is accounting for the state-of-the-art capabilities of MRVs and including them to the processes of project planning and implementation (Fig. 1).

Currently, most project teams actively apply the accumulated experience in the design and implementation of relevant projects and programs, which allows enhancing their efficiency.

Thereat, one of the main conditions to be taken into account when managing projects on water area clearing from UPHOs is the principle of all the project participants being informed and instructed from A to Z.

With consideration to these circumstances, there has been developed a generalized conceptual model of project and program management for water area clearing from UPHOs (Fig. 2). It based on the scientific hypothesis that such projects and programs can be effectively managed with the help of the newly developed and updated methods and models of proactive management, which serves as a framework for establishing a common information space of the project.

Implementation of the proposed model is provided by the relations and interconnections between project management processes and the knowledge base, data-

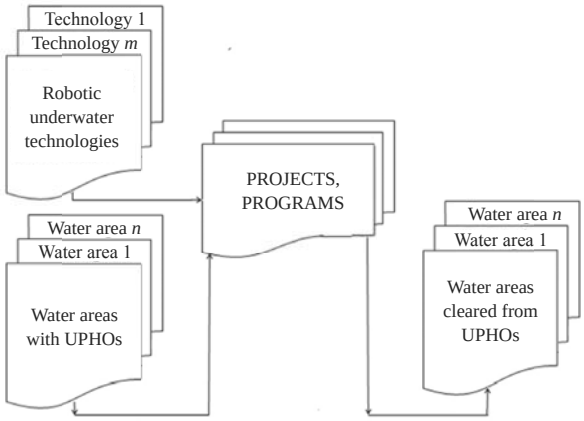

Fig. 1. Generalized framework of the water area clearing from UPHOs

base, and common information space. Formation and operation of the common information space for the projects on water area clearing from UPHOs should be provided with the following:

– a set of standardized data exchange technologies;

– maintenance and use of databases and data banks;

– development of a data security system;

– a set of information and telecommunication systems and networks that operate on the basis of common principles, rules and standards, providing information exchange between organizations and satisfying their information needs [16].

The processes of management of water area clearing from UPHOs from the state of "Contaminated waters" to the state of "Waters cleared from UPHOs" are based on available data on the current state of the water areas and on the knowledge system concerning robotic projects. The latter are basically a collection of ordered knowledge presented in the form of proactive management models and artefact project decisions.

The decision to initiate a project is made by the decision maker (DM) and is driven by monitoring of the UPHO's current state and possible threats, as well as in-

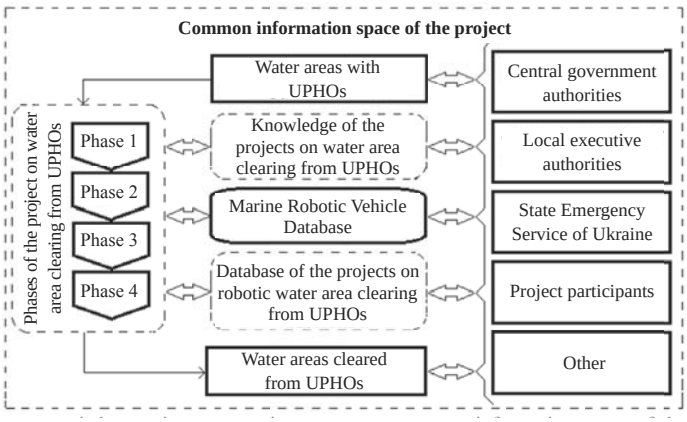

Fig. 2. Generalized conceptual model of project management for water area clearing from UPHOs based on the common information space of the project

formation on the MRVs which are available in "Marine Robotic Vehicle Database" and may be utilized in a particular project (Fig. 2).

Proceeding from the challenges that the State Emergency Service of Ukraine is facing today, it is expedient to create such a database including the following types of MRV:

– self-propelled autonomous underwater vehicles (AUVs) aimed at inspection and search in marine areas, monitoring of the underwater situation in water areas with UPHOs;

– bottom underwater vehicles (BUVs) intended for long-term observation of UPHOs and monitoring of the underwater situation in in water areas with UPHOs;

– non-self-propelled tethered underwater vehicles (NUVs) used for water and soil sampling near UPHOs, spot video inspection of the sea bottom surface and UPHOs;

– towed underwater vehicles and systems (TUVs) aimed at high-performance inspection of the sea bottom surface and water column within large water areas, at creation of digital maps of the sea bottom surface and the UPHOs detected there;

– self-propelled tethered underwater vehicles, or remotely operated vehicles (ROVs) performing search, inspection and technical works near UPHOs;

– small-scale surface vessels (SSVs) intended for operational monitoring of the marine situation near UPHOs, control of access to protected water areas, coverage of surface and underwater situations and their digital mapping;

– unmanned aerial vehicles (UAVs) aimed at covering the surface situation where water area clearing from UPHOs is to be performed.

The results of management and implementation of the project tasks comprise the water area cleared from UPHOs and the artefact project added to the database of water area clearing projects (Fig. 2).

Requirements for comprehensive problem-solving in project management for water area clearing from UPHOs necessitate the creation of a conceptual model based on a common information space. It allows abiding by the following basic principles of project and program development:

accessibility of information;

compliance with the state policy in project management for water area clearing from UPHOs;

unity of technical, technological, economic, information and organizational policies of projects and programs.

The primary principle for building a common information space is the network-centric approach. It is widely applied in the practice of operational management of complex military and civilian systems in the world's leading maritime countries. The main advantage of this approach is the possibility of maximally reducing the time intended for the main operations of operational management, namely, collection, pre-processing and transmission of information to the control center.

Fig. 3. Simplified scheme of the four-level structure of robotic water area clearing from UPHOs

The information component of such a structure is included to the common information space of project management for water area clearing from UPHOs. Its each level is associated with other levels through the information exchange system. Here are the levels of the model under consideration.

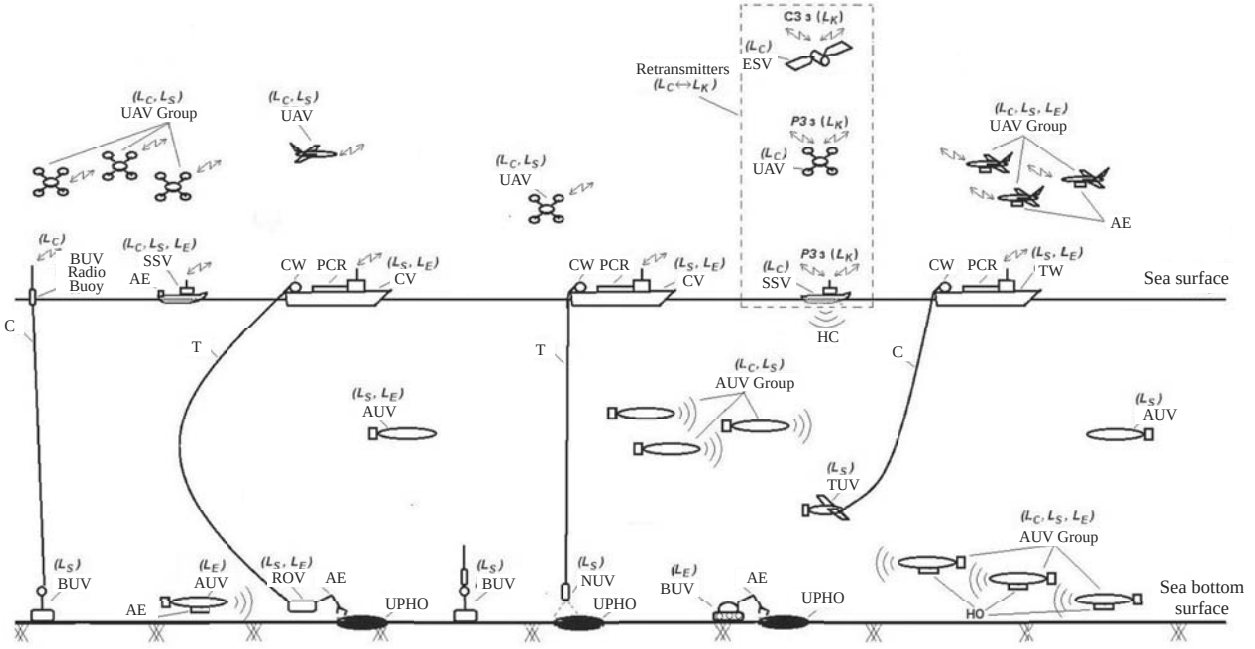

Fig. 3. Simplified scheme of the four-level structure of robotic water area clearing from UPHOs

The executive level L_E comprises bottom, underwater, surface and aerial robot vehicles with their payload being underwater tooling and technological devices relevant for a particular MRV's purpose. They have the capability to perform specific underwater operations (involving underwater manipulators, metal cutters, ground cleaners, etc.). The ROV, TUV and NUV carrier vessels also belong in this category.

The sensory level L_S consists of bottom, underwater, surface and aerial robot vehicles serving as search and measurement instrumentation carriers;

The communicative level L_C contains underwater and surface equipment for satellite, radio, and hydroacoustic communication of the system's components (SC, RC, and HC, respectively). The cognitive level of L_K is realized at the control center for the maritime operation on robotic water area clearing from UPHOs through processing of the data coming from the MRV.

Managerial decisions are adopted by the human operator (single or a group of people) independently or based on the recommendations of expert systems, automated decision support systems, and so on (not considered in this publication).

The proposed model of project management complies with the concept of conceptuality according to the following attributes: consistency of objectives, openness, implementability, comprehensiveness of the approach, etc.

CONCLUSIONS. 1. Water area clearing from underwater potentially hazardous objects with the use of marine robotic vehicles through the formation and implementation of appropriate projects is a scientific and applied problem of national importance. One of the ways to tackle it is to develop the foundations of a common information space for such projects.

2. There is proposed a conceptual model of project management for robotic water areas clearing from UPHOs on the basis of the common information space of the project. The model is essentially a four-level structure consisting of the executive, sensory, communicative and cognitive levels. Each level of the conceptual model is realized with appropriate marine robotic vehicles and connected with others through the information exchange system.

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