Development of underwater robotics

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Abstract. In the scientific surroundings, the statements that Oceanographic researches are, in many aspects, more complex and challenging, even compared to space research are not rare. Now, in the middle of the second decade of the XXI century, there is no doubt that the study of the oceans has become an issue of global importance, covering economic, industrial, social, defense and many other activities and interests of the society in the modern world. We are seeing the necessity of expanding the boundaries of Oceanographic research, increasing the number of types and growth of quality of measurements in the water column as well as their systematization, increasing of the depths of research, which is caused by the growing necessity of sea bottom studies, etc.

1. Introduction

Most projects of similar research are applied and become known mainly due to their commercial implementation. Undoubtedly, in the modern realities, it is more and more difficult to conduct scientific research regardless of the urgent production problems. Thus, cooperation of commercial structures, research institutions, military departments, etc. is required for the successful implementation of most projects. Certainly, the results of such projects can be effectively used by all the organizations listed above. For example, almost any innovation in the surveillance and search, under-ice and other studies in one form or another can be used for strategic or tactical military purposes.

In the present article the authors give an overview of the historical development of underwater technical vehicles and dwell on the modern representatives of this class of vehicles – Autonomous (Unmanned) Underwater Vehicles (AUV). The authors touch upon the structure of this class of vehicles, problems to be decided, and perspective directions of their development, cover scientific materials basing mainly on the data about the benefits of the application of the vehicles in a number of tasks of narrow focus.

2. Materials and methods

"Scat" was the first AUV of its kind, developed in the USSR. It made it possible to conduct research at depths of up to 300 m. The first development of the domestic AUV allowed getting experience that became the basis for subsequent developments, which included the first AUV for deep-water studies like "L-1" (working depth up to 2000 meters) and "L-2" (working depth up to 6000 meters). It should be noted that the working depth of diving up to 6000 meters is sufficient to reach the 98% of the bottom of the world ocean of the Earth. These devices were the first modular AUV that allowed people to work at such significant depths.
In 1982, AUV “L-2” (Fig.1) performed inspection work in the area of the death of the nuclear submarine "K-8", which was at a depth of about 5,000 meters. During that work, more than 80 dives were made and tens of thousands of panoramic images of the surveyed area were taken.

![Figure 1. AUV «L-2». Work in the North Atlantic, in the area of the death of NSM «K-8». 1982. [4]](image)

In five years, with the same apparatus, search and inspection were carried out in the place of the crash of the submarine "K-219" near the Bermuda islands. Then, using the "L-2", rescuers managed to not only find the scene of the accident, but also collect more than forty thousand photographs. And then, in two years, the apparatus participated in the examination of the sunken submarine Komsomolets in the Norwegian sea.

It should be noted that this AUV was provided with mixed management: the targeting was carried out in the manual mode through the transmission of control commands to AUV from the ship of technical support via the hydro-acoustic communication channel; being targeted at the object of study, AUV switched to autonomous work and executed the given program. In doing so, AUV was able to bend around obstacles through the front sonar system rangefinders.

Overall, for the whole world, the 70-s of the last century from the point of view of the evolution of AUV were the time of experimentation with technology in the search for the potential applications of AUV. It was the time of significant success and serious setbacks, and a significant qualitative leap in the development of AUV.

Practical and design experience obtained during the development of these devices has allowed a further increase of the autonomy of AUV. Work was done on implementation of AUV to conduct bathymetric shooting, gravimetric measurements, studies of currents in the ocean, as well as works under the ice.

Another significant advantage of these devices was their modular design, which allowed unifying the system of AUV, making them multi-purpose and managing without re-equipment of technical support vessels to work with them. More fully the advantages of a modular AUV were implemented in such developments as the MT-88 (Fig.2), the test of which took place in the Pacific ocean in 1989.

This AUV was designed for Oceanographic research and geological exploration of the seabed. Tests were combined with pilot-production work on the detailed examination of individual sections of the seabed in the area of rift of the Clarion-Clipperton with deposits of ferromanganese nodules. On the plot with different geomorphological structures and the differences of depths from 4200 to 4600 meters, using the AUV, researchers conducted a hydro-acoustic, video and photo profile of the bottom, worked out methods of work [1-4].

The Naval center of ocean systems, the U.S. (SPAWAR), began development of AUSS (Advanced Unmanned Search System) in 1973. The first test of completed AUSS took place in 1983 and the system operated until 2000. This AUV has a silver-zinc battery at 20 kilowatt/hour, which allowed it to have an autonomous range of up to 10 hours. The unit is used for searching for different objects in the depths of the oceans. Initially, it was used to search for sunken bombs, mines, and submarines.
AUSS (Fig.3) does not use cable, but has a remote control and information exchange on the time scale close to real. An onboard acoustic system transmits compressed data at a speed of 4800 bit/s and takes commands at the speed of 1200 bit/s. AUSS performed the maneuver autonomously. The operator merely pointed out the direction and the purpose of the search. Then, AUSS itself continued to do necessary actions to fulfill the tasks of AUV. For search operations, AUV used two sonars, and a camera installed on board allowed the operator to identify the object definitively. Navigation was carried out with Doppler sonar and the gyrocompass. In addition, the technical support vehicle clarified the absolute position of AUSS through the channel of hydro-acoustic communication. Refinement was performed according to the indications of the GPS receiver installed on the ship.

AUSS is up to 6 m long. Its descent depth is 7000 m, and its reverse ascent takes one hour.

A standard set of research equipment.

AUV of that time already included hydro-physical sensors, a side-scan sonar, video system and a camera.

In 1990-2000, on the basis of the development mentioned above, the developers were able to move ahead from singular samples, which were made rather to confirm one or another concept, to the first generation of operational systems able to achieve definite goals. The range of potential users of the developed devices and the list of targets started to clarify. That decade is characterized by the implementation of a number of international projects and consolidation of developers from different
In the 90-s of the last century, our country participated in a number of successful international projects too. The most important developments of that period are AUV "CR-01" (Fig.4), "CR-02" and "OKPO-6000".

![AUV CR-01](image)

**Figure 4. AUV «CR-01» [4]**

In 1991, the Treaty on construction of AUV "CR-01" was signed between the Far East branch of the Russian Academy of Sciences and Shenyang Institute of Automation of the Chinese Academy of Sciences (SHIA KAHN). The tasks of the unit included Oceanographic studies of the mineral reserves at depths up to 6000 meters, therefore, the set of onboard equipment of the apparatus included an acoustic Profiler. Profiler allows researchers to scan the layers of bottom sediments to a depth of 50 m and to determine the structure of sedimentary rocks [4]. As a result of the project, Russian constructors made the system of "CR-02", the structure of which repeated "CR-01", in collaboration with SHIA KAHN.

The first test of AUV "OKRO 6000", developed in collaboration with DAEWOO Corporation of the Republic of Korea, took place in 1996. "OKRO 6000" was also designed for diving at depths down to 6,000 meters and was intended for Oceanographic research. Further testing at greater depths conducted in the late 90-s showed the possibility of using AUV for geological exploration [4].

Project AOSN (Autonomous Oceanographic Sampling) has much in common with the concept of DSSN. It involves the creation of a network of fast, small and cheap devices of information collection, capable of carrying out various payloads, and allows one to choose the sensors that best suit the specific objectives of the mission [6]. In the framework of AOSN, researchers developed an inexpensive device "Odyssey", which is 2 meters long and is able to operate up to 20 hours autonomously regardless of the temperature conditions, bottom topography and underwater currents. The processor "Motorola 68030" was used in the "Odyssey" on-Board system.

Another important feature of the decade of the 90s is the transition of AUV projects to commercialization. Since 2000, the segment of commercial use of AUV has appeared and begun to grow in the world market. It was in the first decade of the XXI century when the first commercial products appeared in the market of AUV. AUV technologies proved to be useful for commercial purposes. There were commercial programs based on the use of AUV. Thus, in the early twenty-first century, technologies of AUV began to move from a purely academic and research sphere into the commercial mainstream of the ocean industry.

Modern technologies of AUV. The latest developments of AUV in our country can present a small apparatus "MT-2012" (Fig.5) and so-called solar AUV or SAUV [9], designed by the Far East branch of the Russian Academy of Sciences.
We can also mention the device "Bluefin-21" worked out by the company "Bluefin Robotics" and used to search the crash site of the plane "MH370" of Malaysian airlines.

The peculiarities of modern AUV are as follows: the lack of functional dependence on the support vessel, high speed of searching, large coverage, a wide range of depths of immersion, accuracy of the target coordinate determination, accuracy of holding its own place in the area of deployment, underwater autonomy of the vehicle, stealth capability (physical fields), universality for performing a wide range of tasks, gathering data in close proximity to the object.

3. Conclusion
There are already 17 developed oil and gas fields in the Black sea basin [10, 11]. The researchers have planned the study of its shelf area. We expect new discoveries beyond the shelf zone, where 50 places of potential oil and gas extraction have already been found. As it has been noted above, the AUVs of monitoring of wells and maintenance of drilling platforms are highly demanded in these fields.

It is important to track the state of the pipelines and telecommunication lines that stretch at the bottom of the Black sea. So, specialized AUVs which are able not only to detect the inspected object and move along it, but to find the problem areas and prevent accidents, are necessary for these purposes.

AUV can be effectively used to protect the naval bases of the Russian Federation in the Crimea. They can be used to search for mines, including those remaining after the Great Patriotic war.

First of all, it is necessary to create scientific-technical basis, perhaps in cooperation with nearby research-and-production associations, located in the Krasnodar region, while in the Crimea the production base for AUV has not recreated yet. The production potential can be created on the basis of shipyard and ship repair yard.

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