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POLISH EXPERIENCE IN DEVELOPING AND EMPLOYING UNMANNED SURFACE VEHICLES AT SEA

ABSTRACT

This article is based on an analysis of missions carried out by unmanned surface vehicles (USVs). It discusses measures taken in Poland to develop such vehicles, designed to provide support to operations conducted by the country's maritime services, security and monitoring of seaports and critical objects. It summarizes the results of research and development efforts and presents a new approach to employing these vehicles throughout the world.

Key words:
unmanned surface vehicles, swarm of unmanned vehicles.

INTRODUCTION

A threat to ships in anchorages, roadsteads, water lanes and ports seaward, the necessity to protect and monitor seaports and critical objects resulting from the increased threat level of terrorist attacks in littoral waters have resulted in R&D projects focused on protection systems for seaports and ships in anchorages. They have been carried out by the naval forces of many countries, including Poland, for several years. One of the forms of such protection is the continual patrolling of littoral waters — on water lanes and approaches to ports, naval bases, and roadsteads. Uninterrupted patrolling requires the use of many patrol vessels. Employing exclusively manned patrol vessels is associated with certain limitations: length of time

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for patrolling, monotony concerned with the task being carried out and human factor resistance to high seas. Unmanned surface vehicles (USV) appear to be more useful in these situations. The operating range of a USV is, however, limited by the radio horizon. They can be controlled (by radio) from helicopters and manned or unmanned aircraft (the latter can perform the functions of retranslators). The lead producers of USVs are Israeli companies (protector type vehicles, and its derivatives) and American companies (program 'Spartan Scout', initiated to develop a whole family of multi-purpose USVs, among others, for Littoral Combat Ships (LCS) operating in littoral waters. The US Navy has long used USVs — in the Sea OWL version designed for the IHP-class frigate, e.g. USS Nicholas, and patrol versions.

EMPLOYMENT OF USVs IN SUPPORT OF NATIONAL SECURITY [4]

At present USVs encompass a wide spectrum of technological solutions and capabilities to carry out a variety of often highly specialized, missions. Of the various concepts developed by Navies, the most common are remotely controlled constructions installed on board rigid inflatable boats (RIB). Most often, the dimensions of hulls of the present-day USVs range from 3 to 11m in length. The present-day technologies used to build engines and power supply systems allow the vessels to reach speeds of up to 50 knots in a relatively compact drive unit. High speed USVs can be used in patrol, offensive operations, and operations carried out to counter asymmetric threats.

Universality and functionality of USVs with regard to their missions are derived from their modular construction (when receiving the full support of a software platform used to integrate all types of warheads and selected weapons systems) [10].

Depending on the size of a USV, hull type, equipment and installed functional modules, the unmanned missions, typical of operations in support of national security and the Navy can be defined as follows:

- Mine Countermeasures (MCM)
  Unmanned maritime vehicles, both USVs and UUVs (unmanned underwater vehicle) play a very important role in MCM operations as, to a large extent they eliminate, the threat to human life and health. In addition, they offer high effectiveness with regard to detecting and removing mines from water regions at relatively low financial costs. An important factor is, that they can provide MCM support to platforms which are not dedicated to or appropriately fitted to detect and combat

such threats. One of the main missions of an unmanned platform employed in MCM is to detect, identify, localize, classify and neutralize the mine threat.

- Anti-Submarine Warfare (ASW)
  The employment of a USV, located outside the deck-placed platform of external sensors, which are the source of information on underwater objects, contributes to an increase in the range of detection and actions against adversary ASW operations, without increasing the risk for loss of human life or health. An appropriately designed command and remote control center of a 'swarm' of USVs on board the so called 'mother' ship can deliver crucial data regarding enemy ASW operations, which in turn can be used to work out optimum decisions for friendly forces operations. At the present stage research and development projects are carried out to solve the problems relating to command, control and mutual communications of USVs within a 'swarm', to improve algorithms for automatic detection of underwater targets, their classification, localization and tracking.
- Anti-Surface Warfare (ASuW)
  The employment of a USV in combat against surface ships coincides, in many aspects, with USV operations carried out in support of MCM. The main element differentiating ASuW operations from the others is the significantly higher exposure of the unmanned platform to direct engagement by enemy fire assets. In addition, in operations against surface ships the USV is required to feature larger dimensions and be capable of making high speed, ranging from 35 to 50 knots. In the conduct of ASuW operations unmanned surface platforms can proceed to operational areas both from onshore bases and on-board platforms afloat. After reaching the deployment area, they commence analyzing the situation and threats. Depending on the type of mission and operational situation UAVs carrying weapons systems can engage selected targets in the automatic, semi-automatic or manual (mission operator) mode. At the present stage, with regard to ASuW operations, research and development efforts are being made to enhance the autonomy of USVs.
- Support for Special Forces Operations
  Within the support rendered to special forces operations USVs can carry out clandestine reconnaissance and logistic missions, and assault missions employing on-board weapons (e.g. combat against asymmetric threats). In addition, they can be employed to jam communications system of the potential adversary and feign friendly forces operations.

- Electronic Warfare — intelligence, observation, reconnaissance and jamming missions
  USVs are perfect platforms to carry out EW operations. They can constitute a subsystem capable of operating in littoral regions, mainland waters and open seas characterized by a high risk factor with regard to missions conducted by human beings. The small dimensions of the platform fitted with passive sensors, having electromagnetic emissions (EM) maximally reduced, and remote a control system can additionally ensure that an operation is carried out in a stealthy manner. In addition, USVs fitted with active interference systems using high intensity EM wave can be employed to protect key floating platforms stationed in ports and to protect important port objects and facilities against asymmetric threats. An organized swarm of remotely guided and controlled USVs together with strictly defined areas/objects of responsibility can constitute an electronic 'umbrella' activated the moment the threat posed by improvised explosive devices has been detected, including the use of fast motor boats filled with explosives, whose explosion/detonation is activated by radio. Similar missions can be conducted during a transit of important (valuable) platform across the sea.

The USV missions can also include:
- interception of vessels;
- target designation/laser illuminating (laser designators);
- extension of optic and electromagnetic field of view;
- operating in contaminated areas, including detection, identification and localization of chemical, biological, nuclear and radiation threats;
- providing support to measurements in the marine environment and off-shore zone (operational oceanography, hydrography);
- measures in support of the generally defined maritime security, including coastal patrolling, oil rig protection, ship protection (counter-piracy missions), port protection and strategic objects, merchant vessel traffic control in open and congested areas;
- jamming and covert operations;
- measures in support of national interests within the exclusive economic zone (EEZ0).

Other applications of USVs can include fitting a USV with a sound propagation module (megaphone), missions carried out to warn vessels about various hazards or the possibility of occurrence of hazardous situations (contamination, natural disasters, etc.). During patrol missions the megaphone placed on board a USV can be used

to give orders and instructions to vessel crews at sea concerned with their further actions (when the signal cannot be transmitted by radio or if the content of the message cannot be disclosed when using unencrypted communications).

Following the analysis of the tactical-technical particulars, payload options and advantages of the USVs, in which the latest and technologically most advanced subsystems, meeting the standards of the contemporary battlefield, a claim can be made that these vehicles can carry out missions during the operations as follows:

- intelligence, reconnaissance and monitoring the surface, underwater, and ashore situations, including, among others, classification and identification of surface, underwater and ashore objects;
- collecting hydro-meteorological data (collecting meteorological and hydrographic data is an important element in planning operations at both the tactical and operational levels);
- information support special operations;
- capabilty to be integrated in each C4I network;
- electronic warfare, including jamming and generating false targets;
- warning of possible electronic attack;
- surveillance of littoral regions, ports, sea bases and beaches;
- damage estimation;
- placing sensors in littoral regions;
- protection and defense of groups of ships in transit across the sea (employing USVs to generate false targets around groups of ships in transit across the sea, both in, congested regions and in the open sea).

THE STATE OF ADVANCES IN USV TECHNOLOGIES IN POLAND

Toward the end of the first decade of the 21st century a decision was made at the Polish Naval Academy, based on the considerations mentioned above, to begin work aimed at developing the first Polish unmanned surface vessel designed to support the national maritime services, protect and monitor sea ports and critical objects.

In 2009, a questionnaire-based survey (attended by personnel of the Polish Naval Command and Flotillas Commands, ship commanding officers, and naval specialists) was carried out. The purpose of the survey was to determine the missions which the future vehicle would carry out, its technical particulars and payload. As a result, a Harbor-class vehicle was selected. Harbor-class vehicles (3–7 m in length) are designed to counter terrorists threats, carry out EW, ASuW, special operations

forces (SOF) support, maritime interdiction operations (MIO) support, and MCM. This class of vehicles can be armed with conventional or non-lethal weapons. They can make up to 35 knots, and their endurance is up to 12 hrs.

The list of potential recipients of the vessels to be produced together with missions to be carried out included [4]:

- Polish Navy — surface autonomous platform designed to MCM reconnaissance and neutralization, protection of ports and sea bases, off-shore rigs, etc.;
- Coast Guard — support element in the coast monitoring and protection system, ships entering port control, terrorist countermeasures, search for dangerous underwater objects or smuggled objects, etc.;
- Police — terrorist countermeasures, law and order enforcement with regard to general use waters;
- Maritime Authorities — SAR, navigational marking, hazards to the marine natural environment;
- other government bodies held responsible for patrolling rivers, lakes, water;
- reservoirs, etc.

Between 2010 and 2012 within the framework of two R&D projects:

1) 'Unmanned, multi-variant afloat platform designed to support national services operations': project No. O R00 0004 07, leader — AMW, consortium members — PG, 'Sportis Company';
2) 'Integrated system for planning perimetric defense and monitoring of sea ports and critical objects based on the use of unmanned floating vehicles': project No. O R00 0106 12, leader — PJWSTK, consortium members — AMW, 'Sprint Company'

a technology demonstrator for two versions of an unmanned surface vehicle was built. The first version encompassed a 'technology demonstration' of a vehicle controlled by radio (fig. 1), from an operator in a mobile container command post (fig. 3). The second version, based on the vehicle built under the former project, was additionally fitted with a mission planning system (planned task) and mission execution by the control system of the autonomous vehicle (operating the software without operator's participation). For all the recipients the same hull, communications system, and navigation and control systems were adopted (fig. 2). Depending on the missions carried out, the vehicle was to be fitted with different kinds of modules, e.g. weapons systems, surface and underwater surveillance, environment parameters measurement, underwater vehicle, etc. together the control systems of these modules. The capability to change fast from the unmanned version to the manned version and vice versa was also included.

Fig. 1. Unmanned surface vessel 'Edredon' carrying out its missions at sea [4]

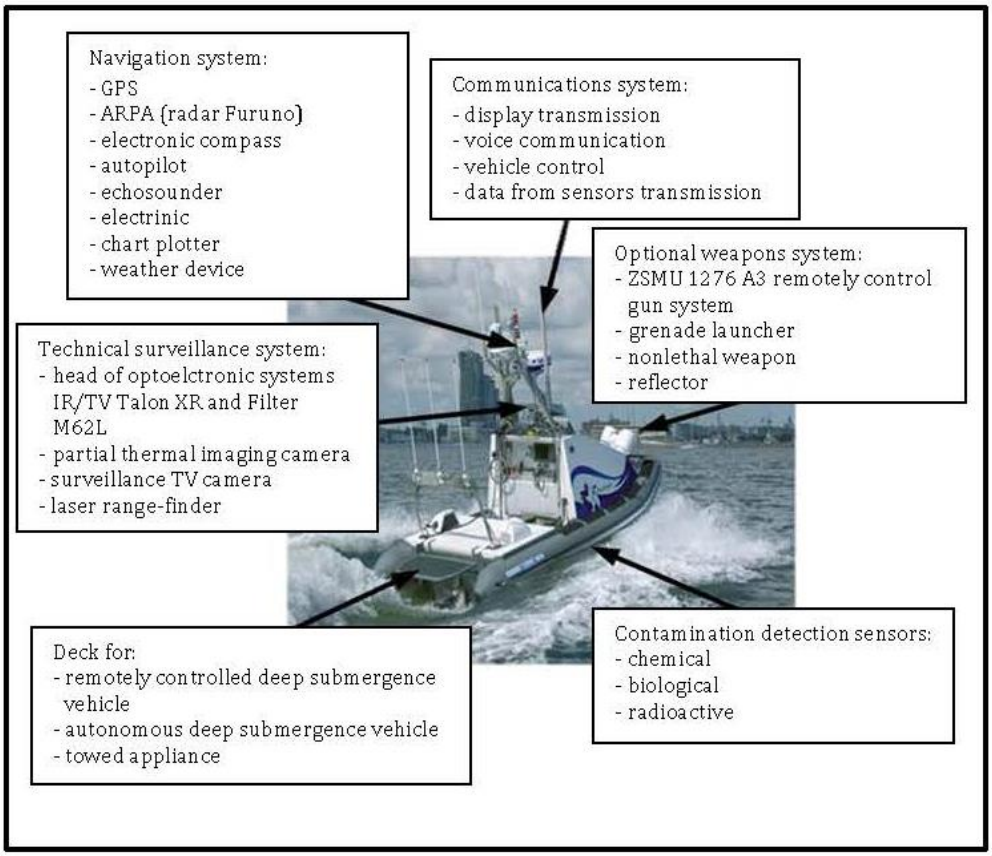

Fig. 2. Sensors of unmanned surface vehicle 'Edredon' [6]

Fig. 3. USV 'Edredon' container-based command post [4]

It must be emphasized that the solutions implemented in the 'technology demonstrator' type of unmanned surface vehicle, built in Poland for the first time, did not solve all the problems associated with building such vehicles. The prototype built was the first step leading from an idea to practical implementation. The experience earned in the course of executing the projects constitutes a perfect base for further advances in the constructing of such vehicles. The results of the research carried out under the project can be implemented during further work connected with e.g. effects by commercialization of both projects or during the conduct of further research. However, attention should be paid to the fact that these demonstrators were built for the first time in Poland and hitherto no other research team has taken steps to build this kind of vehicles. The purposes of the projects carried out between 2010 and 2012 were to specify the designations of the vehicle, select and verify its technical parameters under marine conditions, and variants of its payload. The research carried out under the two projects includes elements which had been neither considered nor verified in Polish conditions [4, 5].

Based on the experience earned in the course of designing USVs and ASVs in 2010–2012 further research and development work focused on building a multipurpose vehicle of this kind is necessary. Following worldwide trends, a new unmanned vehicle should be an example of interpenetration of the individual USV classes specified in *The Navy Unmanned Surface Vehicle (USV) Master Plan* [12]. On the one hand a USV should effectively carry out port patrol missions, inspect port

infrastructure, gas pipelines and piers, etc. On the other hand, armed and fitted with appropriate sensor systems, ensuring inflow of data on the surface and underwater situation the USV should be an important element in preventing incidents outside the port borders (roadstead, anchorage, approach lane) etc. The research done hitherto on the vehicle has also some practical values.

Apart from the projects executed, the team of researchers of the second consortium also developed a design for an 11-meter vehicle (capable to transform into an unmanned unit) fitted with one remotely controlled machine gun. This design referred to as 'Koleń' has not been presented to a wider audience yet (fig. 4 and 5).

Fig. 4. USV 'Koleń' — fore and aft, version 1 [own study]

Fig. 5. USV 'Koleń', version 2 [own study]

As a result of the continued work on unmanned surface vehicles, another 11-meter design of vehicles to detect and neutralize sea mines was developed by a consortium led by OBR CTM S.A. Gdynia. The Naval Academy is one of the consortium members. The project has not been continued as financial support has been suspended.

Eventually the only practical result of the research projects carried out between 2010 and 2017 aimed at developing national unmanned surface vehicles is the vehicle 'Edredon'. Within the framework of the first two projects the possibility was considered to install the following payload on board 'Edredon':

Medium-caliber machine gun

Following the example of the Israeli USV 'Protector' (combat RIB) employed mainly to protect fixed and mobile objects seaward, which is armed with RAFAEL's Typhoon 7.62 mm machine gun, having the range of 1000 m and the rate of fire 950 rounds per minute, an analysis was done regarding the possibility of arming the already built unmanned surface vehicle produced in Poland, by Zakłady Mechaniczne Tarnów S.A., the Remotely Controlled Weapon Module — ZSMU-1276 A3, which is designed, among others, to be installed on board vessels afloat (fig. 6).

Fig. 6. USV 'Edredon' with installed weapon module (first phase of development) [4]

Underwater vehicle

The unmanned surface vehicles co-operating with devices designed to monitor an underwater area have extensive search and reconnaissance capabilities. An example can be USVs additionally equipped with a remotely operated vehicle (ROV). Such a system is designed to perform all kinds of underwater work both at sea and in inland waters. An unmanned surface vehicle combined with an underwater vehicle can be used e.g.in the following cases:

- search for sunken or attached to the hull explosives;
- search for divers;

- inspection of submersed part of construction;
- setting security zones around vessels afloat, or laying in a roadstead or port;
- detection and classification of underwater objects;
- detection of changes in structures of underwater constructions indicating purposeful tampering, etc.

There are few USVs in the world capable of co-operating with ROVs. Most often, these are vehicles specially designed for this purpose, i.e. their exclusive mission is carry on ROV. In accordance with the design assumptions the USV 'Edredon' is designed to perform multi-variant functions. In this connection a launch and recovery system for small ROVs, designed, first of all, to protect e.g. ports, can be installed on board. Under the work done in both of the projects, 3 concepts of an ROV launch and recovery system installed on board an USV were developed (fig. 7–9). The control of ROVs, including launching and hoisting them on the deck of a USV and controlling them together with transmitting images from cameras installed on the ROV to the command post) ie effected by its operator from the USV commnad post located ashore. There is no information in world literature on the implementation of such a function [7].

Fig. 7. Landing placed aft — place to install a launch and recovery system (design developed under the project) [4]

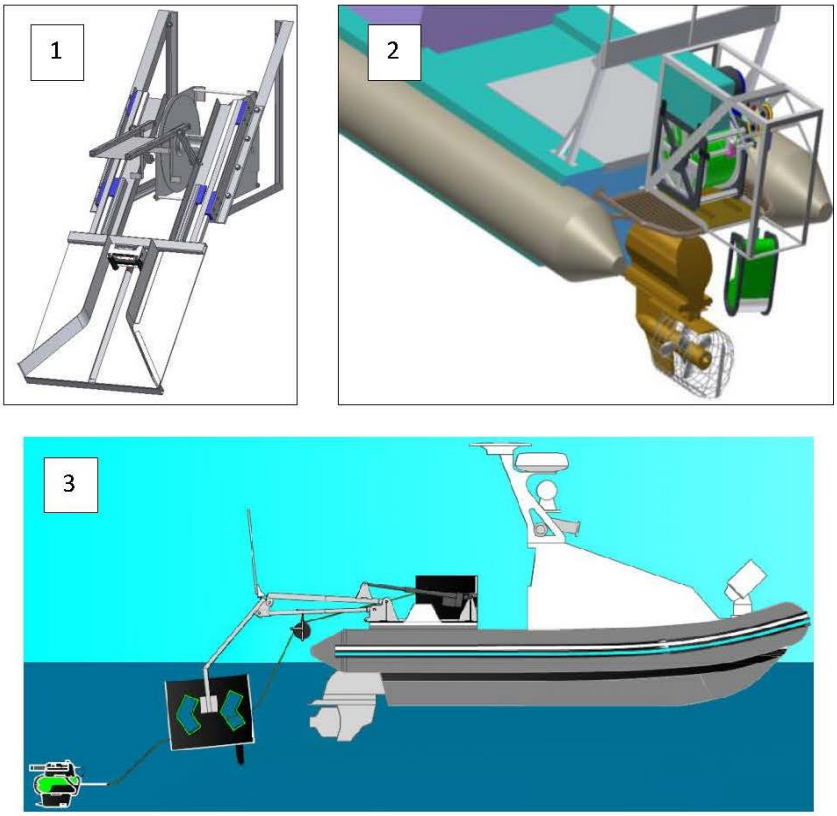

Fig. 8. Designs of ROV launch and recovery system: 1 — design developed by A. Bielecki [1]; 2 — design developed by B. Szturomski [4]; 3 — design developed by Department of Propulsion Systems and Underwater Work Technologies Naval Academy and Forkos firm [5]

Fig. 9. Documentation photos taken during captive testing of the system, version 3 [5]

Day-light and infrared reflectors

Using an additional lighting system — a searchlight with infrared illumination allowing for operating the vehicle in night conditions, providing additional illumination of object with white or infrared light (fig.10). They can be used in automatic tracking of targets.

Fig. 10. Searching the surface with a searchlight [4]

In 2013–2016 in the process of writing MSc theses at the Institute of Electronics and Shipboard Automation, Faculty of Mechanical and Electric Engineering, an additional possibility was considered:

Application of an electric propulsion system for the developed 'Edredon' technology demonstrator [2]

Almost all the unmanned vehicles are fitted with propulsion systems based on internal combustion engines, but more and more emphasis is given to developing solutions alternative to the internal combustion engine (electric or hybrid propulsion).

It was assumed that the unmanned surface vessel 'Edredon', for which the alternative electric propulsion was designed, should meet the criteria as follows:

- speed — up to 35 knots,
- sea worthy ability — to sea state 4,
- autonomy dependent on speed, sea state and amount of payload — approx. 5–10 hrs,
- radio commnunications range — up to 20 km,
- estimated mass of the boat with payload — 1500–2000 kg,
- engine power — approx. 180 KM,
- aggregate weight of propulsion system — approx. 700 kg,

- use of an outboard electric engine as a replacement for the electric inboard engine would entail significant changes in hull construction of vehicle,
- effective use of hull capacity,
- modularity — ability to change elements according to the planned mission of vehicle.

It follows from the analysis carried out under the project that from the technical point of view there is a possibility to exchange a combustion engine for an electric engine on the unmanned platform 'Edredon', ensuring the assumed specifications of the platform underway (fig. 11).

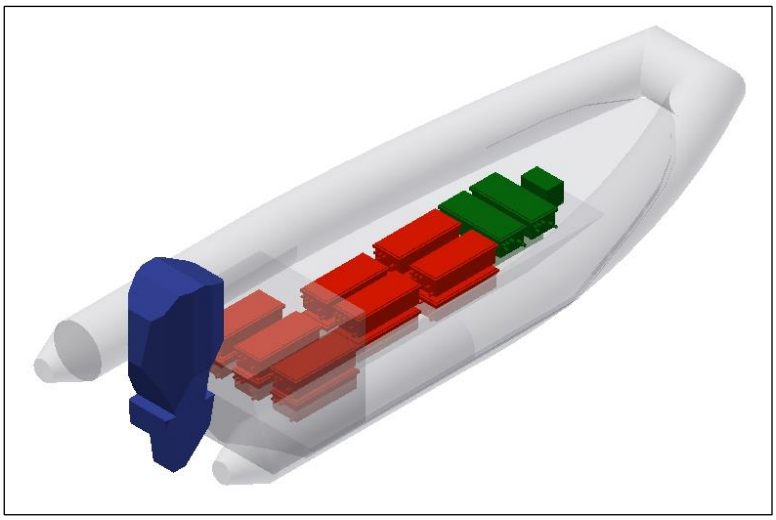

Fig. 11. Array of batteries and outboard engine — top view [2]

A small UAV pneumatic launcher

At present, with regard to technological advances, USVs lag behind their counterparts such as UAVs, UGVs and UUVs. However, new threats, cost-effect calculations, and operational experience gained over the last decade as well as advances in new technologies have contributed to the fact that they are used instead of manned vehicles not only for defense but also for providing protection to critical objects, law enforcement (drug smuggling, piracy), fishing and natural environment control, etc. In the course of protection of and support rendered to strategic objects at sea USVs can perform all the functions relating to provision of security, i.e. supervision, detection, reconnaissance, warning and neutralization of threats. USVs can be controlled

from ashore patrol vessels, etc., significantly reducing patrol costs with simultaneous increase in the patrolled sea areas. In response to these needs a design of small UAV pneumatic launcher was developed within the framework of a MSc thesis written at the Institute of Electronics and Electric Engineering, Faculty of Mechanical and Electric Engineering (fig. 12).

Fig. 12. USV 'Edredon' fitted with the designed small UAV pneumatic launcher [3]

NEW APPROACH TO THE EMPLOYMENT OF UNMANNED VEHICLES

At the end of 2013 the US DOD (Department of Defense) published the *Unmanned Systems Integrated Road Map FY 2013-2038* [8]. This document assumes that the future unmanned systems should be capable of operating in any conditions, even when the enemy has capabilities to effectively counter them, i.e. has effectors capable of effective engagement of unmanned vehicles. This document also assumes improving the unmanned systems by integrating them with the remaining elements of combat components. Efforts taken in this respect should result in meeting the required effectiveness, affordability, interoperability and integrity by the unmanned vehicles not only with regard to the present but also future operational needs.

Experience shows that building an autonomous vehicles requires extensive knowledge and skills to make use of fast changing technologies. American authors emphasize the fact that in recent years the breakthrough technologies dating from 1980s have become common in use and modern electronics and have so far shown

the US superiority have been losing their significance. This is the reason why the Pentagon have come up with the idea that new revolutionary weapon, which will allow the USA to maintain the qualitative superiority over its rivals are, among others, robots, especially robots capable of operating autonomously. In 2012 a Strategic Capabilities Office (SCO) was set up to develop advanced technologies [11]. In the analyses carried out in the USA, strong emphasis was given to the implementation of existing solutions and developing new capabilities based on them. The basis for the new approach is to be maximum reduction in cost and risk. In accordance with this strategy, SCO is not expected to make breakthroughs but creatively utilize this what has been developed so far. Building new systems has to be based on this approach [11]. The emerging new approach to control not only a single vehicle but a swarm of them is the goal of the future which perfectly suits the assumptions presented above. This can be seen clearly by the example of the development of the UAV control systems.

The work performed under the LOCUST (Low-Cost UAV Swarming Technology) testifies to the significance of the problem of controlling a swarm of unmanned vehicles. The project, some information which became known 2, 3 years ago, assumed firing up to a dozen tube drones from a land launcher (fig. 13), which autonomously flying in a swarm can communicate with one another and carry out assigned missions [9, 13, 17].

Fig. 13. A launcher of aerial drones in the LOCUST project [U.S. Naval Research Laboratory]

The drones and the program itself were developed by the Office of Naval Research which coordinates, executes and promotes the science and technology programs of the United States Navy. UAVs are launched like missiles, then, they unfold their wings and continue to fly autonomously. What is important is that they can operate autonomously without instructions sent from land by operators. A swarm of drones, instead of a single UAV, is expected to ensure the total superiority over

the enemy, who will not be able to respond fast enough. At present a film is available in which it is demonstrated that not a few but over 100 drones can fly together in a swarm, communicating with one another, operating like one organism (fig. 14) [16, 20]. The Perdix drones were released from containers suspended from F/A-18 Super Hornet aircraft. The dimensions of the Perdix are only 16.5 cm in length and 30 cm in span. Propulsion is provided by an electric engine and a 2.6 inch (approx. 6.6 cm) pusher propeller at the rear.

Fig. 14. A swarm of or Perdix drones launched from F/A-18 Super Hornet [16]

Most interesting are the assumptions concerning their missions. At present the Perdix drones do not have a specific preprogrammed flight route, they are not controlled individually — they fly in a swarm autonomously, separately but they communicate continually with one another. There is no leader in the swarm, and the swarm of flying drones adapts themselves to the current, changing during the flight mission situation — just, as it happens in nature, e.g. in the case of a swarm of insects (design of UAV swarm control is at the moment being developed at the Military University of Technology in Warsaw).

At the end of 2016 the US Navy released a film, prepared by the Office of Naval Research, which showed a swarm of five surface vehicles attacking enemy ships. Vehicles equipped with the CARACaS (Control Architecture for Robotic Agent Command and Sensing) system performed the function of units capable of detecting the threats before they are in the range of enemy weapons [11, 14, 15, 18–20]. The most important goal of the research was, however, to test advanced software to control a swarm of USVs (team of USV). The individual vehicles in the team had a mission to carry out surveillance of the environment, move safely in it and communicate with other USVs, and coordinate their actions on a continual basis. The mission of the USV shown in the film was to patrol and defend the approach to a large naval base at Norfolk. The USVs had a mission to circle in the assigned sea areas, automatically intercept enemy ships, track them and carry out reconnaissance (fig. 15).

Fig. 15. A swarm of USVs patrolling the approach to the Norfolk naval base [11, 15]

The USVs in the swarm had to make autonomous decisions on how to best patrol the large area of the approach to the base and carry out uninterrupted tracking of the enemy. The goal of the US Navy is to employ swarms of drones not only to patrol its own littoral waters but also provide protection to friendly ships navigating in regions dangerous for them. The presented technologies are expected to provide the superiority of the US navy ships over a maritime adversary [15].

SUMMARY

Despite the fact that their progress relating to technological capabilities, used technologies and the pace of implementation into operation is delayed as compared with their counterparts (UGV, UUV, UAV, etc.). The unmanned surface vehicles

have been more and more commonly used not only for national defense but for civilian applications also. This is mainly due to the emerging threats, low production costs and first of all their positive qualities. At present they are mostly employed to protect and support strategic objects at sea (e.g. in the process of supervision and detection), carry out reconnaissance; provide warning and more and more often to neutralize threats [10]. They can carry out missions from such ships as corvettes and destroyers, serving as an additional platform for detection and identification of enemy ships and missiles. They allow for substantial reduction in cost of patrolling with simultaneous increase in the patrolled area.

The experience gained over the last two decades shows that the technological advances of USVs should improve the level of their integration with other elements of combat components. Such actions should result in meeting the required features of effectiveness, affordability, interoperability and integrity, not only from the present perspective but desired in the perspective of future operational requirements. The areas, where research efforts should be centered are: giving greater emphasis to data scrambling methods ensuring the success of conducted missions, development of new weapons systems, and increasing operating autonomy or modularity of the USVs.

The cost of building present-day naval platforms increases together with the increase in their combat potential whereas the number of platforms built decreases for economic reasons. Introduction of a new notion of cheap 'swarm' USVs is a novel approach to their applications, arisen from practical considerations, i.e. decreasing costs. At present the US Navy tests new technologies, which are expected to result in complete 'swarms' of small unmanned vehicles cooperating with one another, and carrying out their missions autonomously.

According to DOD special attention will have to be paid to the issues concerned with increasing autonomy of unmanned vehicles, data protection and processing, and cooperation between unmanned and manned platforms. Especially the last issue is considered to be very significant for effective employment of the future unmanned vehicles. The areas of co-operation of unmanned and manned platforms will be vast and they will include e.g. neutralization of threats posed by sea mines or improvised explosive devices.

REFERENCES

[1] Bielecki A., *A design of a remotely operated underwater vehicle launch and recovery system stationed on board an unmanned surface platform* [in Polish], PNA, Gdynia 2011.

[2] Borchardt J., *The preliminary project of the electric drive of an unmanned surface vehicle* [in Polish], B. Sc. thesis, PNA, Gdynia 2014.

[3] Jurczyk K., *The project system of cooperation with the small Unmanned Air Vehicle based on the Unmanned Surface Vehicle* [in Polish], M. Sc. thesis, PNA, Gdynia 2016.

[4] Kitowski Z. et al., *Materials development project No. O R00 0004 07 'Unmanned Multi-variant Swimming Platform for Secure Operation of Marine State Services'*, Gdynia 2010–2011.

[5] Kitowski Z. et al., *Materials development project No. R00 0106 12 'Integrated planning system of protection and monitoring of marine ports and critical objects based on the autonomous unmanned units'*, Gdańsk 2011–2013.

[6] Kitowski Z., *Architecture of Control System of Unmanned Surface Vehicle in Harbours Protection*, Solid State Phenomena 'Mechatronic Systems. Mechanics and Materials', 2011, Vol. 180, pp. 20–26.

[7] Leszczyk D., Design a miniature camera control system [in Polish], B. Sc. thesis, PNA, Gdynia 2013.

[8] *Integrated road map of unmanned systems for 2013–2038* [in Polish], [online], http://dziennikzbrojny.pl/artykuly/lista/sub,6,28,lotnictwo,bezzalogowce [access 17.05.2017].

[9] *LOCUST program — military drones flying in a swarm* [in Polish], [online], http://www.swiatdronow.pl/program-locust-drony-wojskowe-latajace-w-roju [access 17.05.2017].

[10] *Plan of unmanned systems development for the Navy* [in Polish], [online], http://www.viribus-unitis.com.pl/2013/12/plan-rozwoju-systemow-bezzalogowych-dla-marynarki-wojennej [access 17.05.2017].

[11] *Swarm of robots — US Navy — testing American armed forces new technologies* [in Polish], [online], http://www.tvn24.pl/wiadomosci-ze-swiata,2/roj-robotow-us-navy-testy-nowej-technologii-amerykanskiego-wojska,700332.html [access 17.05.2017].

[12] *The Navy Unmanned Surface Vehicle (USV) Master Plan*, Washington 2007, [online], http://www.navy.mil/navydata/technology/usvmppr.pdf [access 17.05.2017].

[13] http://defensesystems.com/articles/2015/04/15/onr-locust-swarming-autonomous-uavs.aspx [access 17.05.2017].

[14] http://edition.cnn.com/2014/10/06/tech/innovation/navy-swarm-boats/index.html [access 17.05.2017].

[15] http://futureforce.navylive.dodlive.mil/2015/01/the-swarm/ [access 17.05.2017].

[16] http://newatlas.com/perdix-micro-drones-super-hornets/47333/ [access 17.05.2017].

[17] http://www.siliconrepublic.com/innovation/item/41612-us-navy-testing-terrifying [access 17.05.2017].

[18] https://defensesystems.com/articles/2017/01/10/swarmboats.aspx [access 17.05.2017].

[19] https://www.onr.navy.mil/Media-Center/Press-Releases/2014/autonomous-swarm-boat-unmanned-caracas.aspx [access 17.05.2017].

[20] https://www.youtube.com/watch?v=OixSNQp0S_k [access 17.05.2017].

KRAJOWE DOŚWIADCZENIA W KONSTRUKCJI I ZASTOSOWANIU BEZZAŁOGOWYCH POJAZDÓW NAWODNYCH NA MORZU

STRESZCZENIE

W artykule w oparciu o analizę zadań realizowanych przez bezzałogowe pojazdy nawodne (USV — unmanned surface vehicle) omówione zostały podejmowane w kraju dotychczasowe działania mające na celu konstrukcję tego typu pojazdów przeznaczonych przede wszystkim do zabezpieczenia działań morskich służb państwowych oraz ochrony i monitoringu portów morskich i obiektów krytycznych. Podsumowano efekty prowadzonych prac naukowo-badawczych oraz przedstawiono nowe podejście do zastosowania tego typu pojazdów na świecie.

Słowa kluczowe:

bezzałogowe pojazdy nawodne, rój pojazdów bezzałogowych.