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Materiały Wysokoenergetyczne / High Energy Materials, **2019**, 11 (1), 45 – 55; DOI: 10.22211/matwys/0102E
ISSN 2083-0165

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Review / Przegląd

Unmanned vehicles – a new challenge for explosive materials. An overview *Pojazdy bezzałogowe – nowe wyzwanie dla materiałów wybuchowych. Przegląd*

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Abstract: *The diversity of currently employed unmanned vehicles (UVs) in outer space, flying, driving and walking on land, as well as operating in water (on the surface or underwater) is presented. Examples of applications of national UVs for purposes other than military ones, are shown. It is pointed out that in each of these areas there exist armed UVs as well as ones potentially capable of carrying and deploying offensive weaponry. Trends in the development of UVs for military and commercial applications are described.*

Streszczenie: *Przedstawiono różnorodność obecnie stosowanych pojazdów bezzałogowych (PBz) poruszających się w przestrzeni kosmicznej, latających, jeżdżących lub kroczących po lądzie, czy też działających w środowisku wodnym (pływających po powierzchni lub pod wodą). Zaprezentowano przykłady krajowych zastosowań PBz w innych celach niż militarne. Wskazano, że w każdym z tych obszarów występują uzbrojone PBz jak też potencjalnie zdolne do przenoszenia i użycia uzbrojenia ofensywnego. Określono tendencje rozwoju uzbrojenia PBz oraz uwarunkowania cywilnych zastosowań PBz.*

Keywords: *unmanned vehicles, weapon, development*

Słowa kluczowe: *pojazdy bezzałogowe, uzbrojenie, rozwój*

Acronyms used in the paper are from cited English language literature:

- ACTUV – Anti-Submarine Warfare (ASW) Continuous Trail Unmanned Vessel,
- AMDV – Autonomous Mine Disposal Vehicle,
- AUV – Autonomous Underwater Vehicle,
- BAUV – Biomimetic Autonomous Underwater Vehicle,
- PVDS – Propelled Variable Depth Sonar,
- RMMV – Remote Multi-Mission Vehicle,
- RMS – Remote Minehunting System,
- ROV – Remote Operated Vehicle,
- Remotely Operated Underwater Vehicle,

SHARC	– Sensor Hosting Autonomous Research Craft,
SMV	– Space Maneuver Vehicle,
TUGV	– Tactical Unmanned Ground Vehicle,
UAV	– Unmanned Aerial Vehicle;
	– Unmanned Autonomous Vessel,
UCAV	– Unmanned Combat Aerial Vehicle,
UGV	– Unmanned Ground Vehicle,
USV	– Unmanned Surface Vessel,
UUV	– Unmanned Undersea Vehicles,
VIPeR	– Versatile, Intelligent, Portable Robot,
VTOL	– Vertical Take Off and Landing.

1. Introduction

The beginning of the contemporary history of unmanned vehicles (UVs) dates back to World War II. In the land systems, it was the German, wire-controlled, self-propelled mine Goliath containing 60 to 100 kg of explosive material (EM) [1]. Attempts at aerial UVs (unmanned aerial vehicles – UAVs) were carried out by Germany as part of the Mistel project [2], in which an unmanned aircraft carried up to several tons of EM. The idea behind the Mistel project was to use the aircraft as an unmanned flying bomb, initially guided by the pilot of the “carrier” aircraft.

The basic attributes of UVs, such as low operating costs compared to manned vehicles, the ability to quickly replace one UV with another, observation of the environs and remote control in real-time, without putting people at risk, are particularly conducive to the development of UV applications operating in conditions threatening health and life, not just to complete military missions. An example could be the use of unmanned ground vehicles (UGVs) to extinguish fires. Such a solution seems to be particularly necessary in relation to minimizing hazards during fire-fighting on military ranges (unexploded ordnance) [3] or in munition depots.

The use of drones, *i.e.* UAVs, which actively participate in military operations, has been publicized in the media for over a decade, mainly in connection with the wars in the Middle East. The importance of this type of UAV is due to the general regularity with which military operations focus on land, with the simplest form of counteracting land operations being the attainment of air superiority.

1.1. Development of civilian unmanned vehicles

Dissemination of knowledge about the use of UVs for military, anti-terrorist, border protection and law enforcement purposes, will result no doubt in their introduction into the arsenals of terrorist groups and organized crime. In this respect, the technical possibilities of vehicle construction and remote control are virtually limitless, since model-making is the origin of its knowledge and technology.

The driving force of civilian UAV applications is in filming. The “typical” parameters of a “flying camera for everyone» are embodied by the *Jamara Observer Quadrocopter*: It weighs about 278 g, is 61 cm wide with a flight time of up to 10 min [4]. Work is underway to develop much smaller UAVs. One can buy a model of a UAV which fits in the palm of one’s hand, *e.g.* *Crazyflie Nano*, weighing 27 g and capable of lifting 42 g [5]. *AeriCam Anura* [6] is the size of a smartphone and can be controlled with a smartphone (Android or iOS); with a payload of about 115 g, it allows a 10-minute flight within a 25 m radius. An even smaller “flying gadget” is *Nixie*, whose prototype can be carried on one’s hand like a watch [7]. Miniature UAVs are not just «gadgets» to play with. They can be given very important tasks. Work is underway on a miniature UAV, which is to be one of the robots for pollinating flowers in greenhouses, as part of the B-DROID project entitled “Autonomous system for the mechanical pollination of plants”, started at the Warsaw University of Technology in 2012 [8]. An example of a model of UAV intended for more professional filming and aerial photography is the *Phantom 2* made by the company DJI, which at the end of 2014 could be purchased in a modelling shop, ready to fly,

for PLN 3,700 [9]. This 1 kg multicopter can fly for 25 min with a maximum speed of 54 km/h. The transmitter range is 1 km.

UAVs which are “not for everyone” may have significantly different parameters. UAVs can be as large as manned aircraft and can even be manned aircraft adapted for remote control [10]. For example, the flying wing *Sagitta*, made by the company Casidian (currently Airbus Defense) is 3.7 m long, with a wingspan of 3.1 m and a mass of 150 kg. What is more, its enlarged utility version has also been announced [11]. Regardless of the differences, one reference point is common to all of them – it is possible to introduce an unmanned object capable of performing any task into any area.

It is also possible to use UVs dedicated to military operations in the broadly understood sphere of ensuring security. In 2014, the usefulness of the *S-100 Camcopter* helicopter operating from the deck of a patrol boat, e.g. border guard, was demonstrated in such activities as support during a rescue operation of a person tossed overboard, fire on a vessel transporting hazardous substances or search of an individual suspected of smuggling [11].

Technologies combining operations of land-based and flying UVs are being developed for civilian applications. The Polish flagship in this respect is the „Proteus Project” – an integrated mobile system supporting anti-terrorism and anti-crisis operations” implemented by a consortium consisting of [12]:

- Industrial Research Institute for Automation and Measurements,
- Space Research Centre of the Polish Academy of Sciences,
- Scientific and Research Centre for Fire Protection, National Research Institute,
- Institute of Electronic Materials Technology,
- Poznań University of Technology,
- Warsaw University of Technology,
- Military University of Technology.

The Proteus system consists of two human-operated vehicles, i.e. a Mobile Command Centre and a Mobile Robot Operator Centre. Four UVs are used in the system [12]:

- Unmanned aircraft: 40 kg take-off weight. The endurance is 8 h (internal combustion engine), cruising speed 100 km/h, maximum operational ceiling 4 km.
- Big robot: Weight: 300 kg. The maximum lifting capacity of the manipulator is about 40 kg.
- Medium robot: Weight 65 kg. The maximum lifting capacity of the manipulator is about 28 kg.
- Small robot: Weight: 50 kg. Equipping with a soil, liquid and air sample collector is possible.

1.2. Main barriers to the development of military applications

From the point of view of military applications, the development of UVs requires solving many dilemmas, as indicated by press reports on drones. The basic set of challenges are legal, such as discussions on adapting legal regulations in the field of air traffic in Europe or the US on the issue of whether drone operators involved in military operations can be regarded as soldiers. The lack of clarity in the current operational status of drones is also manifested in the lack of a uniform classification for drones. Several classifications exist in parallel, e.g. [13, 14].

Among the risks associated with the deployment of drones is the matter of “infrastructure” accompanying their operations. The data presented in a report [15] concerning attacks utilising drones, whose victims, apart from terrorists, were or could have been civilians, document 30 cases from the beginning of the century (Afghanistan – 8, Yemen – 6, Pakistan – 8, Somalia – 1 and the Gaza Strip – 7). There also exists information about accidents involving UAVs, e.g. Schiebel S 100 *Camcopter* had an accident in Korea in which one person was killed and two were injured [16]. These cases clearly indicate that the «infrastructure» of UV military missions requires specific refinement.

It is worth highlighting one more group of issues affecting the development of UV armament, i.e. protection against unauthorized use. Electronic fuses have been introduced in mining as, among others, a protective barrier against the unauthorized use of blasting agents. Security issues are not the subject of this paper, but it appears

to be important to consider the following history lessons from the development work:

- a) During the Russo-Georgian war, Georgians could not use UAVs purchased abroad, because the manufacturer had handed the codes to the Russians, resulting in them taking control of the UAVs [17].
- b) Loss of control over UAVs is also possible as a result of the activity of hackers. Such situations are already encountered in Poland [18].
- c) Following the “loss” of a drone during military exercises, a problem arose as to who should look for it. The Ministry of National Defense pointed to the producer, and the producer to the Ministry [18].

1.3. How do you destroy a drone?

It is hard to deny that humankind devises methods of defence against every form of attack. For defence against ground-based UAVs, implementing methods usually used to detect manned vehicles should be sufficient. The situation is different with defence against enemy UAVs, e.g. due to their lower detectability and attack technique. The key condition for the survival of a UAV over hostile territory is not only its stealth capability, e.g. countering radiolocation devices, but – in the event of detection and attack – the ability to successfully repel the attack by passive measures (thermal traps, smoke screens), as well as offensive means (missile systems). Descriptions of operations involving UAVs provide information about their protection by fighter planes. Escorting is sufficient in the case of «official» patrolling of international airspace, however it does not seem to be practiced in an armed conflict or when combating terrorism. Therefore, UAVs will be armed with air-to-air missiles as standard.

The fact that in 2013 Lockheed Martin [19] announced having conducted a series of successful trials of a laser weapon prototype intended, among others, to destroy UAVs may be a harbinger indicating that in the course of a few (over a decade?) years one can expect a revolution in the techniques of combating UAVs. Of course, it cannot be ruled out that the drone was just a target moving slowly enough to test the new weapon. The footage [19] of the destruction of a rocket using a laser weapon indicates that it is an attack virtually unnoticeable to an outside observer, which is also an advantage when attacking a drone, i.e. its navigator does not know that they are being attacked. There are so many obstacles to overcome in the development of laser weapons that for now we can only talk about attempts, not about real defence. Ultimately a class of drones may be created to fight drones, which may also have consequences for the selection of the armament of both types of drones, analogically a fighter aircraft is armed differently compared to a bomber.

2. Unmanned vehicles in space

Because of the military doctrine of the USA, *Prompt Global Strike*, (PGS) [20], any automatic space station can be treated as an armed UAV. The main stages of the development of UAVs operating in outer space are:

- **Early 1960s:** Americans operated the *X-20 Dyna Soar* space glider project, which in the last phase, shortly before its first flight was abandoned in favour of a manned orbital station – which was also cancelled (in 1969) – due to the takeover of reconnaissance by unmanned satellites.
- **1996:** Boeing began work on the *X-40* – US Air Force project, the result of which was a manoeuvrable reusable spacecraft SMV. It would have had great manoeuvring capability, and its mission would have ended with a classic automated landing at an airport.
- **1998:** Tests were carried out on an SMV prototype, called *X-40A*. The final version, *X-40B*, was to have been used in space.
- **2013:** The *Atlas-V* space rocket launched the experimental *X-37B* space aircraft into orbit for the first time [21].

In the second half of the twentieth century, EMs were tested for their applicability in space. In literature from this period, we find information about specific requirements, such as resistance to long-term effect of cosmic radiation or the effects of reduced pressure, or – in relation to rocket propulsion – the efficiency of operation in a vacuum. The current direction of research, which clearly has a strong impact on the possibilities of applying explosives in space, is their susceptibility to laser initiation.

3. Unmanned vehicles in the air

It is believed that the beginnings of the UAV date back to the 1950s [22-25]. Initially, flying UVs were used mainly as air targets during exercises [26]. Almost 700 UAV types have been used in the world since the beginning of the 20th century [24]. Modern UAVs are part of the arsenal of individual armies in quantities of several dozen units. According to *Defence24* [27], in 2013 the Americans created the first squadron of eight manned helicopters and ten unmanned VTOLs *Fire Scout MQ-8B*, which are to be armed in the future. The squadron will secure the operation of ships for coastal operations. Similarly, organized squadrons are also being created in the US air and ground forces.

Over the period 2013-2022 [28, 29] the Polish Armed Forces planned to buy 97 sets, each of which would consist of several UAVs. The plans cover all classes, *i.e.*:

- 66 mini and mini / micro vertical start sets,
- 27 short range, vertical take-off and short-range sets,
- 4 operational sets, UCAV.

Modern UVs are increasingly becoming armed platforms, and can even become a weapon themselves, *e.g.* the *Harop* UAV was presented at Euronaval in 2012 [16]. It is a 23 kg warhead missile, self-propelled, capable of 6-hour flight to search for a target. Previously it only served to destroy radars. Currently it can attack moving targets.

According to a UN report [15], in February 2001 the first attempt was made to launch a rocket from *Predator*. European projects are not finished yet. The first flight of the European technology demonstrator *nEUROn*, an equivalent of the American *X47B*, took place in 2012. Initially (1999) it was a French project, but since 2005 it has become European. External armament will be tested first (two bombs, each weighing 126 kg) [28].

The analysis of literature data is based mainly on information from the Internet – apart from the above, also *e.g.* [30]. However, it allows the conclusion to be drawn that the dominant UAV armament is:

- a) machine guns up to 7.62 mm calibre and multi-barrel *e.g.* 40 mm calibre launchers (*e.g.* *DP-5X*);
- b) rockets:
 - *AGM-114 Hellfire* (*e.g.* *General Atomics MQ-9 Reaper* [31, 32]),
 - *Spike*,
 - *Hydra 70*,
 - *Brimstone*;
- c) guided bombs: *GBU-38 JDAM* or *GBU-12 Paveway II* [31];
- d) EFP charges.

It is worth noting the trend “signalled” in the above list by the British *Brimstone* missile system. It uses a radar warhead, which allows the rocket to operate according to the “fire and forget” principle [31]. This indicates a tendency to develop weapons in this direction, so that one UAV can combat several targets simultaneously.

In addition to the weapons listed above, there are weapon systems presented at defence trade fairs adapted for liaising with UAVs, *e.g.*:

- Thales presented the LMM (Lightweight Multirole Missile) at Euronaval 2012 [16],
- the Chinese presented precision-guided bombs CM-502KG (11 kg warhead) at the Airshow China 2012 [33].

When discussing the domestic possibilities of military UAV development, one should mention the WB Electronics company founded in 1997, the creator of the WB Group [34]. The best-known UAV of the WB Group, produced by Flytronic, was shown to the public for the first time in 2010 *FlyEye* [35, 36]. The WB Group is working on other UAVs which are at the test or project stage. Another solution in this UAV group is *E-310*, developed by Eurotech and PIT-Radwar [37]. An important domestic achievements are VTOLs developed by the Air Force Institute of Technology:

- *ILX-27* – presented at the International Defense Industry Exhibition in Kielce in the armed version [38], and
- *ATRAX* [39].

4. Terrestrial unmanned vehicles

Terrestrial contemporary PBzs, so-called UGVs are very diverse constructions [40], not just travelling ones. Only a few years ago, human-like robots would be treated as *science fiction*. Nowadays, we see the implementation of this type of machine. For now, it is only a “remote controlled autonomous firefighter”; *SAFFiR (Shipboard Autonomous Firefighting Robot)* [41], but this type of UV has a much greater obstacle clearance than an UGV on wheels. Of course, travelling UVs are also used to extinguish fires [42], but it should be remembered that research is underway into alternative solutions, e.g. four-legged UVs, such as *BigDog*, whose advantage is the ability to overcome steep slopes [43]. In the context of possible UV armament, it is worth emphasizing that *BigDog* can transport loads of 150 kg.

In 2014, the Polish Armed Forces began the tender process to acquire by 2016, several dozen unmanned reconnaissance vehicles codenamed *Tarantula* [44]. The requirement is an unarmed vehicle, equipped with a day and thermal imaging camera, night vision device, directional microphone and manipulator.

UGVs are widely used in anti-terrorist operations. The national solutions in this area, mainly developed by the Industrial Institute of Automation and Measurements, are robots: *Inspector*, *Expert*, *PIAP Scout*, *Ibis*, *PIAP Gryf*, as well as *Tactical Toss Robot (TRM)*. *CUTLASS* [45] presents the latest foreign achievements in this field. There are many types of combat UGVs, e.g. *VIPeR* [46], which from the start was designed, among others, as the «platform» of the *Uzi machine gun*. The armed versions of UGVs are referred to as TUGVs. An example from the USA is the *Gladiator* project [47] which has been in development since 1993, and which resulted in machines equipped with, among others, 5.56 mm machine guns (*M249 SAW*), 7.62 mm (*M240G*), or a 9 mm *Uzi submachine gun*.

In December 2012, Israel began using the *Guardium* UGV for border protection in the Gaza Strip [48]. The construction is based on the Tomcar light car, as an unarmed vehicles. The payload is 300 kg. In future, heavier TUGVs are to be introduced.

5. Unmanned vehicles in the aquatic environment

Operating mainly in the seas and oceans UVs (the so-called AUV) are commonly used for hydrological studies, such as AUV *REMUS (Remote Environmental Measuring UnitS)* [46]. These vehicles can be used in combat operations [49]. A AUV's main military tasks are intelligence missions, tasks related to the surveillance of a given body of water, reconnaissance, communication and anti-mine combat.

The relatively low price of AUVs favours their development. A few years ago, the basic version of AUV *Iver2* cost about USD 50,000 [49]. One of the titans of the unmanned vehicle market (not only USV and AUV, but also UGV), company ECA Robotics, reports [50] that it sold 500 submarines to combat mines to 20 countries and that:

- **1972** – the start of the era of remotely controlled unmanned underwater vehicles to combat mines *Subsea Mine Identification and Destruction System* type PAP (sale of 400 units),
- **1982** – constructed the world's first completely autonomous AUV *Epaluard*.

A national example of the implementation of the anti-mine battle is the mine destroyer project 258 *Kormoran II*, which began in 2009 with the construction contract being signed in 2013 [11]. *Kormoran II* will be equipped with:

- self-propelled sonar on the *Orka* submarine,
- Kongsberg Maritime *Hugin 1000MR* autonomous underwater vehicle,
- wired-guided reusable underwater vessel “*Morswin*” (developed at the Centre of Marine Military Technologies of the Gdańsk University of Technology, the construction is to replace the remotely controlled *Ukwial* (eng. *Sea anemone*) vessels, which is the equipment on mini-trawler destroyers of the 206FM project),
- a system of remote-controlled single-use underwater vehicles for identifying and destroying sea mines, *Gluptak*.

Sonars are the basic mine detection tool. Their evolution to date includes 4 generations [51]:

- 1st generation – keel sonars,
- 2nd generation – contemporary, primarily towed,

- 3rd generation – sonars mounted on self-propelled vehicles operating under the ship, e.g. PVDS,
- 4th generation – sonars mounted on AUVs.

Both the concept of mine war *SLAM F* (fr. *Système de lutte nati-mines futur*) as well as the *ESPADON* program (fr. *Aluvaluation de Solutions potentielles d'Automatisation de Déminage pour le Opérations Navales*) is based on the interaction of many unmanned underwater vehicles, autonomous and wired controlled, forming a sonar transport platform, e.g. belonging to [51]:

- 2nd generation – *Sterenn Du* catamaran and semi-submersible vehicle *Seakeeper*,
- 3rd generation – *Double Eagle Mk II* and *Double Eagle Mk III*,
- 4th generation – *Bluefin 21* (length 3.5 m and weight 450 kg), *Alister* (length 5 m and weight 950 kg).

For several years, anti-mine combat has also been analysing AMDV solutions, i.e. autonomous self-propelled explosives capable of “independent” decision making [51]. Due to the defensive nature of these types of tasks, they are unarmed units. An example of the concept of innovative small multi-purpose ships which meet the role of platform for autonomous UVs, is a project developed at the Gdańsk University of Technology [52]. Taken into account was the cooperation of unmanned systems – marine (*BSM*) and aerial (UAV). According to the authors of [52], the main element of the system may be a trimaran (in two versions – 16 m and 24 m long), which can not only be a platform for the *BSMs* and UAVs, but can also be controlled as an unmanned object, as well as being armed. Other AUV projects developed at the Gdańsk University of Technology include:

- *Hydro-Sub* – sub-surface dwelling with a total length of 4.7 m,
- *Sub-Stone* – bottom dwelling with a length of 6.2 m,
- *Fist-RP* – all-water with a total length of 5.2 m.

Height of the above objects were designed to be in the 1.1 m to 1.6 m range. Armed development of 4 versions of *Fist-RP*: for patrol, for deterrence, to combat surface and above-surface facilities as well as to combat submarines and underwater targets. According to [52], work is underway on an integrated *Navy-RP* system combining the operation of manned and unmanned units.

The main group of surface UV are “analogues” of motorboats, as made at the Naval Academy and the Gdańsk University of Technology *Edredon* [53]. USVs can be armed with machine guns up to 7.62 mm, 40 mm grenade launchers, including thunderflash and rockets, e.g. *Protector*® – with the *Spike* missile [54]. At the Euronaval 2012 trade fair, the USV *Protector* was presented, equipped with a 7.62 mm machine gun and two *Spike* missile launchers together with a water cannon which can be used not only as a non-lethal weapon, but also to extinguish fires [16]. The possibilities of USV deployment are highly diverse: the *Protector II* has a range of up to 400 nautical miles and can operate for up to 48 h, while the *Vigilant* from ZyCraft has a range of over 2000 nautical miles and maintains the ability to operate for over 30 days. The *Vigilant* USV can be equipped with a small rotorcraft [16].

USVs can be carriers of explosive products used in combating the mine threat. Surface UVs, equipped e.g. with ROV-type UVs, are also used in this fight. Lockheed Martin has built a multi-task RMMV using the hull of a remote mine system. The main task of the RMMV is the eradication of sea mines and improvised naval explosive devices [55].

There are numerous studies available on the UVs used in the Polish Navy, mentioned above, called *Ukwiał* [56-58]. These are used to place explosive charges for destroying mines. The charges contain up to several dozen kilos of explosive material, such as *Toczek* [59]. The equivalent of Polish *Toczek* is the *Cobra* charge, developed for the *Sea Fox A* ROV, which also served as a remote single use mine destroyer [16]. Thanks to the application of the *Cobra* charge, which is actually a cap placed over the ROV bow made of aluminium and plastic and filled with an explosive (the total weight is 8 kg), the ROV became a reusable vehicle.

At the Krakow University of Technology, in cooperation with, among others, the Polish Naval Academy, the idea of three students to build a BAUV with a wave drive, known as *CyberRyba* (literally: *CyberFish*) [60] has been implemented since 2006. The components of the construction and the operating principle of *CyberRyba* are presented in [61]. In 2013, in the 2nd edition of PIAP Night of Robots (pl. *Noc Robotów PIAP*), the fifth generation of *CyberRyba* was unveiled.

The techniques of objects moving through water imitating fish kinematics, are based on the movement of the fins (dorsal, anal, pectoral), as well as the wave motion of the body and caudal fin, the so-called BCF system (*Body and/or Caudal Fin*). Within the BCF system, five categories are distinguished [62], related to the imitation of eel, salmon, perch, tuna and puffer fish movement. An example of the use of tuna movements is the US Navy project *Silent Nemo*, also known as *GhostSwimmer*, in which the goal is a reconnaissance robot [63-65] which is intended to move and look exactly like a tuna. It also has an intended target speed of 74 km/h in the water [66, 67].

Underwater vessels for reconnaissance which use wave motion are the subject of a project entitled "Autonomous underwater vehicles with a silent wave drive for underwater reconnaissance" financed in 2013-2016 with funds from the National Centre for Research and Development [68]. The project is implemented by a Scientific and Industrial Consortium consisting of:

- Polish Naval Academy (Leader),
- Krakow University of Technology,
- Industrial Research Institute for Automation and Measurements PIAP,
- Research-Production Enterprise FORKOS Ltd..

The military aspect of deploying ROVs also covers a little-known issue which must not be forgotten when analysing the requirements for domestic UVs. According to [69], at least 42,000 to 65,000 tons of chemical munitions (artillery ammunition, grenades, aerial bombs, barrels containing Chemical Warfare Agents) were dumped in the Baltic Sea, as well as other war materials produced in Germany until the end of World War II. The authors of [69] estimate that this means the sinking of 6,000 to 13,000 tons of Chemical Warfare Agents. In 2011, the CHEMSEA (*Chemical Munitions SEarch and Assessment*) project, was launched as a part of the Baltic Sea Cross-Border Cooperation Program. The coordinator of the project is the Institute of Oceanology of the Polish Academy of Sciences in Sopot. The project brings together 11 scientific and research institutions of 5 Baltic coastal states. From Poland, in addition to the Institute of Oceanology of the Polish Academy of Sciences, the Naval Academy and the Military University of Technology also participate in the program. One of the tasks is the examination and compilation of an inventory of the areas of confirmed and probable occurrence of chemical munitions. Inspection in areas with a depth of up to 300 m will be carried out, using among others, a wire guided *Super Achille* ROV, used by the Department of Underwater Works Technology of the Naval Academy since about 2002, for inspecting sea and inland waters. The CHEMSEA project envisages the modernization of the *Super Achille* vehicle to enable the collection of bottom sediment and water samples [69]. Technical data of this type of ROV is available at the website of Arena Sub s.r.l. [70].

The "conquest" of the aquatic environment by unmanned vehicles of "unconventional" design takes place not only by means of "fish-imitating" objects, but also by those in the shape of a sphere (*GuardBot*, as *Spherical Amphibious Robotic Vehicles System*) [71].

6. Summary

The above overview of existing solutions and prototypes in the field of UVs indicates that such equipment will be an important element of prospective battlefields in outer space, air, on land, on or under water. Systems are being built to enable military operations in a variety of environments, such as an unmanned "motorboat" equipped with a drone. The dynamic development of UVs occurs in both the military and civilian sectors. In the latter case, besides the aspect of entertainment, the functionality of UVs is very important as a part of rescue missions and countering chemical and terrorist threats. In addition to the obvious direction of development, *i.e.* adapting manned vehicles to function as UVs, constructions using the shapes and behaviours of animals (movement of fish, land animals) or even people, are being developed.

The following regularities can be identified in the field of developing UV armament:

- 6.1. In addition to the commonly described use of UVs as an unarmed reconnaissance tool, information on their use as an offensive weapon is being disclosed more often. The armament used on manned vehicles constitutes the equipment of UVs. The type of armament dominating in individual UV groups strongly depends on the environment in which they operate:

- a) small land UVs – machine guns up to 7.62 mm calibre,
- b) large land UVs – machine guns up to 9 mm calibre and explosives up to several tens of kg,
- c) marine UVs – rockets weighing in at 30 kg together with the launcher, mines up to several tens of kg,
- d) aerial UVs:
 - large and medium: rockets weighing in the order of 30 kg together with the launcher, guided bombs up to 250 kg, EFP charges,
 - small VTOL – machine guns, including multi-barrelled 40 mm launchers.

In anti-terrorist operations, precision-guided munitions are preferred because the impact of the explosion outside the target of the attack is limited, mainly among bystanders.

- 6.2. The main advantage of UVs is the difficulty of detection, which is why rocket propulsion is preferred as it leaves the smallest possible trace of the rocket's flight path. An important direction in the development of rockets carried by drones is the possibility of attacking several objects, preferably on the «fire and forget» principle.
- 6.3. The choice of armament depends on its impact on mobility, *i.e.* there is a preference for armament which provides maximum firepower with minimum weight and small dimensions. Therefore, explosives with the highest energy concentration are sought.
- 6.4. Deployment of “disposable” UVs as bombs is so expensive that the main area of development of this type of UVs will be reusable constructions, *i.e.* a “carrier” prepared for many missions, capable of self-defence, transporting remotely initiated explosives.
- 6.5. UV armament will evolve towards the possibility of multiple attacks during one mission, *i.e.* two smaller bombs instead of one large one. Reducing the visibility of the flight path trace of a missile launched from a drone can be obtained not only by using low signature rockets, but also guided bombs without rocket motors.

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Polish version:

The work was originally published in Polish, in the High Energy Materials Journal (Materiały Wysokoenergetyczne) 2014 (6): 53-63. Polish version is available in PDF-format at: http://www.wydawnictwa.ipo.waw.pl/materialy-wysokoenergetyczne/materialy-wysokoenergetyczne6/HEM_0102.pdf

English version:

– Revised: November 28, 2019

– Published first time online: December 6, 2019