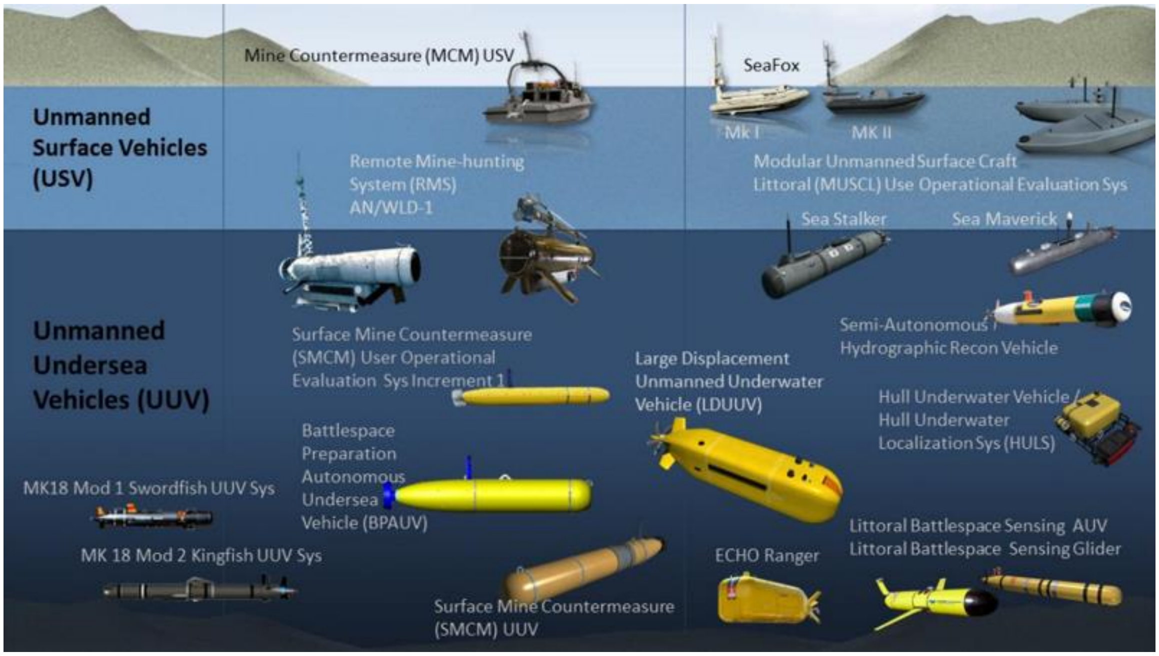
Unmanned Vehicles in the Maritime Domain:

Missions, Capabilities, Technologies and Challenges[1]



Eyal Pinko

Background

In January 2017, during a routine patrol in the Gulf of Aden, a vessel of the Saudi navy was damaged in an attack carried out by the Houthis using an unmanned suicide vehicle. The vehicle was apparently controlled from a distance. American sources believe that it was supplied to the rebel organization by Iran.[2]

This event is highly significant in the domain of maritime warfare, even if it did not gain much media attention, since for the first time an unmanned vehicle was operated from a distance in a real warfare environment and its full operational capability was demonstrated. This event has the potential to change the configuration of the future maritime battlefield, its strategies and its tactics and will contribute to the understanding that major changes are occurring within it.

[1] From http://gentleseas.blogspot.co.il/2016/02/us-diesel-remote-multi-mission-vehicle.html
[2] Cavas Christopher, New Houti Weapon emerges: A Drone boat (19/2/17), retrieved from: https://www.defensenews.com/digital-show-dailies/idex/2017/02/19/new-houthi-weapon-emerges-a-drone-boat/, accessed 9/2017

The changes in the maritime battlefield are related, on the one hand, to the increasing application of asymmetric fighting doctrines[3] (that are implemented primarily by China, Iran and their allies) and to littoral warfare (primarily the protection of national infrastructures and economic waters); and on the other hand to the application of technologies and integration of unmanned platforms in naval warfare, which will in the future occupy an increasingly important place in this type of warfare.

It is the view of the US Department of Defense that unmanned vehicles (in the air, on land and at sea) are and will continue to be the preferred option as fighting systems for scenarios and missions that are characterized as "dirty", dangerous or "boring".[4]

In the aerial domain, both in Israel and other countries, unmanned vehicles have in recent decades increasingly occupied a permanent and central place on the battlefield and even in the civilian sector. In times of peace and in a variety of systems, unmanned aerial vehicles are used for gathering intelligence, observation, attacking targets, electronic warfare and more.

Furthermore, in various countries around the world, unmanned aerial vehicles are expected to replace manned aircraft in coming decades. The unmanned aerial vehicle technology is becoming increasingly advanced and they provide a huge economic advantage and the capability of carrying out a diversity of missions, for relatively long durations, at long ranges, with a low signature and without endangering human lives.

Experts claim that the level of sales of unmanned aerial vehicles is expected to reach $15 billion in 2020 (for both military and civilian uses).[5]

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[3] Asymmetric warfare includes attempts to bypass or undermine the strengths of an adversary, while exposing its weaknesses and points of vulnerability. The weak side does this by using methods that are significantly different from those used by the stronger side. Asymmetric warfare includes almost any action used by the weak side in battle in order to overcome the strong side, particularly if the action is creative and can surprise the other side.

The weak side makes use of non-conventional tactics, weapons or technologies, which can be used at all levels (strategic, tactical, and operational), over the entire spectrum of military operations and at all ranges of fighting. It will even use technologies that neutralize those of the stronger adversary. Naval asymmetric warfare constitutes a challenge and a major threat to modern navies and puts into question their traditional roles.

Navies are being forced to deal with asymmetric abilities and tactics for which they have no response. They were not built to deal with them and naval warfare tactics have not been developed that are effective against adversaries that make use of these tactics.

[4] DoD, U. S. *Unmanned systems integrated roadmap: FY2013-2038* (2013)

[5] Salame David, "Unmanned Vehicles in the Maritime Domain: Challenges and Trends", *Maarahot* 456. [Hebrew]

In the maritime domain, unmanned vehicles are used on a smaller scale and mainly in civilian missions (usually for academic and applied oceanographic research), policing tasks and protection of ports.

The operation of unmanned maritime vehicles in military missions is relatively uncommon and among the countries that do make use of them are Israel, Jordan, Singapore, Iran, the US, Britain and various countries in Europe.

A number of countries are carrying out research to test and develop concepts, fighting doctrines and applications for unmanned maritime vehicles, and a number of countries, primarily in Europe, have begun processes to test unmanned platforms, which are used in the development of capabilities and technologies and in scenario testing, as well as the development of methods of operating unmanned platforms in warfare and in peacetime uses.

Israel is involved in the development (and even the limited use) of a number of unmanned maritime vehicles in two main types of missions: the detection and destruction of submarines (including the already proven capability of firing torpedoes); and the protection of ports, including the ability to fire cannons and short-range missiles, as well as the ability to implement electronic warfare measures.

The transition to the development of unmanned platforms is the result of several factors: The first is the need to operate in littoral warfare situations and asymmetric warfare situations. The second is the existence and maturity of technologies that enable the development of unmanned maritime vehicles. The third is the reduction in defense budgets, particularly in the Western nations, which has motivated navies to reduce their costs. Unmanned vehicles make it possible to reduce costs considerably in terms of both acquisition of vessels and their operation and maintenance.

The final factor behind the accelerated development of unmanned platforms is the desire to reduce manpower and to minimize the risk to human life as much as possible.

This chapter presents an up-to-date overview of unmanned vehicles, including the mapping of potential missions, required capabilities, advantages and disadvantages of their use, key technologies in use and the challenges of integrating unmanned maritime vehicles in navies and military applications. The article will not deal with the civilian uses of these vehicles.

Definitions and classifications

A maritime unmanned system (MUS) operates without a crew onboard and includes at least one unmanned maritime platform with the ability to operate autonomously (i.e. entirely without the intervention of an operator during the mission) or is operated from a distance during part of a mission or its entirety.

Unmanned maritime vehicles can be classified according to a number of criteria:

a. Type of vehicle.

b. The dimensions of the vehicle: length and displacement (weight).

c. Level of autonomy.

d. Type of mission.

There are three types of maritime unmanned vehicles:

a. **Unmanned Surface Vehicles (USV):** These are vehicles that are self-propelled and sail above the water. The vehicle can be controlled by a distant operator or can be autonomous.

b. **Unmanned Underwater Vehicles (UUV):** These are essentially submarines that are self-propelled and usually operate with full autonomy.

c. **Glider:** This is an unmanned vehicle without its own propulsion system.

There are four levels of autonomy for unmanned maritime vehicles:

a. **Non-autonomous:** only human operation in all stages of the mission. The operation is carried out by means of a communication channel from a distant operating station to the vehicle and usually according to information and indications received through the channel of communication from the vehicle (for example: video images, sensors that provide the location and situation of the vehicle, etc.).

b. **Autonomy according to authorization:** The vehicle has the ability to carry out certain functions according to predetermined authorization of the operator (or it is determined during the mission), where the functions are planned and programmed ahead of time (or example: a predetermined course).

c. **Controlled autonomy:** A vehicle with the ability to carry out numerous functions independently according to logical protocols; although certain functions require approval of an operator before being carried out (such as approval to open fire).

d. **Full autonomy:** A vehicle with full capability to carry out its missions, including decision making during them, according to the conditions of the environment or the situation of the vehicle.

Figure 1 – Underwater unmanned vehicles[6]

Potential missions

The potential military applications of unmanned maritime vehicles can be divided by type:

a. Unmanned surface vehicle (USV)

1. **Detection of sea mines** with emphasis on the entrances to ports or in their vicinity (Mine Countermeasures – MCM).
2. **Anti-submarine warfare (ASW)** which includes the detection of submarines and firing of torpedoes or dropping of depth charges
3. **Guarding essential facilities**, ports or commercial sea lanes (Maritime Security – MS).
4. **Surface warfare (SuW)** includes capabilities of detection and firing of missiles or cannons and electronic warfare capabilities.
5. **Gathering of intelligence** at long ranges by means of passive detection systems (such as SIGINT or ELINT systems), gathering of acoustic signatures of sea vessels (ACINT) and/or visual observation systems (Intelligence, Surveillance and Reconnaissance – ISR).

[6] http://cimsec.org/wp-content/uploads/2015/05/LDUUV-18-Nov-2014.jpg

6. **Special operations support (SOS)** includes capabilities of detection, electronic warfare, conveyance of cargo, target saturation, etc.

7. **Electronic warfare (EW)** whose goal is to disrupt the adversary's detection systems and support manned vessels in the interception of enemy missiles.

b. Unmanned underwater vehicles (UUV)

1. **Gathering of intelligence** by means of passive detection systems (such as SIGINT or ELINT) and gathering of vessels' acoustic signatures (ISR).

2. **Detection of sea mines** (MCM)

3. **Anti-submarine warfare** including detection and attack (ASW).

4. **Mapping of the ocean floor** in order to build an underwater database to be used for navigation of submarines and the mapping of navigation obstacles in the sea for maritime vessels.

5. **Conveyance of cargo** and supplies.

c. Gliders

1. Relay for communication channels.

2. Mapping of the ocean floor.

3. Detection of sea mines.

Figure 2 – The Protector unmanned Surface vehicle, which carries the Typhoon gun mount and Spike antitank missiles.[7]

[7] https://armadainternational.com/2017/03/rafael-launches-spike-missiles-from-protector-usv

Advantages of unmanned maritime vehicles

The contribution of unmanned vehicles to maritime military operations is derived from the missions that the vehicle is capable of and its operational advantages:

Nonetheless, a number of generic advantages of unmanned maritime vehicles can be defined:

a. **Autonomy**: The ability to independently carry out missions of prolonged duration can be a force multiplier for a navy and can assist it in carrying out important and complex missions.

b. **Risk reduction**: Reducing exposure of combatants to risk (from adversaries or natural phenomena).

c. **Deployment and operation** from various platforms: unmanned vehicles can be sent from other maritime vessels to a wide variety of missions.

d. **Perseverance:** dealing with various ocean situations and ability to continue the mission, without risk to crew or of mission interruption in severe weather conditions.

e. **Cost:** The cost of unmanned platforms is low relative to manned platforms, in terms of both acquisition and manpower needed for maintenance and operation on the one hand and training and maintenance on the other.

f. **Genericity:** Use can be made of existing civilian platforms and other civilian components that are cheap and accessible (without having to develop them), as well as robots.

g. **Modularity:** Various modules can be combined in unmanned maritime vehicles (such as attack, submarine warfare, gathering of intelligence and electronic warfare) and thus their function and mission can be changed with relative ease.

Figure 3 – Seagull unmanned surface vehicle fire torpedo[8]

Required capabilities

The main capabilities required of unmanned maritime vehicles (both surface and underwater) are the following:

a. The ability to work and **survive** in stormy seas (surface vehicles and gliders) and in strong currents (emphasis on underwater vehicles).

b. Long operating duration (primarily underwater vehicles).

c. **Robustness** and ability to endure long-term and long-range missions with respect to reliability, performance and energy.

d. **Versatility and modularity:** Modular ability to be fitted with various weapons and equipment and according to the mission required of the vehicle.

e. **Stealth:** Low signature which hinders the adversary's detection systems (optical, acoustic and radar).

f. **Physical protection** of the vehicle (against hostile takeover or being fired upon).

[8] http://elbitsystems.com/pr-new/elbit-systems-seagull-successfully-completes-torpedo-launch-trials/

Technologies

In recent decades, a large amount of research has been carried out and technologies have been developed for various autonomous systems, including aerial, ground and maritime systems.

A large portion of the technologies have already reached maturity and can be installed on unmanned maritime platforms while others are still in the processes of R&D.

The key technologies required for the application of unmanned maritime vehicles are the following:

a. Sensors (radar, optical and electronic warfare).

   1. Miniaturization of sensors while maintaining their performance (or improving it).

   2. Minimizing fuel consumption.

   3. Endurance of difficult environmental conditions.

   4. Reliability and high availability.

b. High-capacity energy sources, of dimensions that enable their installation on a relatively small unmanned maritime vehicle and which allow for long-term and long-range operations.

c. Communication that is immune to attempts at disruption, is secure and encoded in high-speed transfer files and is capable of long distance transmission (including underwater).

d. Dynamic mission-planning ability prior to and during a mission, including artificial intelligence abilities.

e. Ability for coordination and autonomous activity between platforms and coordinated activity in a network.

f. Precise navigating technologies (specially designed for unmanned maritime vehicles) and protection from disruption and deception.

g. Autonomous steering ability, including exact navigation (by means of cross-referencing information from the vehicle's sensors and GIS data) and avoidance of navigation obstacles (dynamic or static).

h. Technologies to reduce the vehicle's signature (radar, acoustic and thermal).

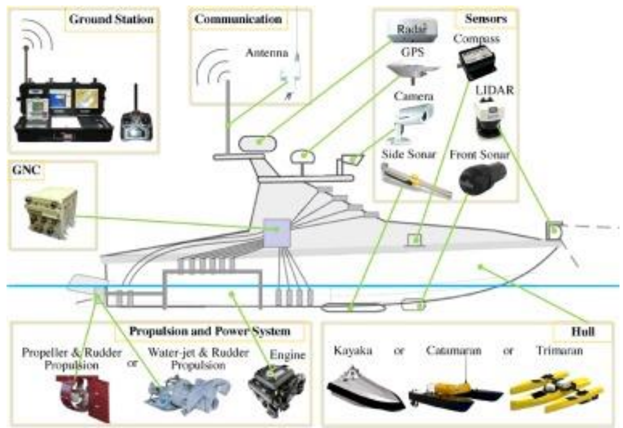

Figure 4 – Systems and technologies of a unmanned surface vehicle[9]

Development of battlefield doctrine

There is need to learn, define, develop and test the maritime warfare doctrine for the integration of unmanned maritime vehicles within the navy's missions (whether independent missions or missions in which manned vessels and unmanned vehicles are combined).

The battlefield doctrine that includes use of unmanned vehicles may include a number of components:

a. Guarding and security:
    1. Short ranges: protection of port entrances and infrastructure sites along the coast.
    2. Intermediate ranges: protection of critical state infrastructures in Exclusive Economic Zones.
b. Warfare:
    1. Assistance in the protection of manned vessels on the open sea ("blue water") against surface and underwater threats.
    2. Assistance in the protection of manned vessels in littoral warfare.
    3. Assistance in special operations.
c. Intelligence and infrastructure:
    1. Gathering of information.
    2. Mapping (oceanography).

[9] http://www.sciencedirect.com/science/article/pii/S1367578816300219#fig0001

3. Logistical support.

The integrated maritime warfare doctrine should take into account a number of criteria:

a. Identification and mapping of missions in which unmanned vehicles are a significant force multiplier.

b. An analysis of missions and study of performance with regard to the required number of vessels that need to operate simultaneously, the number of vessels required for backup (logistical redundancy), etc.

c. Time at sea and definition of mission lengths that are characteristic of the platforms.

d. Motion: speed and maneuverability.

e. Degree of autonomy and degree of involvement of the operator.

f. Modularity and ability to carry out a variety of missions.

g. Ability to destroy targets and killing power that is required and can be created by the vessels (for missions that are part of a naval battle).

h. Effectiveness of the use of the various sensors (such as the range of detection by radar, optical means or the detection range of sonar for detection of submarines).

   Consideration of the effectiveness of the sensors is important since the mast height of an unmanned vehicle is usually very low and the installation of detection instruments on the vehicle will lead to relatively low detection ranges.

   In the underwater dimension, the vehicles are usually acoustically noisy and their noise is liable to lessen detection ranges (although there are technological solutions for this as well).

i. Compatibility and integration within the navy's other systems (command and control systems, communication systems, encoding, electromagnetic capability and the like).

j. Transport: The requirements for transport of the vehicles on other vessels and the manner of their launch and pickup after the mission.

k. Survivability of the vehicle from the perspective of environmental conditions.

l. Mapping of the threats to the vehicles and assessment of the protection required (physical protection against hostile takeover, protection against cyber attack on the vehicle's systems by way of its communication and control systems and protection against other threats such as attacks using various types of weapons).

m. Identification of existing technologies and of technological leads that need to be developed.

Challenges

Navies that wish to integrate unmanned maritime vehicles as part of their capabilities face a number of challenges. These can be divided into a number of categories:

The first challenge is cultural. Navies throughout the world are by nature conservative, particularly at the level of decision makers, and find it difficult to accept change and in particular changes involving the introduction of unmanned vehicles that will replace manned vessels or will operate together with them.

The second challenge is the formulation of strategies and an overall operational doctrine, including the definition of missions for unmanned vehicles, their integration within the navy's missions and the operational strategy in various warfare scenarios (for ongoing security tasks and in conflict) and formulation of command and control processes (including the authority to open fire from unmanned vehicles that combine weapons and command and control positions on the shore or on another vessel), etc.

The third challenge is to protect the vehicles, which has a number of elements: The first is the physical protection of the vehicle, particularly vehicles with a high level of autonomy, from capture and takeover. In this context, it is worth mentioned as an example the capture of an American unmanned underwater vehicle by the Chinese navy in December 2016. The second element is protection of the vehicle against various types of weapons (bullets, shells and even missiles). Another element is protection against cyber threats and electronic warfare, particularly in the case of vehicles controlled through communication channels.

There is another group of challenges which are technological and which make possible the development of the vehicle's capabilities. Among the most significant technological challenges are: energy (prolonged operation of the vehicle and its systems); precise navigation systems (particularly for underwater vehicles); miniaturization of sensors (to reduce power output and to be able to fit them on the

vehicles) while maintaining high levels of performance and reliability; secure, secret and encoded communication; and the ability to work autonomously in a network, including coordination between all of the vessels.

Conclusion

The maritime domain plays a central role in a country's economy, its level of prosperity and its choices. Maritime trade grows every year and the reliance of coastal countries on maritime commerce and the production of offshore energy is increasing. Thus, for example, there has been a massive increase in recent years in the declaration of Exclusive Economic Zones and in the production of oil and gas in these territories.

The character of maritime warfare has also changed and navies who in the past built up blue water firepower and fighting capabilities are now placing emphasis on the development of capabilities and the buildup of force in scenarios of littoral warfare and protection of offshore assets. These scenarios are usually asymmetric and require naval power to deal with naval forces of terrorist organizations or countries that adopt asymmetric tactics, such as China and Iran.

Another prominent characteristic of modern maritime warfare is the ability to project force from sea to land at long range from the coast (such as the attacks carried out from sea to land in Syria by the Russians and Americans, attacks by the allies in Libya, etc.).

The traditional missions of navies, such as escorting convoys in time of war and maritime warfare against other navies, are diminishing in scope, nearly to the point that they don't exist at all. It can be said, for example, that there has not been a classic sea battle (i.e. one that includes one ship firing on another) for many decades, while asymmetric battles and scenarios for protecting critical infrastructures in economic waters, as well as the projection of power from the sea, are becoming increasingly common.

The characteristics of maritime warfare and the emphasis on naval missions in the modern era indicate that naval power must be versatile and must possess diverse capabilities. It must be able to operate in situations of high risk and particularly in situations of littoral warfare.

Unmanned maritime vehicles may be one of the main solutions in the development of diverse capabilities in modern maritime warfare situations.

Many countries, including Israel, the US, France, Iran, Holland and others, have begun to develop unmanned maritime vehicles for various applications and missions, some of them underwater and some of them above the surface.

Unmanned maritime vehicles, perhaps like unmanned aerial vehicles, have a huge potential in carrying out complex military maritime missions, with long durations and at long ranges from the coast. This potential has grown significantly alongside the potential reduction in risk to human life and significant savings in manpower, budgets and resources for the acquisition of vessels and their systems and their maintenance.

The realization of this potential will expand as supporting technologies reach maturity or to the extent that existing civilian technologies are integrated within unmanned maritime vehicles, that autonomous operating capability is improved and that the cultural barriers to the use of unmanned vehicles and the replacement of humans are lowered.

The use of unmanned vehicles will increase with the level of understanding that current and future maritime warfare situations are expected to be asymmetric and will primarily involve littoral warfare. In these types of warfare scenarios, unmanned vehicles have the ability to carry out relevant missions, at the required level of operational efficiency, at relatively low cost (of acquisition and maintenance) and without risk to human lives.

Our recommendation is to continue with the development of unmanned vehicles for naval missions, including the development of operational concepts and the integration of unmanned maritime vehicles within fighting doctrines and training exercises, as well as the development of capabilities to protect unmanned vehicles (i.e. electronic warfare measures) and the integration of attack capabilities within the vehicles, including the firing of missiles and cannons.

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