INTEGRATING MARITIME UNMANNED SYSTEMS ONBOARD MINE HUNTERS AT HEART OF STAND-OFF MINE CLEARANCE

Antony PENN, ECA GROUP, penn.a@ecagroup.com

Abstract

Developed by ECA GROUP, UMIS™ is the new generation Mine Counter Measure (MCM) unmanned system able to carry out any Mine Counter Measure (MCM) mission, using a collaborative system of surface and underwater robots even in the most challenging environments. In use within several navies since 2016, and being chosen in 2019 by leading NATO navies for MCM missions, the Belgian and Netherlands Navies, UMIS is a game changing solution for mine hunting at sea. It has proved to be faster in fulfilling operations, more efficient, cost-effective and safe, as the crew is kept away from minefield. Comprehensive and modular, UMIS™ includes a wide range of interoperable unmanned vehicles such as USVs, UUVs (AUVs, ROV, MIDS ROVs), towed sonars, UAVs, etc. UMIS™ also integrates UMISOFT™, a C2 MCM comprehensive software suite allowing easy and complete management of the entire unmanned mission: preparation, run and supervision, data processing, analysis and management. UMISOFT™ enables to manage parallel drones missions, robot-from/on-robot deployment (such as USV deploying and retrieving a UUV) as well as automatic launch and recovery systems (LARS from USVs) and can be integrated into the combat management system (CMS) of the vessel (MCMV).
We believe that next generation mine counter-measure vessels will be shaped by unmanned systems onboard.

ASSESSMENT ON RISKS AND THREATS OF MARITIME MINES

Naval mines can be used in offensive purpose, to ensure destruction of enemy's assets or to deny access into a harbor, to block a choke point... Mines represent the majority of these threats since their objective is to at least damage ships, at most to sink or destroy them completely. Easy to produce and deploy, this relatively cheap mean with a great destruction potential attracts also terrorist organizations.

Used in defensive way, mines are used to protect own or allied force's assets in order to control a "safe" zone.

Yet there are also remnant bombs dropped during World War II with some 400 000 mines estimated lying in the Baltic Sea, North Sea and the Channel. Not to mention those dropped during more recent conflicts and some hundreds of millions of them still remaining in stock all over the world.

Maritime mines have become a threat when found at the bottom of a harbor or in a fishing area since their explosive material can still be active despite decades spent in seawater; they may also have become unstable over time, which makes them potentially even more

dangerous. They represent a threat for economy, since over 80% of world's trade is carried by sea.

In the last decades several incidents causing material damages and human lives losses at sea have been reported (e.g. USS Samuel B Roberts in 1988, USS Princeton in 1991, then more recently in 2018 s ships, including minehunters, have been damaged by mines used in Bab-el-Mandeb Detroit area).

PASSIVE AND ACTIVE MINE COUNTER MEASURES – TWO DIFFERENT BUT COMPLIMENTARY APPROACHES

There are two approaches for Mine Counter Measures: passive and active. Passive approach implies a certain number of preventive measures to design and equip the vessel in order to minimize the risk for a ship to detonate the mine and/or to resist to mine detonations while the active measures deal with mine hunting and their neutralization or destruction.

Magnetic Risk Management as A Passive Protection Against Mines: From Platform Design to Maintenance Treatment

The first implies to design, build, equip and maintain the platform in the way to protect it from mine activation and detonation by controlling its magnetic and acoustic signatures. Therefore, the design of the platform is specific: the hull built of fiber glass or wood and equipped with a low acoustic signature propulsion systems. Yet these kind of ships are expensive, can be slow and therefore vulnerable to enemy's attacks. More affordable and stealthy at sea, steel-hulled ships used by most navies can preventively be fitted with degaussing systems and/or depermed using underwater deperming stations. The magnetic signature of the ship is a critical point when it comes to mine threat. Degaussing systems installed onboard vessels as well as deperming of ships reduce the risk of magnetic sensors detecting the steel hulls of both surface ships and submarines. Degaussing reduces magnetic signature by passing an electric current through coils arranged inside the ship depending on the ship's heading, position on the globe…whereas deperming is an operation performed from time to time in order to reduce permanent magnetization of a vessel (surface ship or submarine). Both aim at altering the magnetic signature of the vessel in order to protect vessels by acting as a form of camouflage from magnetic detection, and as a precaution against magnetic mines.

The traditional deperming process sees the entire ship or submarine wrapped with a massive wire coil. Electricity is then passed through the coil to reduce the magnetic 'signature' of the vessel - a process that can take up to 10 days.

An innovative approach uses wire coils laid down on the sea bed through which an alternating current is passed as the vessel moves over the coils. This deperming 'over-run' process takes less than one day and therefore provides a significant operational and economical advantage when compared to the traditional wrapping.

The new-generation deperming system developed by ECA GROUP and proposed to the RAN by Advanced Magnetic Ranges Australia Pty Limited (AMRA - a French-Australian Joint Venture bringing together Amog, Tycon and ECA GROUP) simplifies this laborious process significantly and reduces the time required from as much as ten days to about one day. It is an 'over-run' treatment range for submarines and surface ships with:

- Magnetic treatment of both submarines and frigates
- Fast treatment time (low down time)
- High precision of measurement and treatment
- On-board Degaussing system calibration and checking
- Low maintenance needs
- Overrun station that operate without any cable-wrapping operations – Reduced manual handling
- Treatment loop and sensors that are fixed so displacement-related damages are avoided and maintenance is reduced.

Ship trajectory over the underwater coils and magnetic sensors is determined accurately through a DGPS system. The over-run treatment range can be combined with the RAN's existing multi-influence range that is designed to detect and measure a variety of other 'signatures': acoustic, magnetic, electric, and pressure. ECA GROUP manufactures ranging systems for the French Navy and is installing a similar over-run range for another South East Asian Navy.

Active Mine Counter Measures: Threat Detection And Neutralization - Two Distinct And Complex Operations

Though it is a complex matter to detect remnant underwater mines and ammunition[1] lying on the bottom of an ocean, it is equally complex to have sea divers destroy them due to environmental constraints (e.g. sea currents, water depths, etc.).

This led naval forces and the industry worldwide to develop systems designed to reduce the risks associated with neutralizing such threats while optimizing the effectiveness of such disposal operations, i.e. destroying the largest possible number of threats in the shortest possible time.

One of the first effective systems built to eliminate underwater threats stemmed from France's ambition to develop its own nuclear deterrent weapons delivered by submarines. With its nuclear powered ballistic missile submarines (SSBN) based in the Brest roadstead, the French Navy had to be able to detect and destroy any underwater threats on the access routes of these submarines to make its deterrence concept credible. This was one of the main reasons behind the development of the French Navy mine-hunting fleet.

Minehunter Ships As Main Response to Mine Threats Since 1970

Maritime mine clearance has conventionally been conducted since the 1970s by dedicated ships called minehunters. Mines are detected and classified using mine-hunting sonar systems installed under the ship's hull or towed by the ship. Sonars retrieve seabed images and the analysis is made by specialized operators onboard.
When detected, objects that are likely to be mines, a mine identification and neutralization vehicle, such as a PAP or mine killer (such as K-STER), is deployed to identify and neutralize the mine.
The cost of these ships can be astronomically high as they need to be able to enter minefields and detect mines without being detected by the mine, which would trigger its explosion.
Were any mines to explode, the ships also need to be able to withstand or at least survive such a blast.

In addition to a non-magnetic hull, resiliency of these ships and their equipment is paramount, today's military standards require a large number of protection systems such as degaussing, shock resistance, low radar and acoustic signatures or CBRN protection.

The growing and evolving threat (more and more sophisticated mines fitted with acoustic sensors to detect, localize and recognize particular a target such as military ships, asymmetric threats such as underwater IED and new conflicts) generated the need to operate more safely, keep crews out of danger zone, protect costly equipment onboard and reduce operations' costs and time, has led navies to specify and evaluate different automated solutions through several R&D programs (SeaKeeper, ESPADON, etc.) challenging industry to develop new operational solutions.

New solutions are now available, naval drones also called unmanned systems are integrated within naval forces and especially Mine Clearance units. These drones can be autonomous underwater vehicles (AUV) or unmanned surface vehicles (USV). French mine clearance divers (GPD), Latvian and Romanian Navies use A9 AUVs, Kazakstan Navy uses INSPECTOR class USVs, Singapore Navy uses USVs equipped with mine-killers. They can be remotely deployed in the minefield by specialist mothership, non-dedicated ships or from land. In order to detect and classify mines, they carry or tow acoustic sensors. In order to identify and neutralize mines, these naval drones (especially USVs) deploy other drones that are remotely controlled from the support vessel or from land.

One example is the Unmanned Mine Counter Measures Integrated System (UMIS^{TM}) developed by ECA GROUP. This system is a result of decades of developments in robotics, hydrodynamics and IT systems in order to address the growing need of operational autonomy at sea.

Mine Countermeasures: Legacy vs. Stand-off concept

Several decades of mine hunting using dedicated ships show some shortfalls of traditional and current mine hunting concepts.

Existing high frequency sonars are designed to detect ground and in-water mines and are ill-suited to detection of mines near the interfaces (e.g. drifting and buried mines)… Detection of buried mines is known to be feasible with low frequency sonars (e.g. parametric sonars or synthetic aperture sonars, possibly even combinations thereof) operated close to the seabed, mounted on towfish or AUVs. The other steps, such as buried mine classification, identification, relocation and neutralization remain very challenging today.
A near surface sonar is not suited to the detection of drifting mines due to lack of "height of eye". An airborne LIDAR is a more effective solution.

The second is the operations time since the ship's hull mounted sonar cannot function properly at high speed and the operations are made in sequence by the minehunter: detection/classification then identification/neutralization.

The third is the risk for personnel especially when it comes to enter the minefield or to dive for a mine neutralization operation.

Delivering the UMIS™ system to the first customers in 2016 and being evaluated then chosen by Belgian and Netherlands Navies to provide a set of unmanned systems as a 'toolbox' for the next-generation mine counter measures operations for NATO missions, ECA GROUP's solution has proven to be faster in fulfilling operations, more efficient, cost-effective and safe, as the crew is kept away from minefield. Using conventional mine hunters on a minefield have many drawbacks.

First, the high cost to reduce the ship's magnetic signature to a very low level. Secondly, the ship detects mines using a Hull Mounted Sonar (HMS) of which mine classification depends, on its range and resolution. ECA GROUP sonar expert Dr. Marc Pinto explains that "*Physics of sonar dictates that you can't have both range and resolution: Long range sonars have poor resolution. High resolution sonars have very limited range. With conventional mine hunters, it is either required to approach and manoeuver close to the possible mine for a good classification, which is risky and time-consuming, or, the minehunter stays far from the targets, leading to a low resolution and a high probability to miss some mines, which is also a high risk*".

In comparison, ECA GROUP's UMIS™ deploys Autonomous Underwater vehicles (AUVs) carrying the sonar close to the seabed and Unmanned Surface Vessels (USVs) which bring identification and disposal vehicles in the minefield, leaving the mothership away in a safe zone. The UMIS manages a set of drones which cooperate autonomously into the dangerous area. "It is proved that, operating in parallel, the UMIS system can divide by 3 at least, the time of missions, and comes with a higher efficiency and clearance rate." reports

VADM (Ret.) Christian CANOVA, FRN, Undersea Warfare Expert and former NATO Maritime Command Deputy Commander.

TECHNOLOGICAL ADVANCES ADDRESSING NEW OPERATIONAL CONCEPTS: THE BELGIUM AND NETHERLANDS NAVIES "TOOLBOX" CASE

In 2017 Belgium and Netherlands Navies specified their requirements for the replacement of their MCM fleet (tripartite mine hunters in operations since 1985 built by Naval Group and equipped by ECA GROUP with PAP mine identification and disposal ROV) after two unmanned MCM trials conducted in August-September 2016 and Mid-2017. The two navies adopted a completely new approach, the stand-off mine hunting concept requiring a new technological solution for the unmanned system as well as the ship for its deployment.

In May 2019 the Belgium Naval & Robotics consortium, composed of Naval Group and ECA GROUP, was notified the contract to supply twelve mine-hunting vessels to the Belgian and Netherlands navies, leading navies for Mine Counter Measures in NATO. Six ships are destined to the Belgian Navy, while the other six will be delivered to the Netherlands Navy. As a part of the contract around 100 drones, constituting approximately ten drone systems (toolboxes) will be delivered by ECA GROUP.

The contract, worth nearly two billion euros, will last ten years. After a design phase of the ship and adaptations for the tools, Belgium Naval & Robotics will launch the production phase of the ships and drone systems with a first delivery in 2024. This contract includes a vast cooperation plan with the Belgian industry in order to carry out a significant part of the contract in Belgium, in particular the production of ship equipment and naval drones composing the toolbox as well as their maintenance. The winning offer includes also training solutions using virtual reality to be implemented at NATO MCM training center in Ostende as well as an implementation of two R&D labs dedicated to cybersecurity and mine counter measures unmanned systems. Over 39 Belgian industry and scientific partners are involved in this program.

An Innovative Solution For Robotic Mine Warfare As A Response To An Operational Need

Belgium Naval & Robotics, thanks to Naval Group's recognized expertise, will deliver a militarized ship with military characteristics (acoustic and electromagnetic discretion, shock resistance) adapted to the operational use targeted by the Belgian and Dutch navies designed for mine warfare using an ECA GROUP system of robots. In particular, this vessel incorporates a launch and recovery system for ECA GROUP's INSPECTOR 125 unmanned surface vehicles (USV). This innovative, robust and reliable system ensures the safety of operators and enables to protect the ship, the USV and its payloads, while offering a high level of mission availability.

The drone systems on board these new-generation vessels are composed of latest generation of drones developed by ECA GROUP. They are integrated into the ECA GROUP command and control MCM UMISOFT™ system that is connected to the Naval Group's I4drones® system to

form the mine-warfare mission system itself interfaced with the ship's combat management system.

The solution includes: A18-M autonomous underwater vehicles (AUVs), T18-M towed sonars and Mine Identification & Destruction Systems (MIDS) composed of SEASCAN and K-STER C remotely operated vehicles (ROV). All these drones can be operated autonomously from the USV INSPECTOR 125. The drone system also includes unmanned aerial vehicles (UAVs) and influence sweeps.

The program provides for the supply of drone systems that can also be used for expeditionary mine warfare. Containerized and equipped with handling and communication systems, the mine-hunting drone systems can be airlifted and deployed directly from the coast without the need of a ship.

Toolbox To Configure According The Mission: UMIS™ as a modular and mobile MCM system

The UMIS™ toolbox is particularly interesting as a flexible and stand-alone unmanned solution. To meet navies' requirements and their logistic constraints, ECA GROUP designed specific storage and transportation equipment for each possible configuration. The containerized configuration can be deployed in coastal areas, ports and harbors.

A typical UMIS™ configuration is its containerized version that is composed of a dedicated C2 container and its set of containers for the "tools" themselves. Only ISO containers are used in order to facilitate their transportation and deployment.

The C2 container will be deployed on land or installed on ship of opportunity, while the drones will be able to be deployed from beaches, river banks, port docks, etc. or non-dedicated ships. The main functions of the MCM C2 system is to operate the drones like USV INSPECTOR 125, mid-size AUV A18-M, towed sonar T18-M, MIDS configuration made of inspection ROV SEASCAN and the "mine killer" K-STER and men portable AUV A9-M and its equipment such as LARS (Launch and Recovery System), but also to prepare the missions and tasks, process and manage the data collected.

A complete UMIS™ in its containerized configuration is air-transportable and can be deployed very quickly anywhere in the world. It is fully compliant with safety and transportation standards.

Reducing the duration of the operations with drones missions "parallelization"

The Toolbox, consisting of stand-off (remote) sub-systems corresponds to the gradual change of paradigm in MCM, providing high-level flexibility in the planning and completion of operations that can be carried out in parallel and at a distance from the platform and its crew. This innovative solution increases the speed of mine clearance in a given area and above all, prevents exposing human life to the risks inherent to this type of operation.

The stand-off concept inherent to the project requires full control of durable, autonomous vehicles with a wide variety of payloads (including sonars).

Commonality For Operations Efficiency, Logistic Flexibility and Reduced Cost of Ownership

An important commonality of tools (eg: common software, AUV-derived towed sonar, common launching and recovery systems) allows an optimization of the logistics with an undeniable operational impact.

As an example, the T18-M towed sonar is derived from the A18-M autonomous underwater vehicle, which reduces the logistic footprint required by maximizing the use of common subsets between the two systems. In addition, since the tow fish is battey powered (such as the A18-M AUV), it is no longer necessary to feed it by its towing cable, which makes it possible to use a small diameter towing cable and consequently a smaller towing winch and a more compact electric generator aboard the USV the INSPECTOR 125 deploying it.

The reduction of the logistics footprint also extends to accessories, tools, software, spare parts that can be shared by several drones, for example battery chargers for A18-M / T18-M, battery replacement tools etc. .

The use of energy autonomous vehicles as for the T18-M towed sonar, but also for the ROVs SEASCAN for inspection and K-STER C for neutralization, allows the increase of their areas of use (maximum immersion and deployment distance from the surface drone) and their use in demanding environment conditions (up to 4 knots). This is made possible by the significant reduction in the diameter of the towing or connecting cables between the vehicles and the surface drone (USV), which reduces the hydrodynamic drag and therefore the efforts on the cables enabling higher performances (speed and or depth) that are impossible to achieve with vehicles powered by the surface drone whose size and mass are constrained by the ships they are deploy from.

These technological breakthroughs integrated into the robot systems that will be delivered to the Belgian and Dutch navies allow great flexibility in carrying out MCM operations.

DRONES SYSTEMS "TOOLBOXES" SHAPING NEW GENERATION MINE COUNTER-MEASURE VESSELS

Integrated approach – the system dimension central to MCMV missions

In the context of the Belgian/Dutch contract, the toolbox own mothership (MCMV) benefits from Naval Group's expertise in the complete chain of the Combat System (design - integration - maintenance) and provides an operational solution with a reduced risk. That expertise includes a consistent choice of off-the-shelf Sea Proven equipment, integrated and implemented via the Combat Management System (CMS). Rapid data processing, sharing of

the tactical situation (interoperability of the ship in joint or international operations) maximizes mission efficiency.

Naval Group and ECA GROUP offer an integrated global solution, the Integrated Mission Management System (IMMS), which brings together all the operational information systems of the MCMV and the MCM Mission System which provides end-to-end management of the Tools' mission (Supervision, Planning, Evaluation, Data Management and Analysis, Command / Control of vehicles).

A combination of the Mine Warfare (MW) and Planning and Evaluation (PE) components, the MCM Mission System is a solution based on existing products SMMD® and UMISOFT™ which has been the subject of technical cooperation between Naval Group and ECA Robotics since 2016. Within the ship's Command Information Center (CIC), operators coordinate all of the operations from their Multi-Function Consoles.

Which architecture for optimal deployment of UMIS™ drones systems?

In the Belgian-Netherlands MCMV replacement program, aspects related to the deployment, storage, maintenance and reconfiguration of the USV are crucial. This is for the deployment and recovery of drones, to minimize the constraints related to swell and movement of the platform, especially in high sea-state.

Naval Group has been working on this issue for many years and while different architectures have been imagined, such as stern ramps or gantry systems, Naval Group engineers have finally opted for a shipside launch and recovery of the USV. The major problem is the pitch which, unlike the roll, cannot be controlled by a stabilization system.
Of all the comparative and very exhaustive studies carried out, it appears that the best location is close the quiet point of the ship. In addition, the safest way is to adapt a preferential route relative to the swell and to be positioned at the right of the quiet point, which because of the forms of hull, is located between the middle and the back third of the ship. Analyzes and simulations have been multiplied and they have shown that this is the optimal location to deploy drones and in particular USVs in high sea states.

Beyond the calculations and simulations, this is a solution that is put into practice by the offshore oil industry, whose ships equipped with drones work in very harsh seas and also launch and recover their ROVs from the ship side.
Note that the ships will also, in addition to the side LARS, have the possibility of deploying their AUVs from the rear, using a hydraulic crane. The robots will then be launched and recovered using specific cages.

Consistent with the choices made for deployment and positioning, launch and recovery devices (LARS) were positioned at the quiet point. There are two of them, one on each side, in the form of tilting A-frames, associated with floating docks capable of handling the USV, who's mass can reach 18 tons.

A particularly innovative floating docks system has been conceived in a system approach and allows in particular to limit the pendulum phenomena of the assembly by working in a combined and automated way with the kinematics of the gantry combining guide arm, winches and a synchronized damping system as well as constant tensioning to limit the overall effort in ensuring the road stability of the floating dock.

Tilting LARS fit into the superstructure when folded. With this design, surface drones that are large and heavy equipment do not need to be moved for reconfiguration or maintenance. This is a real asset because it simplifies and secures operations. Not only for the personnel, but also for the mission because each handling operation presents a risk and it is thus necessary to limit them as much as possible in order to avoid damaging the USV and injuring the personnel.

It is also for the reason of redundancy that Naval Group has opted for two identical, symmetrical and independent LARS, which makes it possible, in case of possible failure of one device, to be able to continue the mission with the other one.

The LARS are located on each side of a large “garage” bringing together all the marine gear of the toolbox. Curtains closes this space, so sailors can proceed to maintenance or reconfiguration operations sheltered from the weather.

Conclusion

Since the beginning of the 20th century, ships and their crews had to enter the minefields in order clear the area. This was firstly made using mine sweeping systems towed by minesweepers, where the aim was to trigger mine fuses, in order to make the mine explode, or to cut the mooring line of moored mines. Then in the 50’s with the technology evolving, sonars and remotely operated vehicles appeared giving birth to mine hunting and minehunters. But in both cases the ships have to enter the mine fields in order to detect or neutralize the mines.

The progress made in the past decade, in batteries, computing technology, low consumption electronics, sensors, materials, communications have enabled the development of a complete range of unmanned systems (AUVs, USV,s) that are now available to be used to perform mine detection and clearance without having the need for the ship and her crew to enter the minefield. This is the route taken by the Belgian and Dutch navies to replace their current mine-counter measure fleet that selected ECA GROUP solution for the system of robots (toolbox) that will be provided as part of the program.

The contract is for ECA GROUP the result of two decades of innovation in underwater robotics and mine warfare as well as the recognition by two major NATO navies in the field of underwater mine warfare of ECA’s expertise in this area.

The toolbox solution that will be delivered to the Belgian and Netherlands navies can easily be adapted to fulfil any other navy requirement.