Increasing threat of stealthy, smart and lethal sea mines driving development of new Mine countermeasure platforms and systems

Traditional navies as well as maritime terrorists can and have used mines and underwater improvised explosive devices (UWIEDs) to challenge military and commercial uses of the seas. More than thirty countries produce mines, and twenty countries export them. Iran has reportedly laid several thousand naval mines, North Korea’s 50,000, China 100,000 or so, and Russia estimated quarter-million. Since World War II, sea mines have damaged or sunk four times more U.S. Navy ships than all other means of attack combined, according to a Navy report on mine warfare.

Sea mines range from cheap, simple explosive devices which many fear may fall in the hands of terrorists, to sophisticated computerized systems equipped with sensors and designed to wait hidden on the sea bed for years until the right target presents itself. They are fitted with acoustic, magnetic, seismic, and pressure sensors, which can pinpoint the size and shape of a ship moving in water and detect ship’s approach. They have become stealthier by minimizing their sonar profiles, smarter in distinguishing targets from decoys and evolved into lethal systems that can fire torpedoes. There are also rumors of nuclear armed mines in the inventories of China and North Korea. They have potential to become surprise weapon in any future war. Indeed, sea mines are key to regional navies’ anti-access/area-denial (A2/AD) and sea-
Mine warfare is important component of US Navy’s one of the nine S&T focus areas of “Assure Access to Maritime Battle space”. Proliferation of anti-access, area denial capacity and capabilities among potential adversaries drives the need for technologies that assure access for naval forces, says US Navy. The capability to detect, locate, classify and neutralise these weapons remains a key requirement for navies around the world.

Mine Countermeasures

Mine Countermeasures (MCM) include both minesweeping and mine-hunting. Influence minesweeping uses acoustic, magnetic, and pressure signals to detonate emplaced mines. Mechanical sweeping uses a towed sled or other type of device to cut the cables of moored mines. These mines then float to the surface and are detonated by other means.

Mine hunting is the safest and most effective method of dealing with mines, particularly with modern influence mines. Mine countermeasures vessels equipped with variable-depth sonars, hull-mounted sonars and minesweeping systems are primary systems to detect and remove mines. Upon identifying the target using sonar, the mine-hunter vessel neutralizes the explosive with the help of deep-sea divers or remotely operated vehicles (ROVs).

With improvements in autonomy, endurance, underwater navigation, data communication, detection and identification
sensors, Autonomous Underwater vehicles are increasingly being used for mine countermeasures.

Oceanic conditions greatly influence offensive mining and MCM operations. Variations in environmental parameters, such as bathymetry, salinity, temperature, tidal range, currents, water clarity, and seafloor character, can alter and significantly degrade sensor performance and reduce operational capabilities.

**Mine Countermeasure Platforms and systems**

The current primary MCM platform is the MCM class of ships that are of wooden construction, and meant to enter into a minefield to perform operations. The LCS is a metallic host ship designed to perform MCM remotely from outside the minefield by deploying unmanned systems to transit to the minefield and return after performing their missions. Looking forward, as more systems are being pushed to become expeditionary and platform-agnostic, these future MCM vehicles will need to be very modular and adaptive in terms of integrating into the host platform on which they might reside. Several USVs and UUVs are going through this development cycle, and the lessons.

The US Navy is trending towards a mix-and-match set of people, platforms and sensors to detect and destroy mines, said Marine Corps Maj. Gen. David Coffman, director of the expeditionary warfare division on the chief of naval operations staff (OPNAV N95), “The more the merrier in terms of diversity of approaches.”
The Navy’s “triad” of “dedicated” mine countermeasures forces comprises surface mine countermeasure ships, airborne mine countermeasures helicopters, and Explosive Ordnance Disposal (EOD) divers and their systems. Once a threat region has been identified and bounded, a sonar or laser detection sweep for candidate mines is conducted from an Avenger class ship (MCM-1), a LCS, or MCM helicopters (including the MH-60S or MH-53E).

The systems currently employed for detection and classifications are:
- SQQ-32 variable-depth mine detection and classification sonar (MCM-1)
- AQS-24 multi-beam side-looking mine-hunting sonar (MH-53)
- Remote Multi-Mission Vehicle (LCS)
- AQS-20A Mine Hunting Sonar (MH-60S and with Remote Multi-Mission Vehicle from LCS)
- AES-1 Airborne Laser Mine Detection System (MH-60S)

Another platform under consideration for detection and classification is the common unmanned surface vehicle (CUSV).

Once a field has been mapped and objects classified, the target data is used by neutralization assets to reacquire (locate), verify (identify), and if required, neutralize the target. The systems currently employed (or planned for future use) for reacquisition and neutralization are:
- SLQ-48(V) Mine Neutralization System (MCM-1)
- SLQ-60 SeaFox (LCS)
- AN/AQS-235 Airborne Mine Neutralization System (MH-60S or CUSV)
- Barracuda Mine Neutralization System (MH-60S or CUSV)
- EOD Divers with Navy Marine Mammals

US Navy is attempting to achieve a number of objectives concurrently, writes Maj. Gen. Christopher Owens Director, Expeditionary Warfare (OPNAV N95): “Our primary air and surface platforms must be replaced with multi-mission platforms—in particular, littoral combat ships and the
MH-60. Our primary hunting, sweep and neutralization systems must be replaced with new technologies that will do the time consuming, dangerous, and dirty work. We must continue to increase our clearance and confidence levels across our portfolio of mine countermeasures programs.”

Textron Systems Corp. is continuing its support for a fast unmanned boat designed to provide the U.S. Navy’s Littoral Combat Ship (LCS) with unmanned minesweeping capability to detect, pinpoint, and destroy ocean mines

The UISS, which uses the Textron Common Unmanned Surface Vessel (CUSV), will target acoustic, magnetic, and magnetic and acoustic combination mine types, and provide the LCS with a rapid, wide-area coverage mine-clearance capability to neutralize magnetic and acoustic influence mines.

US Navy’s fourth increment will deliver the Knifefish UUV, a development lead by General Dynamics Mission Systems based on the Bluefin-21 UUV equipped with a side-scan sonar that will provide a buried mine-detection capability up to a speed of three knots (5.5 kilometres-per-hour) to a depth of 275 metres/m (902 feet/ft).

**BAE Systems to deliver Archerfish mine neutralisers to US Navy**

The US Department of Defense (DoD) has contracted BAE Systems to manufacture and deliver Archerfish mine neutralisers and to continue supporting its minesweeping operation. BAE will manufacture Archerfish, which is a remotely-controlled underwater vehicle equipped with an explosive warhead, at its Broad Oak facility in Portsmouth, UK, and will also supply fibre-optic spools.
Deployed from a launch ‘cradle’ with a fibre-optic data link providing exacting command of the weapon, the equipment can be launched and operated from surface ships, helicopters and unmanned underwater vehicles (UUVs).

Archerfish leverages on the high frequency sonar and low light video data to track mine threats and fires the shaped charge warhead, initiating a full order detonation of the target.

The fibre-optic spools will link the Archerfish mine neutraliser and the launch platform, which is an MH-60S helicopter deployed from the US Navy’s littoral combat ships.

The advanced technologies of these systems deliver a comprehensive, end-to-end solution – detection to neutralization – enabling the Navy to safely and effectively execute its mission with reduced risk to its ships and crews.

**Remotely Controlled and Autonomous underwater vehicles (AUVs)**

Autonomous underwater vehicles (AUVs) have gained increasingly importance in the area of reconnaissance and mine countermeasures (MCM). It is expected that AUVs will be integral part of seagoing vessels. Unmanned systems have the potential to clear larger areas and to keep personnel and vessels out of the danger zone. Using unmanned systems, Owens said, will lead to a significantly more effective minehunting operation. “It’s a force protection aspect, certainly,” he said. “But probably as important, or more so, from our mission standpoint, is that the unmanned systems don’t have crew decks. They don’t get fatigued after eight hours in the direct sun working a minehunting problem. We can do this reliably 24 hours a day, not affected by darkness, not affected by the heat ... it gives us the ability to over time really expand our clearance rates.”
A major disadvantage of a typical MCM AUV operation is the time delay between survey and evaluation of collected side scan sonar data which typically doubles the overall mission duration. In order to exploit the full potential of MCM AUV missions, on-board data processing and the capability of online automatic detection and classification (ADAC) of mine-like objects is necessary.

**British Royal Navy tests first unmanned minesweeping system Hussar**

The British Royal Navy is currently testing the first unmanned minesweeping system to be specifically designed to deal with modern mines along sea lanes. The autonomous system comprises an 11m-long ‘mother ship’, known as Hussar, followed by a series of small ‘coil auxiliary boats’ (CABs) that replicate ship signatures in order to detonate the latest underwater explosive devices, which could potentially enable the safe and effective clearing of minefields.

Atlas Elektronik UK carried out the development and construction of the Hussar unmanned system. The solution was delivered to the Royal Navy in May 2018 after successfully completing four months of initial trials and evaluations. Royal Navy commander Mark Atkinson said: “In the digital age, magnetic minesweeping was becoming obsolete; it goes back to World War Two. “It could not deal with modern, digital mines.”
US Navy’s COBRA mine detection system achieves initial operational capability

The Coastal Battlefield Reconnaissance and Analysis (COBRA) system, a minehunting payload designed to operate aboard the MQ-8 Fire Scout unmanned aerial vehicle, has achieved.

Last Year US Navy issued SBIR to develop a “Night Time” capability for Coastal Battlefield Reconnaissance and Analysis (COBRA) that will provide the necessary light source for the COBRA camera. The current COBRA sensor is only capable of daytime operation. The objective is to create a small form factor, light weight, low power, and medium repetition rate broadband illuminator that is robust enough to be integrated onto the Fire Scout MQ-8B. The innovation of the COBRA Multi-Spectral Illuminator will be to provide the broadband light that will provide sufficient illumination power for the COBRA camera to image mine lines and minefields at night.

Three illumination technologies—Red Green Blue/Infrared (RGB/IR) lasers, RGB/IR light emitting diodes, and small/lightweight strobe lighting, have been previously explored for potential multi-spectral illumination. However, none of these technologies are mature enough to meet the technical requirements for COBRA camera illumination without further technical development and innovation. However, any of these three technologies, as well as other approaches, could serve as the basis for meeting the objectives of this topic.

COBRA represents a real step forward for tactical reconnaissance of beach areas,” said Melissa Kirkendall, mine warfare programs. “With COBRA, the Navy/Marine Corps team can quickly look at a possible landing zone and detect mines and
obstacles that would inhibit landing force mobility during an assault.”

**End-to-End Mine Countermeasure Capability**

Raytheon provides both a modern minehunting and mine neutralization capability to the U.S. Navy, which are two of the components in the mine countermeasure mission package for the Littoral Combat Ship class. Supporting mine-clearing operations in both deep-ocean and littoral waters, AN/AQS-20A minehunting sonar detects, localizes bottom, close-tethered and volume mines, and identifies bottom mines.

**European Unmanned Maritime Systems projects**

The European Defence Agency (EDA) is continuing to promote maritime affairs and to develop, with Member States, the next generation of mine countermeasure solutions via the successful delivery of Unmanned Maritime Systems projects.

ATLAS Remote Combined Influence Minesweeping System (ARCIMS) is manufactured by Atlas Elektronik UK. Based on an unmanned surface vessel (USV) platform, the ARCIMS is intended to offer next-generation mine countermeasures (MCM) capability to the naval forces.

The ARCIMS with ‘in-theatre’ proven technology is an ideal platform for multi-influence minesweeping missions. It offers remote mine hunting and disposal payloads in a flexible and cost-efficient package to counter a range of mine threats.

Meanwhile, mine-hunting methods have grown increasingly
sophisticated as well, but it costs 10 times as much and it’s 10 times slower to remove a mine as to lay it. In an effort to make mine-hunting operations faster, cheaper, and safer, France and Britain are looking into robotic systems that have a high degree of autonomy.

French Defence Procurement Agency (DGA) has teamed up with UK’s Defence Equipment and Support organization, to create high-tech robotic systems capable of locating and neutralizing naval mines and other Underwater Improvised Explosive Devices (or UWIEDs) with greater ease and accuracy.

When deployed, Thales sees the mine hunters of tomorrow as a fleet of underwater robots, unmanned surface vessels, towed sonars, and remote operated vehicles connected by Iridium satellite links as well as radio, acoustic, and direct cable links that allow the command ship, robots, local operations centers, and Reach Back data centers to remain in close communications.

**Britain’s Royal Navy receives its first autonomous minesweeping system**

The Ministry of Defence (MOD) said the system has been designed and manufactured by Atlas Elektronik in Dorset, England, under a $20.3 million contract.

“This autonomous minesweeper takes us a step closer to taking our crews out of danger and allowing us to safely clear sea lanes of explosives, whether that’s supporting trade in global waters and around the British coastline, or protecting our ships and shores,” Xinhua quoted Bebb as saying.

Easily transported by road, sea and air, the high-tech design means a small team could put the system to use within hours of it arriving in any theatre of activity, added Bebb. The sweeper system, which features a sense and avoid capability,
could also work together with other similar autonomous systems for the common goal of making our waters safer, said the MOD.

Brigadier Jim Morris from the Royal Marines who is senior responsible officer for the Mine Counter Measures and Hydrographic Capability (MHC) programme said: “The mine sweeping system is the Royal Navy’s first fully autonomous capability demonstrator and paves the way for the introduction of this technology across the full range of maritime capabilities.” “This autonomous system will restore the Royal Navy’s sweep capability, enabling it to tackle modern digital mines that may not otherwise be discovered in challenging mine hunting conditions.”

Thales Launches Pathmaster Unmanned Mine Countermeasures System

Thales Pathmaster draws on the latest imaging technologies and Thales claims that it is the most advanced unmanned mine countermeasures system in the world. It can be deployed from the shore, from a mine countermeasures vessel or from any other type of naval platform.

Pathmaster is equipped with SAMDIS, Thales’s latest-generation high-resolution synthetic aperture sonar. With its multi-aspect functionality, the SAMDIS sonar views targets from three different angles. The technology has previously been successfully evaluated by the French defence procurement agency (DGA). Thales is already using multi-aspect technology on the French-UK maritime mine countermeasures programme (MMCM).
**Jointly Develop Autonomous Underwater Mine-Hunting Robots**

A set of geolocated Autonomous Underwater Vehicles (AUVs) will be used to locate the target, with the help of synthetic aperture sonar. The system would also use Towed Synthetic Aperture Sonar (T-SAS) with very high-resolution multiview imaging, while Unmanned Surface Vehicles (USV) with autonomous navigation and threat-avoidance sonar worked in conjunction with Remotely Operated Vehicles (ROV) capable of identifying and neutralizing mines by means of new analysis tools.

**Deep driving drone submarine**

Worst of all are mines buried under the bottom of the sea. There is no sonar in current service that can find them, said Navy Captain Aaron Peters, an explosives ordnance disposal (EOD) specialist.

“The only things that can detect buried mines right now are your marine mammals,” he said, primarily trained dolphins. But the Navy is working on a new system called Knifefish, with a special low-frequency sonar that can penetrate ordinary soil and detect small, dense objects such as explosives. It won’t be ready until 2017.

**European Maritime Mine Counter Measures project (MMCM) delivers modular toolbox**

Belgium, Estonia, Germany, the Netherlands, Sweden as well as Norway agreed on 8 October 2014 to launch a new research project regarding future Maritime Mine Counter Measures (MMCM) capabilities.

Compared to existing solutions, future MMCM capabilities are
expected to bring increased flexibility through a modular “toolbox” comprising a range of systems adaptable to different platforms, environmental, or operational conditions. The use of unmanned vehicles will also be developed and new detection techniques could be introduced. Future MMCM operations are also expected to be conducted with state-of-the-art sensors and effectors carried and deployed from dedicated or hybrid platforms as well as from stationary or mobile shore installations.

Challenges for Lockheed Martin Remote Multi-Mission Vehicle (RMMVs)

Remote Multi-Mission Vehicle also called a “semi-submersible” swims along with its upper surface just above the water. Being mostly submerged helps stabilize the small craft in choppy seas, enabling its sonar a much better picture. Being partly exposed to air allows it to burn diesel fuel, which gives it much longer endurance than batteries.

The Lockheed Martin-built system has three key problems to overcome:

**Unreliable.** The RMS was supposed to run for 75 hours between operational mission failures, but scored a dismal 19 hours in tests this summer. The Remote Multi-Mission Vehicle, the system’s centerpiece, fared slightly better with 25 hours between operational failures.

**Losing contact.** The RMMV is an unmanned, autonomous, semi-submersible system. It was to be a key component of the littoral combat ship’s mine countermeasures mission package, but has been unable to interface with LCS systems, according to a 2014 Pentagon report. The RMMV is billed as capable of line-of-sight and over-the-horizon operations, but control from the ship has not proven reliable, and communication is typically lost when the vehicle is out of sight
**Missing mines**: The self-propelled RMMV tows the AN/AQS-20A minehunting sonar that is supposed to detect and classify mine-like contacts, but a 2013 Government Accountability Office report noted that the towed sonar failed to detect certain mines, was slow in identifying others, and falsely identified some objects as mines.

**AQS-24B Minehunter**

The AQS-24B completed fleet introduction as an upgrade to the already operational AQS-24A in the spring of 2017. The upgrade added a state-of-the-art High Speed Synthetic Aperture Sonar capability, developed and built by Northrop Grumman, which significantly increased the system’s sonar resolution for mine detection, localisation and classification.

The manufacturers say it uses a high-resolution, side scan sonar for real time detection, localisation and classification of mines at high coverage rates and a laser line scanner to provide precision optical identification. The AQS series minehunter is used both domestically and abroad and has logged thousands of hours of operation.

“The AQS-24B is operated from both the MH-53E heavy lift helicopters from Helicopter Mine countermeasures Squadron 15 (HM-15) and from the Mine Hunting Unmanned Surface Vessels (MHU) in the Arabian Gulf.”

**Conclusion**

The mine and mine-countermeasure technologies are a race akin to stealth-counter stealth race, not expected to subside very soon. With increasingly aggressive Russia and China amassing
hundreds of thousands of increasingly sophisticated naval mines, a revolution in minesweeping and continuing research in the mine countermeasures is what is needed.

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