Access: The Wildcard in EMW

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EXECUTIVE SUMMARY

Title Access: The Wildcard in BMW

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Thesis: *The anti-access threat of sea-based mines must be neutralized to conduct EMW*

Discussion: As the overseas bases of the United States continue to close, Naval expeditionary forces carry the burden of providing rapid crisis response to the nation. The ability of the Navy to project power allows other forces time to deploy as the situation dictates. The Marine Corps, as part of the expeditionary force, utilizes the Expeditionary Maneuver Warfare (EMW) concept to project a strong showing of power. In order for EMW to be successful, freedom of movement must be present in each realm of the sea, air and land. If access is denied to operate freely in any of these areas, the U.S. presence may be curtailed, which will hinder our ability to respond rapidly to any crisis. As the most visible symbol of U.S. presence, naval ships are expected to become primary targets for anti-access strategies. The use of naval mines by an enemy is cheap, deadly and readily available. In the past, the Navy neglected to pursue and develop countermeasures against mines. The loss of two ships during the Gulf War prompted action. Currently, the Navy has an established Mine Warfare Command to coordinate mine countermeasure (MCM) operations. The success of this command is tempered by the slow reaction speed, overt systems utilized and deliberate nature of (MCM) operations. Technology has improved several MCM systems that may help to speed up the pace. The Remote Minehunting System (RMS), the Airborne Mine Neutralization System (AMNS), the Rapid Airborne Mine Clearance System (RAMCIS), and nascent Unmanned Underwater Vehicles (UUV's) are top projects designed to improve MCM operations. Future projects must focus on improvements in covert MCM systems. These systems would be designated as assigned MCM assets resident on forward deployed vessels. The preponderance of these systems would be UUV's and help provide a clear path for Naval forces to follow.

Conclusion: Naval mines remain the deadliest anti-access strategy an enemy can use to adversely impact forward presence and the ability to conduct EMW. The success of power projection and BMW depends on the dedication of the Navy to continue to enhance the current technology and make mine countermeasures a priority.

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Access: The Wildcard in EMW

The National Military Strategy requires the military services to prepare for an uncertain future and respond to a full spectrum of crisis. Naval expeditionary forces are the premier forward presence force capable of providing rapid crisis response for the nation. In the future, as overseas forward bases continue to decrease, greater reliance will be placed upon naval expeditionary forces, because of their seabasing and crisis response capability. They will project power from a secure sea base that allows other forces time to deploy from the Continental United States (CONUS) as the situation dictates. The Marine Corps, as an inherent component of naval expeditionary forces, plans on utilizing the Expeditionary Maneuver Warfare (EMW) concept to project power across the spectrum of conflict. A precursor to the ability to maintain forward presence and to enact the operational concept of EMW is the freedom to operate in all domains; sea, air, and land. Access is key to the freedom of movement for naval expeditionary forces. Future adversaries will recognize this need for access and attempt to deny it via anti-access strategies. These strategies will apply to any attempt by U.S. forces to access a region, but naval expeditionary forces as the most visible symbol of U.S. presence, will be the primary targets[1]. Numerous anti-access strategies could adversely affect Naval expeditionary forces and the Marine Corps' concept of EMW. The most cost effective and easily attainable anti-access strategy is the use of naval mines by an enemy. *The anti-access threat of sea-based mines must be neutralized to conduct EMW.*

Power Projection

As a global power, the U.S. will confront crisis' concerning national interests in many regions of the world. Some of these crisis' will require global power projection

from CONUS bases. This power projection relies on naval expeditionary forces and strategic lift. Strategic lift will both deploy and sustain the forces. Although strategic lift can be air or sealift, the declining state of airlift shifts a heavier reliance to sealift. Strategic sealift assets link up with forward deployed NEF's and maritime prepositioning force (MPF) ships to provide a seabasing option to mitigate many anti-access strategies.

EMW

EMW emphasizes the seabasing concept. EMW is the capstone operational concept for the Marine Corps, and as such, applies the doctrine of Maneuver Warfare to Marine Corps operations across the spectrum of 21st century conflict.[2] The basic tenants of Operational Maneuver from the Sea (OMFTS) are resident in EMW. As Stefanou, the author of a paper about future anti-access threats to NEF's stated, "The sea is utilized as a means of gaining operational advantage in order to facilitate friendly movement, pose a barrier to the enemy and avoid disadvantageous engagements."[3] The sea is used as both maneuver space and sanctuary from the enemy. The forward deployed Amphibious Ready Group (ARG) link up with MPF assets to enhance operational reach. These MPF assets will be modernized by 2010 and "provide for the arrival and assembly of troops and equipment at sea, eliminating the need for access to secure ports and airfields for the flow of forces and associated logistics into the theater."[4] The reduction in the need for access to secure ports and airfield increases the requirement for freedom of movement on the sea. An opponent can prevent this by adopting an anti-access strategy of sea denial.

Anti-Access Strategies

An opponent has numerous anti-access strategies to choose from depending on their goals. But what is meant by the term access? As Stefanou explains "access

connotes not only physical access to an adversary's territory, territorial waters, and airspace in time of conflict, but also the ability to freely maneuver U.S. forces in the waters and airspace of adjoining regions during peacetime"[5] An opponent can attempt to deter, slow or prevent U.S. forces from entering an area.[6] The anti-access measures available are grouped into four overlapping categories: deterring measures, coercing measures, anti-deployment measures and anti-invasion measures.[7] Anti-deployment and anti-invasion measures have the greatest effect on naval expeditionary forces.

The anti-deployment measure category encompasses the military weapons systems and strategies that an adversary can use to prevent or slow the deployment of U.S. forces by sea or air to friendly ports and airfields in an area.[8] Also, the measures utilized against forward deployed naval forces to deny or limit their freedom of movement and action.[9] The strategies available range from the use of naval mines, submarines and cruise missiles to the use of Weapons of Mass Destruction (WMD) or information warfare (IW) threatening the use of WMD.[10]

The anti-invasion measure category encompasses the military weapons system and strategies that an adversary can use to deny U.S. forces the capability to execute sea-control, amphibious, airborne, air assault and air superiority missions in an area.[11] The strategies available for use are basically the same as outlined in the anti-deployment measure category. A key difference would be the type and number of strategies employed and the risk versus gain assessment concerning their use. Yet, for both anti-access strategy categories, the most probable strategy to affect naval expeditionary forces and EMW is the relatively low technology and inexpensive sea-mine.

Mine Threat

The naval mine threat is extensive. Mines, often described as "poor man's artillery", remain lethal and inexpensive regardless of the age of the technology.[12] As Jeanne Avery, a mine expert for the Office of Naval Intelligence (ONI) stated, "The historical success of simple contact and influence mines suggests these weapons will continue to challenge U.S. Naval forces. However, today's Navy can expect to encounter the gamut of naval mine types and must be prepared to counter traditional low-tech mines as well as technologically advanced systems."[13] The lessons from World War II concerning the success of naval mines are heeded by many nations. During World War II more than 700,000 mines were laid and more ships were lost or damaged by mines than by any other weapon.[14] This trend of effectiveness continued through Korea and the Gulf War until present time. During the Gulf War, Iraq laid approximately 1300 mines, and damaged two warships.[15] The USS Princeton suffered $24 million in damages from an Italian manufactured Manta mine that cost $10,000.[16] The USS Tripoli suffered $3.5 million in damages from a LUGM-45 moored contact mine that cost $l500.[17]

Naval mines are readily available, easily obtainable and represent a growth industry in the international arms markets. Presently, over 48 of the world's navies possess mine-laying capabilities and access to mine inventories.[18] At least 30 countries are engaged in the development and manufacture of sophisticated mines and 20 are known mine exporters.[19] Many countries that possess extensive mine inventories and mine laying capabilities that could adversely affect EMW are in regional "hot spots", i.e. Iran, Korea, China and Russia.[20] These countries and others such as Croatia, India and Sweden export both low technology and increasingly sophisticated mines. This

represents a 40% increase in countries that produce mines and 50% increase in those that export mines since 1991.[21] These trends will continue to increase and lower the cost of a weapon that has historically proven to be one of the most cost-effective weapons that causes physical damage, psychological uncertainty and requires countermeasures out of proportion to the cost of the mining effort.[22]

The increase of mine producers and exporters provides future adversaries with a variety of low technology and sophisticated mines. This mix ranges from the rudimentary low technology moored, bottom or drifting contact mine to more advanced mines such as propelled-warhead (PW) mines. Countries with mine production capabilities are focusing on the growing demand for more capable weapons.[23] The most expedient method to improve a mine is through an upgrade. According to Avery, "Upgrade kits are used to modernize the mine firing mechanism while retaining its original case and warhead."[24]

The application of advanced technologies to the naval mine will greatly enhance future effectiveness. For instance, stealth technology, through the use of irregular shapes, anechoic coatings and non-magnetic materials (fiberglass case materials) will increase resistance to countermeasures and reduce maintenance requirements.[25] Improvements through a combination of magnetic, active acoustic, passive acoustic, seismic and pressure influence sensors on the same mine will prove more resistant to countermeasures.[26] Advances in signal processing techniques will increase the sensitivity of influence sensors, such as magnetic or acoustic, and allow increased target discrimination. Mines will possess microprocessor-controlled target detection devices, ship counters, remote control and delayed arming mechanisms to thwart detection and

neutralization.[27] These counter-countermeasures enable a mine to eliminate contacts, lay dormant and activate after mine countermeasure (MCM) assets have cleared an area for access. An example of this technology currently available on the export market is the Swedish Rockan bottom-influence mine. It has a wedge shaped, corrosion-resistant fiberglass case considered to be one of the stealthiest designs in the world.[28] The Russians market a UDM bottom-influence mine that can be purchased or back-fitted for remote control capability and a SMDM high sweep-resistant mine for use in coastal waters.[29]

The greatest threat and technological challenge in the future is the propelled warhead (PW) mine. These mines will allow mining of areas like the Straits of Hormuz that previously defied effective mining with moored mines because of surface currents.[30] PW mines quickly close on a target, not allowing evasive maneuvers. The lethality of this weapon is further enhanced by guidance systems and a remote control capability.[31] An example available on the export market is the Chinese EM-55, a straight-rising, rocket-propelled warhead mine.[32] The implication of the future mine threat to EMW is clear. Naval mines greatly limit the freedom of movement of naval expeditionary forces and limit the Marine Corps' ability to conduct EMW.

Current MCM Status

The end of the Gulf War brought a renewed emphasis on the topic of mine warfare (MIW). The damage of high value assets and the denial of access combined with the effect on operational planning options by a relatively inexpensive weapon exposed a deficiency in U.S. forces-Mine Warfare capabilities. Mine Warfare was revitalized and attempts were made to upgrade the concepts, doctrine, equipment and most important, the

Navy's cultural mindset concerning mine warfare. In an effort to improve mine warfare, a Mine Warfare Command was established, and the Navy's MCM assets fell under its purview. These assets are 14 Avenger class MCM ships, 12 Osprey class (MHC) ships, 2 squadrons of MH-53 E Sea Dragon, 1 Squadron of SH-2G Super Seasprites, special operations divers, marine mammal units, 10 mobile assembly units and the USS Inchon.[33] The majority of these assets are CONUS-based and require notification and strategic lift to a crisis area for operations. The exception is the 2 MCM ships deployed to the Persian Gulf, 2 MCMs homeported in Sasebo Japan, and detachments of divers.[34] All of the ships except for the Avenger class MCM ships belong to the Naval Reserve Force (NRF). This puts a premium on the Naval Reserve during a time of crisis. These MIW forces are called dedicated or supporting to reflect the status of not being forward deployed with a battle group (BG) or amphibious ready group (ARG). The term organic or assigned denotes MIW forces resident or forward deployed in a BG/ARG.

Twin Problems: "Overt Platforms & Reaction Speed

Currently, MIW forces deploy from CONUS to a crisis area and commence MCM operations to support the theater commander. They rely heavily on "overt" MCM platforms to conduct MCM operations, i.e., surface ships, helicopters. These platforms detect, classify and neutralize mines overtly because they lack a clandestine capability. Possession of predominantly overt capabilities allows an adversary to observe and react to MCM efforts and possibly discern future intentions. The paucity of clandestine MCM capabilities is compounded by the need to deploy MCM assets from CONUS. A recognized critical shortcoming of the dedicated MCM forces is slow reaction speed.[35] The inherent delay caused by the requirement for strategic airlift, sealift or slow transit

time impedes operations. This operational pause to deploy MCM assets is unacceptable and reflected in the Concept for Future Mine Countermeasures in Littoral Power Projection where it states "Current MCM capabilities will not satisfy the requirements of the future battlespace-they are limited by lengthy timelines for surface assets to arrive in theater, inadequate integration of assets, minimal reconnaissance means and operational pauses created by the slow, deliberate nature of MCM operations."[36]

Near Future MCM Proposed Changes (By 2005)

In recognition of these deficiencies, the Navy proposed changes in the basic concept of operations for MIW. The changes revolve around the idea of organic or assigned MCM capabilities. The concept is that a BG/ARG will possess assigned MCM capabilities allowing them to initiate MCM operations, avoiding an operational pause while CONUS-based supporting MCM forces deploy to the crisis. MCM systems and weapons will be integrated into the combat systems of BG/ARG assets.[37] Surface combatants would be outfitted with MCM systems and weapons either currently in use or under development. An example is the integration of the Remote Minehunting System (RMS) to a surface combatant. This system is a semi-submersible, remotely operated system that tows a mine reconnaissance sonar.[38] The system conducts reconnaissance of bottom and moored mines, detecting, classifying and locating mines from the deep water to very shallow water region.[39] Airborne assigned MCM proposed capabilities would utilize the CH-60 helicopter as the primary platform. The airborne laser mine detection system (ALMDS) and AN/AQS-20X Sonar Mine Detection set would be used to conduct reconnaissance; detecting, classifying and locating mines. The ALMDS is a non-towed, electro optic system that will detect floating and near surface moored contacts.[40] The

AN/AQS-20X is a towed minehunting system that detects bottom and close-tethered mines.[41] The airborne platform will contain MCM systems to neutralize the located mines. These systems are the Airborne Mine Neutralization System (AMNS) and the Rapid Airborne Mine Clearance System (RAMCIS). AMNS neutralizes bottom, close tethered and volume contacts with a warhead.[42] RAMCIS neutralizes near surface like contacts by firing a supercavitating shell guided by a laser targeting fire control system.[43]

The subsurface contribution to assigned MCM capabilities for a BG/ARG is initially the Near-term Mine Reconnaissance System (NMRS) and eventually the Long-Term Reconnaissance system (LMRS). These systems are Unmanned Underwater Vehicles (UUV's) carried by a submarine and detect, classify and locate mines.[44] NMRS and LMRS are deployed through torpedo tubes with NMRS controlled via a fiber optic cable and LMRS capable of autonomous operations.[45] LMRS possesses greater endurance, reliability and search rate. Both systems transmit selected data to the submarine and, upon recovery; the entire data recording is downloaded for transmission to other MIW forces.

Supporting MIW elements deploy from CONUS and expand this "in-stride" MCM effort. They possess basically the same systems, but more enhanced capability for minehunting or minesweeping. These forces will be most capable of detecting and neutralizing buried mines. A specific addition is a surface MCM platform mine neutralization system such as the AN/SLQ-48 (V) Mine Neutralization System (MNS) found on Avenger and Osprey vessels.

The Navy's effort to improve deficiencies in MCM capabilities and assets covers all dimensions but remains reliant on overt systems. The RMS, NMRS and LMRS are all

clandestine, but they are only reconnaissance systems. They assist the commander in making decisions concerning "avenues of approach" and "mobility corridors." However the ability to neutralize mines continues to reside in overt MCM systems; specifically on a helicopter platform. In-stride capabilities avoid an operational pause but compromise of intentions is still an issue.

Clandestine MCM

The MCM issue needs to be addressed from a predominantly clandestine view. The MIW concept of operations should retain the assigned and supporting MCM forces systems concept but transition to clandestine systems. The need for clandestine systems is greatest for the assigned MCM systems. Naval expeditionary forces and strategic sealift assets will appear harmless to an adversary while they actively clear the path to an operational area. In addition to the clandestine emphasis, supporting MCM forces should remain forward deployed. They can remain in theater at a naval base or co-located with the maritime pre-positioning squadrons (MPS). Forward deployment allows rapid reinforcement of the assigned MCM forces/systems.

A shift to predominantly clandestine MCM systems and platforms entails an emphasis on submarine compatible systems. The NMRS and LMRS represent the initial strides in this direction for MCM systems. The continued development of UUV's and their applicability to future warfare is the key to this concept. An initiative currently underway at the Naval Undersea Warfare Center (NUWC) is a new UUV called the Manta. The Manta is designed to be a semi-autonomous, reusable UUV that a submarine carries in a conformal depression in the hull.[46] The Manta will carry it's own sensors, weapons and countermeasures.[47] This is an important point because the inclusion of

weapons implies that the Manta will not be strictly a reconnaissance asset like NMRS and LMRS. A few scenarios for the Manta include: searching for and neutralizing mines in amphibious operating areas; deploying acoustic sensors in a high risk area or populating passive or active sonar barriers.[48] The possibilities are endless for the Manta.

Surface Clandestine MCM

The Manta is precisely the type of clandestine MCM platform required for the future. Yet there is no need to restrict the system exclusively to submarines. A UUV type system like the Manta could easily be incorporated into a surface combatant. The UUV could replace or enhance the RMS that the Navy will incorporate on surface combatants by 2005. In this case the RMS conducts the reconnaissance in tandem with the UUV. The UUV neutralizes the contacts detected, classified and located by RMS. The UUV will utilize an extended power source that allows longer operation time and can continue MCMI operations when the diesel powered RMS returns for fuel. This allows continuous coverage that helps increase the tempo of operations for a naval expeditionary force. An electronic link between the surface combatant launched UUV and the submarine launched UUV further enhances the situational awareness of the surface ship. The UUV's exchange intelligence, surveillance, and reconnaissance data creating a shared network of information.

The UUV's should be included in MPF assets and deploy from the MPF ships enroute to the operation area, and upon arrival in the operation area. MPF ships in the future will require well-deck capability and the UUV can either be launched via the well-deck or from the deck. This provides MPF ships with a robust MCM capability and allows them to enter potential mine areas with confidence. There may be times when

Navy assets are unavailable and this is the only option. The most beneficial use will occur in the operation area. An MPF ship with assigned MCM systems adds to the overall MCM defense during the unloading process.

Subsurface Clandestine MCM

The main arena for an increased reliance on UUV's is in the underwater realm. The employment of UUV's should not be delayed by a lag in submarine technology and the perceived need for a conformal depression in the hull. The UUV's should be developed for utilization in the current Dry Dock Shelters (DDS) that Sea Air and Land (SEAL) teams use for the SEAL Delivery Vehicle (SDV). A procurement of additional DDS's for UUV's allows for no loss in SDV capability. This procurement will be cost efficient because the SDV is a legacy system in the active force structure. Submarines could operate in pairs with UUV's in the DDS until the development of the conformal depression in future submarines, Pairs of submarines would be capable of employing the LMRS and Manta type UUV in tandem for more efficient MCM operations. This would provide rapid identification and clearance of mines in conjunction with surface and air MCM assets. Selected submarines should be refitted to act as "motherships" for the UUV's. This underwater tender would provide logistical support for the UUV's. They could rearm, refuel and refit from a dedicated platform. This tender would centrally locate and act as an underwater version MCM command and control support ship. The tender would transport a number of MCM systems to the operations area but predominantly act as a support vessel for other UUV's launched from submarines in the area. This allows the other submarines to focus on other missions while the tender

supports their assigned UUV. The tender would be capable of docking UUV's and providing maintenance beyond the UUV's parent ship.

This tender concept would also support a family of UUV's of the future, UUV (F). The family of UUV's would enhance and complement the basic UUV, the Manta. The Manta represents a baseline for the future. This UUV should act as an intermediate tender for smaller UUV's. These UUV's would emphasize robotics and be capable of transiting on the ocean bed to locate, classify, detect and neutralize mines. They would increase the ability to neutralize buried mines for assigned MCM assets without waiting for supported MCM assets to arrive on the scene. This UUV (F) would provide a scalable range of options to the MIW commander. Many of these needs are identified in the Concept for Future Naval Mine Countermeasures; "future platforms require high performance capabilities in terms of speed, precision navigation, range, endurance, communication, sensor payloads...and the footprint within the host platform."[49]

Airborne Clandestine MCM

The underwater and surface MCM assets for the future will require complementary space and air assets. These assets must stress the shift to a clandestine detection, identification, classification and neutralization focus like the surface and subsurface elements. Upper atmospheric aviation assets need to be employed with an improved version of the ALMDS (F). This version would fill the reconnaissance role of detection, identification and classification of mines and the neutralization of them with laser energy. Such directed energy technology would be designed to saturate the mines with energy to incapacitate the actuation sensors.[50] The ALMDS (F) would link into a

shared network with other MCMI assets to provide the MIW commander a common picture.

The ALMDS (F) would be capable of fitting into satellites and provide reconnaissance but no neutralization capability. Eventually the neutralization capability would be incorporated with further advances in directed energy weapon technology. Yet the immediate gain of increased reconnaissance support would focus MCM efforts.

Other Future Measures

In addition to the active MCM systems and efforts to ensure access, other passive self defense measures should be adopted for in extremis use or to complement active MCM systems. MPF ships and surface combatants should be equipped with a family of drones deployable from the ship or from an airborne platform. These drones would mimic their host vessels magnetic, acoustic, and pressure signatures. Pre-programmed chips would be inserted into the drone for each mission allowing interchangeability of drones between platforms. The drones would be expendable, but recovered if not destroyed by a mine. The drone would function until out of fuel and then sink to the ocean floor for recovery operations. A transponder would activate and broadcast the drone location until directed by the host vessel to cease transmissions. Then an anti-handling device would activate precluding inadvertent compromise by enemy forces. This device is de-activated by an encrypted code during recovery operations. The drone would be recoverable by subsurface assets or an SDV type system that tows the drone back to the host vessel.

An additional self-defense measure to complement the family of drones would be a retractable gun mount in the hull of surface combatants. This would resemble in concept the ball turret on the B-17 from WW II. The system would initiate upon sensors

indicating activation of a PW mine. Sonar and a laser detection and ranging (LIDAR) sensor would direct the fire of the mount. The LIDAR sensor assists by using a blue-green laser, which has a frequency compatible with seawater, to locate and target the mine.[51] The LIDAR sensor then provides aiming coordinates for the mounts gun fire control system.[52] The system would be an underwater version of the proposed helicopter borne (RAMICIS). These self-defense systems would enhance the ability to ensure access in time of crisis.

Conclusion

The anti-access strategy of naval mines remains an inexpensive, easily obtainable and relatively low technology capability that adversely impacts forward presence and the ability to conduct EMW. Mine technology continues to improve and requires heightened efforts to develop countermeasures. The Navy's current efforts to develop and deploy MCM systems face an intense resource conflict.[53] Despite the inherent challenges from a resource allocation view, the ability to continue unfettered forward presence and conduct EMW is held hostage by the wild card of naval mines. MCM enhancement through technology, prioritization and a shift in employment strategy will help ensure the continued sanctuary of the sea base and access in times of crisis.

Appendix A: Acronym Table

ALMDS — Airborne Laser Mine Detection System (airborne reconnaissance only)

ALMDS (F) — ALMDS Future (proposed upper atmospheric recce & neut. capability)

AMNS — Airborne Mine Neutralization System (airborne neutralization only)

AN/AQS-20X — Airborne MCM system (airborne reconnaissance only)

ARG — Amphibious Ready Group

BG — Battle Group

CONUS — Continental United States

DDS — Dry Dock Shelter

EMW — Expeditionary Maneuver Warfare

IW — Information Warfare

LIDAR — Laser Detection and Ranging

LMRS — Long Term Mine Reconnaissance system (subsurface reconnaissance only)

MCM — Mine Counter-Measures

MIW - Mine Warfare

MNS — Mine Neutralization System -(surface neutralization, part of minesweeping ship)

MPF — Maritime Pre-positioning Force

MIPS — Maritime Pre-positioning Squadron

NEF — Naval Expeditionary Force

NMRS — Near Term Mine Reconnaissance System (subsurface reconnaissance only)

NRF — Naval Reserve Force

NUWC — Naval Undersea Warfare Center

OMFTS — Operational Maneuver From The Sea

ONI — Office of Naval Intelligence

PW — Propelled Warhead

RAMCIS — Rapid Airborne Clearance System (airborne neut. only LIDAR helps locate and guide the gun's fire control system.

RMS — Remote Minehunting System (surface reconnaissance only)

SEAL — Sea, Air and Land

SDV — SEAL Delivery Vehicle

UUV — Unmanned Underwater Vehicle

UUV (F) — UUV Future

WMD — Weapons of Mass Destruction

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[49] MCM Littoral, 18.
[50] Stefanou, 30.
[51] Millennium, Appendix C, 3.
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