Transitioning Unmanned Underwater Vehicle Technology from Commercial Use to Naval Mine Countermeasures Operations

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I. INTRODUCTION

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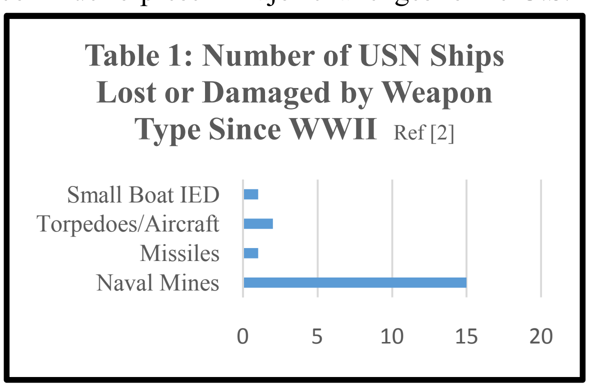
Ever since the original sea mines (kegs of gunpowder) were floated against sailing ships during the Revolutionary War, the underwater Mine Countermeasures (MCM) mission has been considered one of the most complex operations that the U.S. Navy conducts. Historically, MCM operations have incorporated specialized divers, wooden or fiberglass-hulled ships, helicopters towing sensors and sweeps, and even specially trained marine mammals to locate and neutralize underwater mines.

Since the Korean War, the number of ships sunk or damaged by mines triples those sunk or damaged by missiles, torpedoes, aerial attack and small boat attack combined. Mines continue to present major challenges to the U.S. Navy's ability to project power against enemy shores and secure Sea Lines of Communications (SLOCs). The decision by the US Navy *not* to conduct amphibious operations against the heavily mined waters off of Kuwait during Operation Desert Storm exposed gaps in our MCM capability.



Today, underwater mine technology includes solid state, programmable bottom mines that are triggered from the influence signature of a target vessel (magnetic, acoustic, pressure, electric potential) and can employ ship counters and other anti-sweep features. The Navy's legacy systems of ships, helicopters and divers have been increasingly challenged to keep pace with modern underwater mine technology. MCM Operations continue to be highly dangerous and labor intensive. Advances in Unmanned Underwater Vehicle (UUV) technology have presented opportunities for the Navy to fill MCM capability gaps and reduce the risk to sailors and ships that are conducting MCM operations.

UUVs have been extensively used by scientific and commercial organizations to conduct hydrographic surveys (bathymetry, currents, and water characteristics), oil and gas underwater infrastructure surveys, searches for lost objects such as shipwrecks and plane crashes, and other underwater survey tasks. Many of these underwater UUV capabilities are directly applicable to conducting underwater MCM operations.

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In the 1990s The Office of Naval Research (ONR) recognized the potential utility of the early scientific versions of the UUV for use by the Navy and funded several efforts to introduce the technology to the fleet. Building off these efforts and the lessons learned from the impact of naval mines during Operation Desert Storm, the Navy Explosive Ordnance Disposal Program Office (now PMS-408) initiated a small UUV acquisition program that, in a very short time in acquisition terms, has produced a highly effective, agile, Expeditionary MCM capability.

The purpose of this paper is to present an overview of PMS-408's acquisition program for the MK 18 UUV Family of Systems (FoS) and to discuss the lessons learned that contributed to the success of the acquisition effort.

II. REQUIREMENTS

The introduction of a small UUV to the Navy was intended for use in the Very Shallow Water (VSW) MCM mission, which is conducted in nearshore waters that are approximately 10 to 40 feet deep. Shallower waters are considered the "surf zone", and UUVs were not, and still are not, expected to be effective in such a dynamic environment. Historically, the VSW region has been very challenging for mine hunting due to the acoustic affects in shallower water and sloping bottom; the heavy surge that is typical near the shore, and the proximity of the mission to enemy forces on the beach. Existing methods of mine hunting using divers in the VSW zone were problematic due to the newer influence mines and a lack of low influence dive equipment that was effective in the water depth and surge profile of the VSW Zone. UUVs were thought to be a potential solution to getting the man out of the very hazardous VSW minefield.

A prototype small UUV originally developed by Woods Hole Oceanographic Institute (WHOI) was introduced to the Navy for use on hydrographic reconnaissance missions. In addition to the hydrographic mission, the small two-man portable UUV known as the REMUS (Remote Environmental Mobile Undersea System) also showed potential as an MCM asset when using its side scan sonar sensors. PMS-408 began exploring the possibility of using a small UUV in VSW MCM operations and started working closely with the active duty Navy EOD operators to acquire a product that would meet their operational requirements.

Figure 1: An operator from Naval Special Clearance Team ONE launches a REMUS UUV in Iraqi waters during Operation Iraqi Freedom March 2003. (Navy Released photograph).

Early and frequent engagement with the end users and regular technological, tactical, and program reviews involving all the UUV stakeholders were key to the program's initial traction and subsequent growth. Requirements Working Groups (RWG) between the Program Office and the fleet stakeholders helped to identify, document, and validate the operational requirements that any UUV MCM system would need to meet.

Since the VSW mission was originally intended to be clandestine, the small UUVs had to be transported in manned small boats from over the horizon to the VSW area near an enemy shore at night. This manned transit imposed risk to the transporters and exposure of VSW MCM mission. The idea of launching a UUV with greater mission duration capability from over the horizon was proposed to reduce that risk, and resulted in the expansion to the MK 18 “MOD 2” as a system improvement of the smaller MK 18 MOD 1.

With the state of UUV battery technology at the time, the only way to increase the range of the vehicle was to increase the battery capacity of the UUV, which required a larger vehicle. The other advantage of the larger vehicle was the ability to add additional and bigger sensors to the UUV. The vision was to create a generic underwater “truck” that could be integrated with various advanced sensors as they became technologically mature and could support over-the-horizon mission duration.

III. INDUSTRY RESEARCH AND UUV ACQUISITION STRATEGY

Introducing the first UUVs into the Navy for VSW began in 2001, when the Navy’s EOD Program Office, armed with a fleet requirement for VSW mine hunting, conducted a thorough search of Commercial-Off-the-Shelf (COTS) UUVs and associated underwater sensor technology. Using standard Department of Defense acquisition research tools, such as Industry Days, Requests for Information (RFI), and academic paper research, an initial group of potentially viable MCM technologies using UUVs and associated sensors was established.

A competitive bid process was conducted, based on identified requirements to generate a Request for Proposals (RFP). A Foreign Comparative Test (FCT) was also conducted using a prototype of a foreign made UUV that showed potential for meeting the MCM UUV requirements. The FCT UUV and two domestic UUV COTS prototypes were leased or acquired through the RFP process and tested for requirements suitability. The UUVs were extensively tested by government engineers and fleet operators in a “swim off” that compared the actual hands-on operational and tested results of each type of small UUV with the published specification.

At the time of this competitive process none of the COTS small UUVs fully met all of the requirements. But each one had unique features and capabilities that contributed to the refinement of requirements for the next generation MCM UUV. The vision of the EOD Program Office was to acquire the best available small UUV as quickly as the acquisition process would allow and get it into the hands of fleet operators. Due to the speed at which the UUV and underwater sensors were developing it was very difficult to start a traditional DoD system acquisition without running a significant risk of delivering to the fleet a UUV System that was already obsolete.

Based on the strategy of getting the best available small UUV as quickly as possible, the EOD Program Office selected the most technically mature and readily available small UUV “at that time”. Using the free and open competitive bid process and acquisition selection process, the EOD Program Office selected the REMUS 100 UUV from Hydroid.

The initial small MCM UUV prototypes were delivered to Naval Special Clearance Team ONE (NSCT ONE) for operational testing, tactics development, and integration with other MCM systems designed to operate in the VSW region.

In support of the small MCM UUV program the EOD Program Office funded contracted Fleet Support Representatives (FSR) or “tech reps” to act as a bridge between the operational units, the Program Office, and the manufacturer. The FSR was tasked with interfacing with the fleet users, documenting the significant lessons learned during the UUV operations, tracking failures and repairs, and documenting the Tactics, Techniques, and Procedures (TTPs).

The FSRs became the technical Subject Matter Experts (SME) on the UUV and assisted the manufacturer with training the fleet operators and troubleshooting vehicles that were operating in the fleet, since the UUVs were being employed in ways and environments that had not previously been tested by the manufacturer. The FSRs have become an enduring requirement for the current MCM UUVs and provide SME continuity during fleet turnover and some assistance to the active duty operator with the administrative and maintenance burden that came with the new equipment.

Regular Program Reviews with all of the stakeholders was instrumental in keeping open lines of communication between the Program Office and the fleet operators. This forum helped to identify and track to resolution any potential problems or delays in the acquisition cycle.

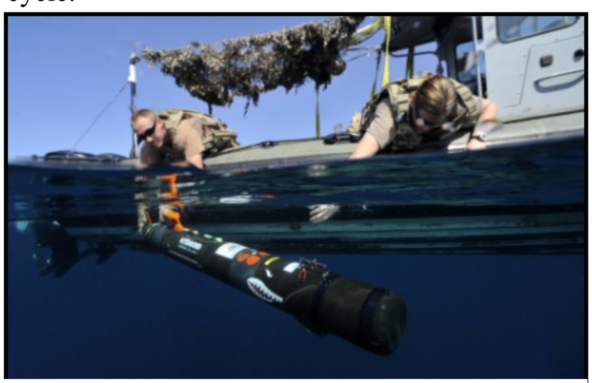

Figure 2 Members assigned to Commander, Task Group 56.1, deploy a MK 18 MOD 2 Swordfish to survey the ocean floor during the International Mine Countermeasure Exercise (IMCMEX). in the U.S. 5th Fleet area of responsibility. (U.S. Navy photo by Mass Communication Specialist 1st Class Blake Midnight/Released)

IV. USER OPERATIONAL EVALUATION SYSTEM

Once the first small UUV prototypes were transferred to NSCT ONE, a User Operational Evaluation System (UOES) was initiated by the EOD Program Office. The UOES is an acquisition process that gives fleet operators the ability to use the equipment in various environments in order to generate the most relevant feedback possible on suitability to the mission, feasibility for tactical employment, and suggested improvements.

The UOES was broken down into the following seven phases listed in Table 2.

Table 2

LIST OF UOES PHASES

Phase	Description
A	Vendor Supplied Training
B	Baseline Tactics
C	Concept of Operations Variations
D	Integration Operations
E	Environmental Variations
F	Blind Tests
G	Fleet Exercises

After the initial vendor training, establishment of baseline tactics and development of UUV Standard Operating Procedures (SOPs), the UUV Platoon at NSCT ONE began working on operational variations of tactics and environmental conditions (cold water, warm water, high/low salinity, varied bottom types, etc.) The ability of the UUV to integrate with existing MCM systems and command and control systems was tested and validated during fleet exercises. Independent testing agencies conducted "blind" tests on the UUV to test the performance against the required specifications.

Reports on the phases were drafted, and lessons learned were compiled and documented. An online Failure Analysis Report database and mission statistics tracking website were established to track failures, identify failure trends, and organize mission data. Some of the user feedback that resulted in system improvements included:

- Identified the need for additional ballasting for high salinity operations;
- Suggested improvements for vehicle handling and storage features;
- Introduced additional maintenance procedures to reduce corrosion in the tail sections;
- Developed real world tactics for employment of the system.
- Developed SOPs for integration of the UUV system aboard ships and with other MCM systems.
- Training and Logistical Support requirements were identified and documented.

The successful deployment of the VSW REMUS 100 prototype UUVs during Operation Iraqi Freedom in 2003 validated many of the UOES lessons learned and created a baseline system configuration for the smaller VSW vehicles.

As discussed in Section II a significant recommendation that came out of the UOES process was the need for a vehicle with greater duration to satisfy the VSW over-the-horizon mission. As a result, a larger version of the original COTS UUV was acquired, and an expeditionary support craft with an innovative UUV Launch and Recovery system was included as part of the package. The resulting MK 18 UUV Family of Systems (FoS) includes the MK 18 MOD 1 Swordfish (man portable) and the MK 18 MOD 2 Kingfish (larger vehicle requiring specialized launch and recovery system).

V. CURRENT UUV DEPLOYMENT TO C5F IN SUPPORT OF MCM

In late 2011, as the MK 18 Mod 2 system was being prepared for delivery for the VSW mission, a "blue water" mine threat emerged in the Arabian Gulf, which is in the Fifth Fleet area of responsibility. To help counter the threat a demonstration of the MK 18 Mod 2 system was conducted in November, 2011, from Bahrain, where the Commander, Fifth Fleet (C5F) is headquartered. After the successful demonstration of the MK 18 Mod 2 in C5F, an Office of the Secretary of Defense (OSD) "Fastlane Initiative" program was put in place to redirect all the MK 18 Mod 2 UUVs being developed for VSW to be deployed to C5F as soon as possible.

Figure 3: Personnel assigned to Commander, Task Group (CTG) 56.1 conduct unmanned underwater vehicle operations while CTG 56.4 riverine personnel provide security. (U.S. Navy photo by Mass Communication Specialist 3rd Class Michael Scichilone/Released)

Due to the compressed timeline and lack of trained military UUV operators, the MCM UUVs were initially operated by contractors with government oversight. The deployment was conducted as an extension of the UOES and produced invaluable operational lessons learned that were used to establish the follow-on expeditionary, military-operated system.

The utility of the Mk 18 FoS for Expeditionary MCM operations continued to be demonstrated during numerous exercises and real world operations throughout the theater. Based on this initial success, Navy leadership created a new concept under Naval Expeditionary Combat Command (NECC): the Expeditionary MCM (ExMCM) Company. The

ExMCM Company is comprised of EOD divers/operators and UUV operators, MK 18 UUVs (Mod 1 and Mod 2), Remotely Operated Vehicles (ROV) and support craft that enable the company to conduct the full detect-to-engage sequence as a fly-away unit. The ExMCM Companies can deploy independently to conduct MCM missions, emphasizing their value by deploying to distant locations by airlift in a fraction of the time that it would take MCM ships or helicopter detachments to arrive. They have also demonstrated their value as an agile set of systems working from an Afloat Forward Staging Base in a larger, integrated MCM Force.

Figure 4: A MK-18 MOD 2 Kingfish Unmanned Underwater Vehicle, is recovered aboard a Rigid Hull Inflatable Boat (RHIB) in the 5th Fleet area of responsibility. (U.S. Navy photo by Mass Communication Specialist 1st Class Blake Midnight/Released)

VI. CONCLUSION

The US Navy has had tremendous initial success with transitioning COTS UUV technology into an effective fleet expeditionary MCM system. Research and testing of advanced mine hunting sensors and autonomous target recognition algorithms into MCM UUV systems shows enormous potential for establishing the next level of technological and operational capability in UUVs. This will further improve the Navy's ability to conduct the MCM mission using safer and more efficient techniques.

Lessons Learned from this effort that could be useful for similar acquisition efforts in the future include:

- **UOES -** The UOES is key to creating a solid feedback loop between the end users and the developers of new technology via the Program Office. It is vital to engage the end user early and often to identify and validate system requirements. It is important to remember that the end user is looking for a "capability" not just cutting edge technology.
- **COTS Prototypes -** Getting the best available COTS prototypes into operators' hand as soon as possible is vital to generate feedback that can assist with the spiral development and innovation of the final product. Getting the active duty operators to use different types of vehicles and sensors under as many operational conditions as possible to see what works and doesn't work can produce a highly focused first-generation requirement.
- **FCT -** Explore using a Foreign Comparative Test (FCT) on promising foreign made equipment that might meet requirements. The Office of the Secretary of Defense (OSD) administers and funds the FCT selection and acquisition.
- **Field Service Representatives -** Funding an independent Field Service Representative with a background in the military operational expertise associated with the new technology provides continuity in a unit that is normally manned with rotating personnel. It also provides a bridge between the operators and the manufacturer to document requirements and feedback and is invaluable to the successful transition of the program.
- **Independent Testing -** Utilizing an independent organization to conduct realistic "Blind" tests of the equipment against the performance specifications gives the Program Office a snapshot of the actual

maturity and capability of the system throughout its development or acquisition lifecycle.

- **Program Reviews -** Regularly bringing together the program stakeholders and reviewing the various projects progress and challenges keeps everyone on the team aware of schedules, technological challenges, and manufacturing delays that might affect the progress of the program. Implementing a disciplined approach to assigning and documenting action items, and tracking them to resolution also helps to keep the program on track.
- **Fastlane Initiative –** The speed at which UUV technology was and is developing made using a traditional acquisition and development program problematic due to the real risk of delivering an obsolete system to the fleet user after a traditional 5-6 year acquisition cycle. The urgent operational needs statement issued by the fleet due to real world MCM operational requirements allowed the use of a Fastlane initiative to streamline the acquisition of the MK 18 MOD 2 UUVs and get them into the customer's hands in time to make a significant operational difference.
- **Ancillary Equipment and Logistical Support** – In addition to the acquisition of the UUVs themselves, the system also required significant ancillary support equipment to be able to integrate the system with fleet operations. Development, testing, and documentation of Launch and Recovery Systems, boats, charging and storage containers, all had to be done in parallel with the acquisition of the UUVs. High energy battery storage, charging, shipment, and shipboard use approval required significant resource and time expenditures. Spare parts, repair, and maintenance strategy all had to be developed and documented for this new type of technology before turnover to the fleet.
- **Training** - Due to the highly technical nature of the equipment and very changing software and sensor configurations of the UUV prototype, operational testing of the UUVs evolved as the system matured. The use of a "Beta" UUV Operators Course developed around the manufacturer's baseline training with additional MCM and operational training objectives was introduced prior to the fleet turnover of equipment. The course was frequently reviewed and updated during the Beta phase and formatted into Navy training standards.

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