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Navy Explosive Ordnance Disposal Maritime Expeditionary Standoff Response Case History

June 2024

LCDR Andrew W. Cassity, USN

Thesis Advisors: Dr. Robert F. Mortlock, Professor
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ABSTRACT

This thesis is a case history on the Mk 20 VideoRay remote-operated vehicle (ROV) platform acquisition, application, and future developments for Navy Explosive Ordnance Disposal's (EOD's) Maritime Expeditionary Standoff Response (MESR) ROV program of record.

Primary objectives of this case history include describing PMS 408 Expeditionary Mission's middle tier of acquisition (MTA) strategy, the use of rapid prototyping of commercial items to meet the Navy EOD mission requirements, comparative analysis to determine factors that made the Mk 20 VideoRay successful in selection for MESR, describing iterative development and incremental fielding of hardware and software capabilities to support Navy EOD current and future mission requirements, and how MESR fits into the unmanned undersea arena.

Using the MTA pathway, Other Transaction Authorities, and Defense Innovation Unit allowed the best of market and commercial technologies to be incorporated into the ROV prototypes. Over a multi-year user evaluation, a holistic comparative analysis between the two platforms utilized data gathered informing sustainability, supportability, reliability, and capability.

This research ties a successful MTA with one of the leading technological fields employed in the undersea arena. The research supporting this study can be applied procedurally across the acquisition framework and through specific unmanned solutions applications.

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ABOUT THE AUTHOR

LCDR Andrew Cassity is a Navy Explosive Ordnance Disposal (EOD) Officer. He graduated from the United States Naval Academy in 2008, where he received a Bachelor of Science in International Relations. After graduation, he completed the EOD pipeline and reported to Explosive Ordnance Disposal Mobile Unit TWELVE in Little Creek, VA in 2010. During his first tour, he deployed twice to Afghanistan supporting Special Operations Forces. His second tour was at Explosive Ordnance Disposal Detachment Panama City, FL in 2013. In 2016, he reported to Special Operations Command in Tampa, FL for an assignment on of the program offices supporting counter proliferation. In 2019, he reported to Naval Expeditionary Combat Command as the Future Operations Officer. Upon completion, he reported to Explosive Ordnance Disposal Group TWO as the Material Officer from 2020 to 2024. He is currently stationed at a Special Operations Command in Virigina Beach, VA. He is married to his wife, Rebecca, and has two children.

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I would like to thank my advisor, Professor Robert F. Mortlock and my second reader, Professor Keith Hirschman for their support throughout this process. Additionally, I would like to thank all the Chief of Naval Operations (OPNAV) 957, Program Management Ships (PMS) 408 Expeditionary Missions, and Naval Information Warfare Center Pacific (NIWC PAC) personnel who supported my requests for information while working on this capstone as well as during my time supporting Navy Explosive Ordnance Disposal (EOD) requirements and fielding of EOD specific equipment.

Finally, to all the Navy EOD technicians doing the job, continue to lean forward in the execution of tactical to strategic-level engagements using the latest technologies. We continue to lead unmanned efforts across the Navy and provide the Department of Defense with critical capabilities applied towards increasingly complex problems. Embrace the changing landscape, train and incorporate these technologies, and continue to execute on the leading edge.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAF	adaptive acquisition framework
ATR	automatic target recognition
CDD	Capabilities Development Document
CDS	charge delivery system
COTS	commercial-off-the-shelf
CUI	Controlled Unclassified Information
DIU	Defense Innovation Unit
DOD	Department of Defense
EOD	explosive ordnance disposal
ExMCM	expeditionary mine countermeasures
ISEA	in-service engineering agent
KPP	key performance parameters
KSA	key system attributes
MESR	Maritime Expeditionary Standoff Response
MCM	mine countermeasures
MOTS	modified commercial-off-the-shelf
MTA	middle tier of acquisition
NECC	Naval Expeditionary Combat Command
NIWC PAC	Naval Information Warfare Center Pacific
NPS	Naval Postgraduate School
OPNAV	Chief of Naval Operations
PEO USC	Program Executive Office Unmanned and Small Combatants
PMS	Program Management Ships
POR	program of record
RDT&E	research, development, test, and evaluation
ROV	remote operated vehicle
SSW	seabed and subsea warfare

UOES	user operational evaluation system
UUV	unmanned underwater vehicle

I. INTRODUCTION

Navy Explosive Ordnance Disposal (EOD) strategic vision states, "We eliminate explosive threats so the Fleet and Nation can fight and win-whenever, wherever, and however it chooses. We envision a Nation undeterred by explosive threats" (Navy Expeditionary Combat Command, n.d). To execute these missions, the Navy EOD employs various unmanned systems, including underwater remotely operated vehicles (ROVs). ROVs currently perform commercial and military applications in multiple configurations and capabilities. "The commercial unmanned systems industry enables DOD to rapidly field leading-edge technology to operate more effectively and in spaces that may be inaccessible to legacy systems used today" (Defense Innovation Unit [DIU], 2019, p. 14). The VideoRay Mission Specialist Defender ROV is one such commercial off-the-shelf (COTS) ROV rapidly acquired by Project Management Ships (PMS) 408 Expeditionary Missions to support Navy EOD's urgent operational needs and capability gaps. Through a COTS to modified commercial off-the-shelf (MOTS) approach, PMS 408 and Navy EOD users evaluated VideoRay and other ROVs as a potential baseline configuration for the Maritime Expeditionary Standoff Response (MESR) EOD ROV program of record (POR). Through this process, the MOTS Mk 20 VideoRay Mission Specialist Defender became the backbone of Navy EOD's MESR program. Factors such as rapid prototyping, modular design, open systems architecture, incremental development and delivery, incorporation of leading technologies, and the acquisition process utilized by PMS 408 provide a successful example application of the adaptive acquisition framework (AAF) for a middle tier of acquisition (MTA) case study of a COTS product transitioning to a POR. This case study highlights and links those common methods for success in an MTA's focus on rapid development and fieldable prototypes using proven technologies.

The researcher leverages experience as a member of the Navy EOD community currently acting in requirements, equipment fielding, and sustainment roles. These duties require working with the end user, PMS 408, in-service engineering agent (ISEA), and resource sponsor levels with this POR.

A. RESEARCH QUESTIONS AND OBJECTIVES

This research focuses on PMS 408 procurement of COTS maritime ROVs, the MOTS prototypes developed, and the MOTS Mk 20 VideoRay Mission Specialist Defender ROV transition to the MESR POR for Navy EOD. PMS 408 leveraged:

> The modernization of maritime capability through technology deployment agreements, new start candidates and other science and technology interactions for Navy EOD to provide Expeditionary Mine Countermeasures (ExMCM) warfighting capability by eliminating threats from sea and limpet mines, maritime improvised explosive devices (IEDs), natural hazards, and enable freedom of maneuver. (Malatesta, 2021, p. 4)

This research highlights the use of the adaptive acquisition framework for PMS 408's procurement of COTS ROV platforms, prototype conversions to MOTS ROVs, and the factors leading to the successful transition of the Mk 20 VideoRay to the MESR POR using the MTA pathway. Secondary research objectives include addressing the factors that contributed to the selection of the Mk 20 VideoRay over other ROV platforms, what acquisition strategies PMS 408 utilized to assess the MOTS Mk 20 VideoRay and the alternate MOTS Mk 21 Fusion ROV, what incremental hardware and software current and future technology developments VideoRay adopted to support Navy EOD mission requirements, and how MESR fits into the larger unmanned systems initiative.

B. RELEVANCY OF RESEARCH

This research ties a successful adaptive acquisition MTA with one of the leading technological fields employed in a demanding undersea arena. The research supporting this study can be applied procedurally across the acquisition framework and through specific unmanned solutions applications. Much of the research is utilized both commercially and militarily. The demand for autonomy and the rapid pace of technological change leveraged "Defense Innovation Unit (DIU) maritime autonomy efforts act as a force multiplier by fielding faster, cheaper, and more effective autonomous, unmanned, or remotely operated vehicles that remove divers from minefields and displace manned vessels from hazardous waters" (DIU, 2019, p. 14). The Department of Defense (DOD) frequently leverages and partners with industry on rapid commercial developments to support immediate operational requirements. The DOD then looks at some of these materiel solutions to transition to POR systems. As part of a POR, these solutions come with program office life cycle support.

One of the most prevalent areas where DOD leverages commercial technology for current challenges is unmanned systems. These unmanned systems are being purchased and fielded across Joint Services to cover immediate missions across all domains. Rapid commercial acquisitions enable the DOD to learn in real-time, adapt future acquisition strategies, develop training and sustainment plans, and gather user feedback to better inform future requirements. Figures 1 and 2 depict Mk 20 VideoRay Defender baseline configuration employment supporting EOD requirements.

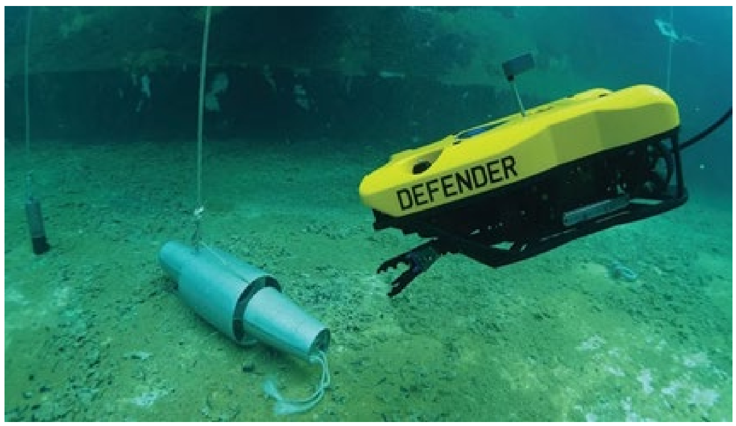

Figure 1. Mk 20 VideoRay Training. Source: Gibson and Bentley (2022).

Figure 2. Mk 20 VideoRay Defender. Source: R. Cooper (PowerPoint slides, March 1, 2023).

C. METHODOLOGY

This research uses a case study methodology to study the COTS to MOTS to POR transition of the VideoRay ROV through the MTA adaptive acquisition framework pathway. The capabilities of the MOTS Mk 20 VideoRay and Mk 21 Fusion ROV, PMS 408's acquisition process, and future MESR increments are assessed through a decision matrix, alternatives analysis, and an overall assessment of the acquisition strategy. Additionally, a broad perspective examines how this capability fits into the more significant DOD unmanned systems initiatives.

This case study research utilizes a range of sources, including peer-reviewed journals, conference papers, trade journals, NPS Defense Acquisition Innovation Repository papers, other government documents, Program Executive Office Unmanned and Small Combatants (PEO USC) and PMS 408 program office products, Navy EOD user-generated documents, ROV company product descriptions, and reports from RAND, Congressional Research Service (CRS), and the Government Accountability Office (GAO). These sources cover commercial and military applications and similar themes, including commercial and military applications, artificial intelligence and autonomous capabilities, current and future technology developments, and PMS 408's VideoRay acquisition process.

Limitations for this study are primarily due to the relatively new fielding of VideoRay as MESR for Navy EOD users and the classification of some of the requirements and operational usage of the platform. Information will continually be gathered from the users to PMS 408 and Naval Information Warfare Center Pacific (NIWC PAC) as MESR increments are fielded and utilized more in training and operational settings. This study did not focus on comparisons with other nations' ROV capabilities for military application and instead concentrated on PMS 408 acquired platforms. One possible vulnerability of this study is that much of the market research is focused on a single platform and program office acquisition for VideoRay. Many commercial ROV platforms exist, but for the Navy applications, Navy EOD and PMS 408 are the primary customers, leading unmanned systems' seabed and subsea warfare (SSW) lines of effort.

One challenge for this research is that some applications, requirements, and performance data are at a higher classification level. The capabilities development document (CDD) for MESR POR contains many requirements at the controlled unclassified information (CUI) or secret clearance levels. These restrictions limited some aspects of the comparative analysis and use of specific operational data.

D. ORGANIZATION

Chapter II of this study provides a background framework of the AAF, MTA, DIU processes, a summary of PMS 408's MESR program and acquisition baseline, and a literature review. Chapter III addresses the MESR POR from a case study analysis methodology. Chapter IV describes the decision by PMS 408 for the MESR POR and analyzes the various criteria used for the POR decision, and how that was a successful COTS to MOTS to POR process. Chapter V consists of the summary, conclusion, and recommendations.

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II. BACKGROUND AND LITERATURE REVIEW

This section provides a background framework of the traditional acquisition process, and the AAF focuses on urgent MTA and major capability acquisition (MCA) pathways, DIU processes, how these efforts fit within the larger DOD unmanned systems initiative, and a literature review.

A. BIG "A" ACQUISITION

The big "A" acquisition refers to the three "DOD decision support systems consisting of the Joint Capabilities Integration and Development System (JCIDS), the planning, programming, budgeting, and execution process; and the defense acquisition system (now referred to as the Adaptive Acquisition Framework (AAF)" (Schultz, n.d). These three pillars are the foundation for the acquisition model that takes a requirement through JCIDS, allocates resources and budgeting, and then pushes those to the DOD to work on an acquisition to support that requirement, whether buying or developing existing solutions. Figure 3 shows the big "A" acquisition dependencies.

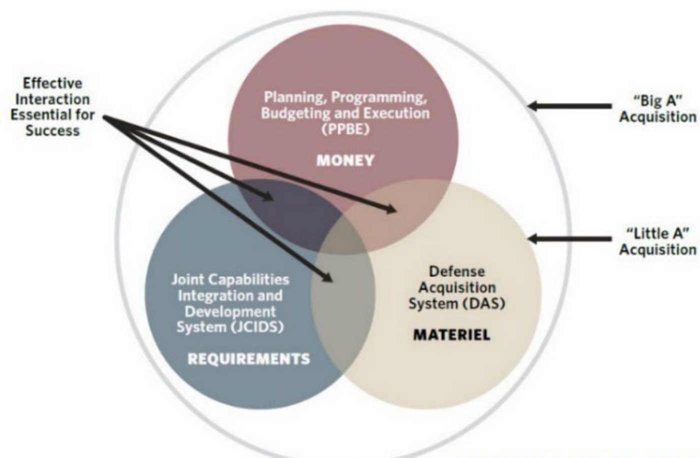

Figure 3. Big "A" Acquisition. Source: Schultz (n.d.).

Regarding the DOD process, DOD instruction 5000.02, "Operation of the Defense Acquisition System," lays the foundation for how the DOD will manage acquisition programs and transition to an adaptive acquisition mindset. Guidance on the relationship between these three processes is centered on working at the lowest level possible, ensuring the total life cycle of the acquisition is planned for, and ensuring there are appropriate milestones and validation of the acquisition baseline throughout the program. The major capabilities acquisition pathway phases include the materiel solution analysis phase, technology maturation and risk reduction phase, engineering and manufacturing development phase, product and deployment phase, and operations and support phase. The Under Secretary of Defense for Acquisition, Technology, and Logistics reinforces the need to be flexible and adaptable based upon requirements and guides milestone decision authorities (MDAs) to:

> Tailor program strategies and oversight based on the specifics of the products being acquired, including complexity, risk factors, and required timelines to satisfy validated capability requirements. When there is a strong threat-based or operationally driven need to field a capability solution in the shortest time, MDAs are authorized to implement streamlined procedures designed to accelerate acquisition system responsiveness. (Office of the Under Secretary of Defense for Acquisition and Sustainment [OUSD (A&S)] DOD INST 5000.02, 2013, p. 3)

B. ADAPTIVE ACQUISITION FRAMEWORK

The AAF emphasizes the need for multiple acquisition pathways to allow for flexible, tailored options best suited to the requirement. The AAF is "a policy re-envisioned and restructured in a framework that encourages critical thinking by program managers in selecting and tailoring the best-suited approach or pathway for a particular acquisition. It facilitates more rapid delivery to the point of need" (Defense Acquisition University, n.d., p. 1). The paths created in AAF are "urgent capability acquisition, middle-tier acquisition, major capability acquisition, software acquisition, defense business systems, and acquisition of services" (OUSD [A&S], 2020, p.10). Each pathway has supporting DOD instructions, timelines for the program, milestones, and tailored approaches. PMS 408 utilized the MTA pathway to develop prototypes and technologies in support of the MESR POR from a rapid prototyping and fielding approach. DOD Instruction 5000.80 is the "*Operation of the Middle Tier of Acquisition*" instruction. This MTA pathway intends to provide a capability within five years leveraging how a "rapid prototyping path provides for the use of innovative technologies to rapidly develop fieldable prototypes to demonstrate new capabilities and meet emerging military needs" (OUSD [A&S], 2019, p.3). Figure 4 illustrates the multiple pathways for AAF.

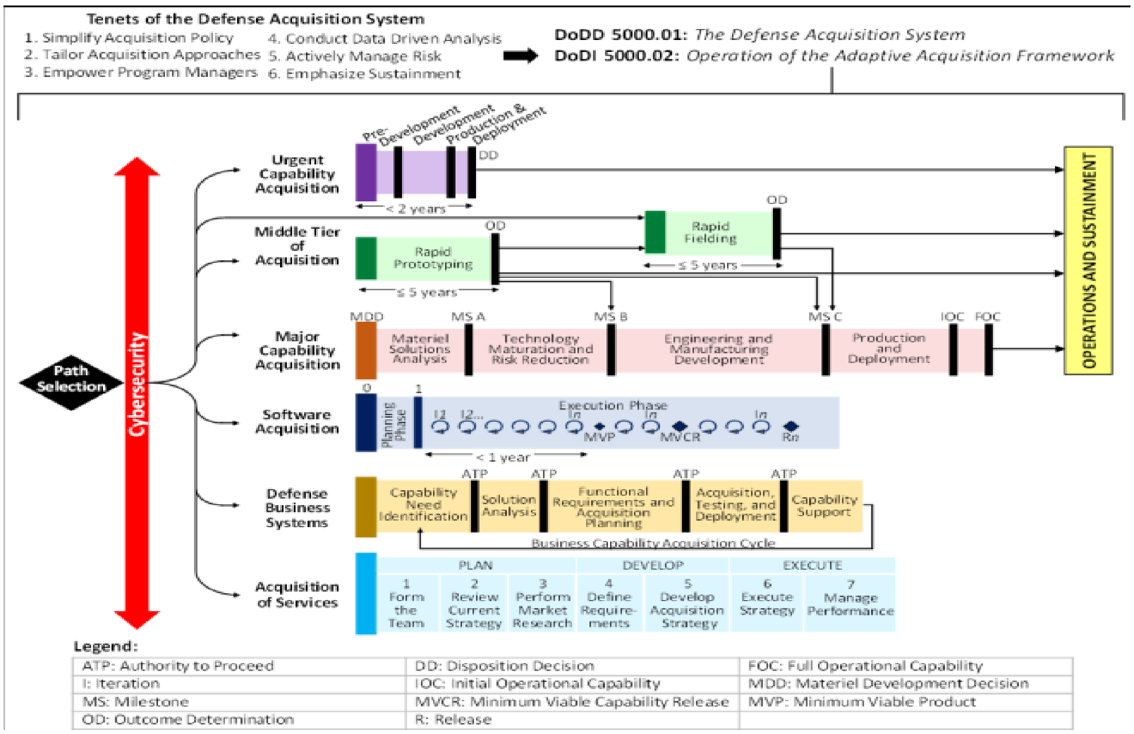

Figure 4. Adaptive Acquisition Framework. Source: OUSD (A&S, 2020).

C. DEFENSE INNOVATION UNIT

Supporting the MTA pathway, PMS 408 utilized DIU to accelerate further the acquisition and prototyping of the VideoRay ROV baseline configuration, resulting in the Mk 20 VideoRay Defender, to support urgent Navy EOD requirements. DIU's mission statement is to work with commercial and DOD partners to "rapidly prototype and field dual-use capabilities that solve operational challenges at speed and scale. DIU is the department's gateway to leading technology companies across the country" (DIU, n.d., p. 1). DIU offers companies a streamlined process and increases the opportunity for commercial technology companies to work with the DOD on initiatives that support DOD requirements as well as the interests of the company. This facilitation approach allows all parties to benefit and allows the latest commercial technology to be applied to DOD problems.

D. DOD UNMANNED SYSTEMS INITIATIVE

In the current global power competition, technology drives both the threat and the systems developed to induce or counter those threats. Unmanned systems, such as robots used for sensors or explosive hazards, have been employed for decades to reduce the probability of harm to personnel. This momentum shifted from a protective stance to an offensive one, significantly increasing unmanned aerial vehicles used for intelligence, surveillance, and targeting. The unmanned surface and undersea domain is one of the current strategic to tactical-level initiatives driven primarily by global power and competition from China.

The DOD and Navy's pursuit of unmanned systems as a force multiplier includes strategic to tactical level guidance documents. The National Defense Strategy, Unmanned Campaign Framework, Navy Advantage at Sea, the Chief of Naval Operations Navigation Plan, and the Navy's Intelligence Autonomous Systems highlight these systems' development, acquisition, and utilization. Figure 5 highlights some critical phrases within these documents emphasizing unmanned systems' utilization in the current and future battlespace.

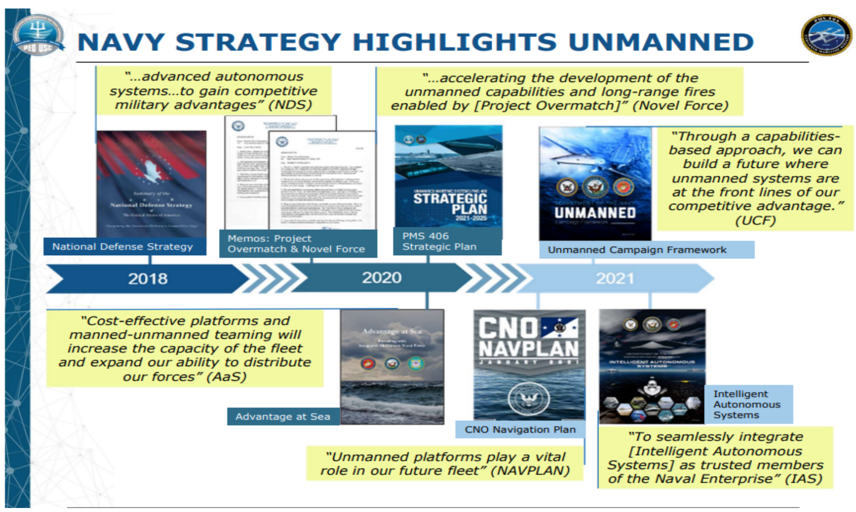

Figure 5. Unmanned Systems Strategy Documents. Source: Small (2022).

The multi-domain usage of unmanned systems includes the sea and subsurface battlespace. A specific focus area is the unmanned underwater vehicle (UUV) capability and a wide range of industry-supporting commercial and military applications. Strategically, "unmanned and autonomous systems are a demonstrated force multiplier for DOD. The commercial unmanned systems industry enables DOD to rapidly field leading-edge technology to operate more effectively and in spaces that may be inaccessible to legacy systems today" (DIU, 2019, p. 14). Unmanned systems provide the capability to access areas, gather data, and provide options to decision-makers that manned systems cannot accomplish. Humans will remain relatively limited in their abilities to continue improving their skills, but hardware and software solutions will evolve rapidly. The emphasis on integrating unmanned systems as a force multiplier in the current and more significant near-peer type conflict is more relevant than ever.

Navy EOD currently utilizes various unmanned systems in the air, ground, and sea environments with different configurations and capabilities. The DOD has developed strategies, doctrine, and multiple policies to support these unmanned initiatives, with increasing focus on artificial intelligence and machine learning. The ability to remotely search, detect, identify, and engage targets in all environments will be critical for future steady state and crisis operations. Figures 6, 7, and 8 provide examples of concepts of operations and layered approaches to SSW where Navy EOD and other users employ the larger UUV platforms and the smaller ROV systems to offer strategic to tactical-level actions.

Figure 6 illustrates a combination of manned and unmanned systems supporting the full range of detect to engage tasking in the undersea domain. The range of capability scales down from large UUVs to smaller ROVs, which are the final configurations that support actions on desired targets. The UUVs provide unmanned systems with the fidelity to locate and identify the target and then have the ROV conduct the fix and finish aspects of the operation. This wide array of capabilities continuously narrows the search and identifies operation elements, and then the ROV is employed on that isolated target for final actions.

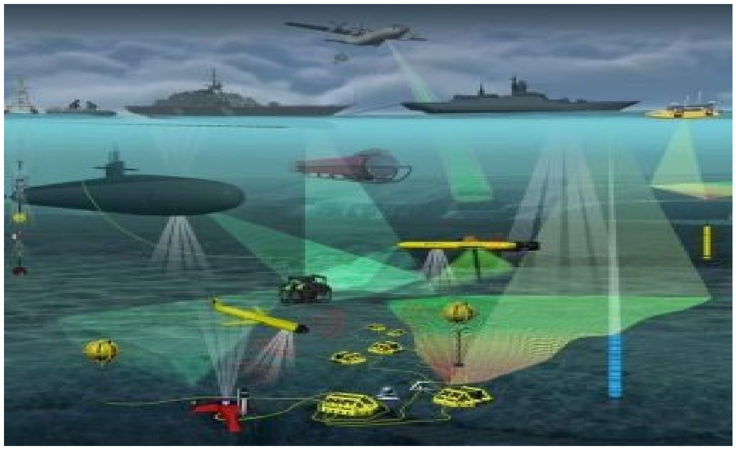

Figure 6. Undersea Autonomous Operational View. Source: Nichols et. al (2020).

Figure 7 shows the Naval Expeditionary Combat Command (NECC) operational concept and where integration of unmanned UUV and ROVs provides support. NECC is the Type Commander for Navy EOD forces. Navy EOD's utilization of UUVs, ROVs, and divers are the primary capability for ExMCM and route clearance. The UUVs conduct the wide area search and detect undersea targets for follow-on ROV or diver fix and finish options.

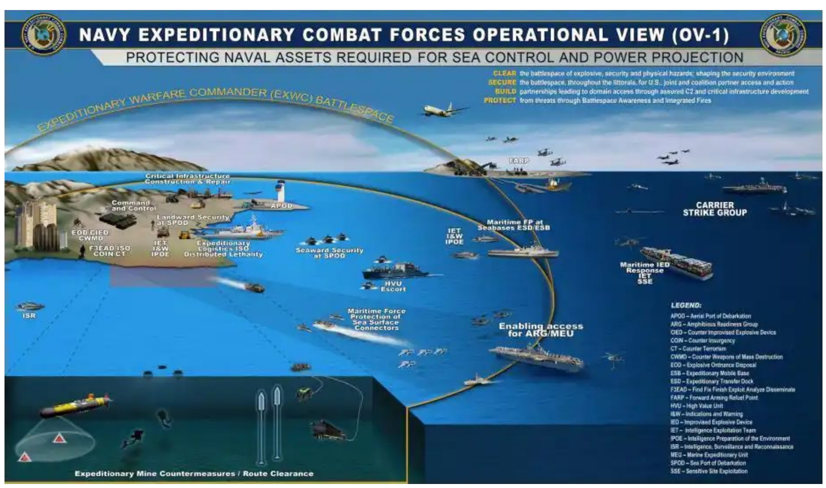

Figure 7. Navy Expeditionary Forces Operational View. Source: Juve (2020).

Figure 8 depicts the PMS 408 and Navy EOD timeline for capability development and fielding of the larger Mk18 UUV family of systems. PMS 408 utilized a similar iterative development and incremental delivery strategy for a UUV family of systems to support Navy EOD requirements.

Figure 8. PMS 408 and Navy EOD UUV Initiative. Source: R. Cooper (PowerPoint slides, March 1, 2023).

E. LITERATURE REVIEW

This case study research centers on using unmanned systems for ExMCM and SSW requirements. This study differentiates itself by focusing on using ROV platforms to accomplish ExMCM and SSW tasking rather than the larger UUV platforms. The larger UUV platforms provide greater capability for searching and identifying functions for follow-on ROV fix and finish actions. Additional focus on supporting urgent operational needs, PMS 408 fielded multiple ROV configurations and incorporated user feedback to down-select the VideoRay for transition to a POR. Finally, this case study highlights the VideoRay and PMS 408 strategy for implementing an iterative development and incremental fielding to deliver various capabilities to the warfighter and specific DOD applications.

Most literature supporting unmanned ExMCM and SSW capabilities centers on UUV lines of effort under the Program Executive Office Unmanned and Small Combatants (PEO USC). PEO USC's mission statement is "PEO USC will design, develop, build, maintain, and modernize the Navy's unmanned maritime systems; mine warfare systems; special warfare systems; expeditionary warfare systems; and Small Surface Combatants" (Naval Sea Systems Command, n.d). Within this portfolio are a wide range of configurations and capabilities, ranging from small to extra-large. Figure 9 shows the range of PEO USC UUV platforms.

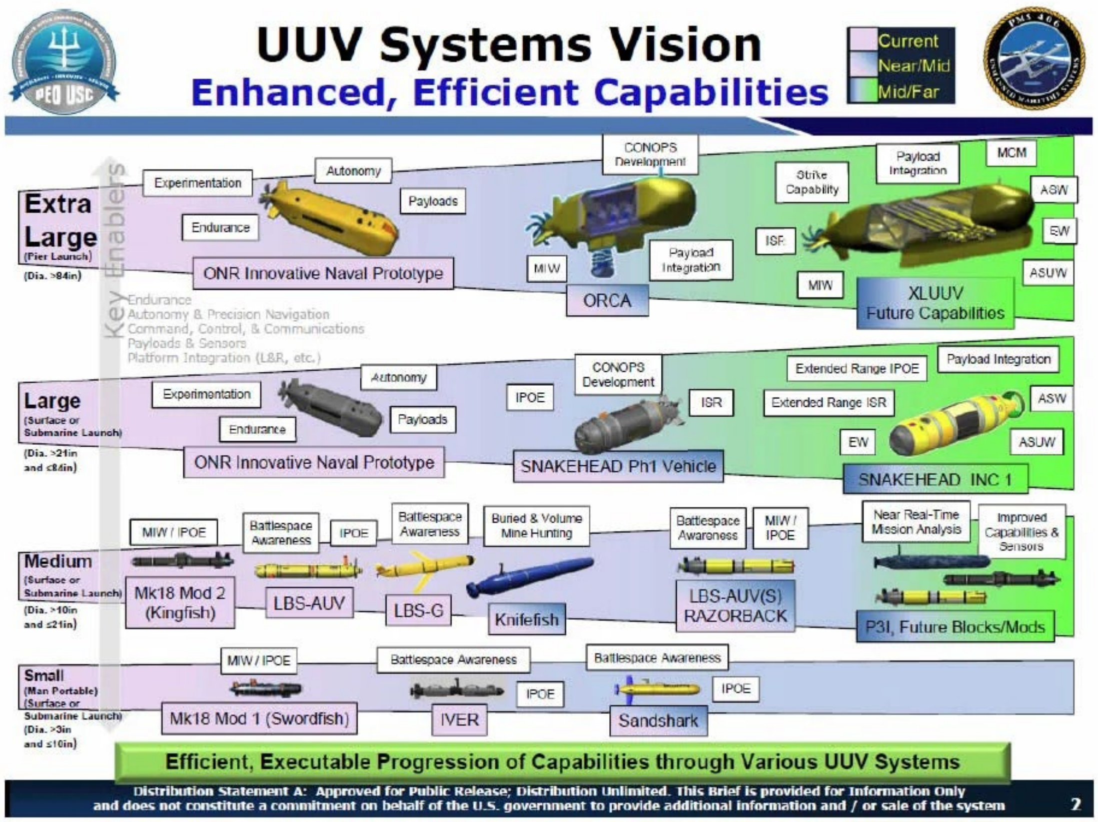

Figure 9. PEO USC UUV Systems Vision. Source: SeaWaves Press (2023).

The UUV is considered the workhorse of the ExMCM and SSW missions due to its capabilities, which support the entire search, detection, identification, and engagement process, reducing the overall time of the process and increasing the probability of detecting desired targets. They conduct pre-programmed, autonomous navigation to conduct search operations utilizing a variety of sensors to detect and identify potential targets of interest on the seafloor or in the water column. UUVs can cover an extensive search area, carry larger sensor payloads, have a greater battery endurance, and operate at much greater depths than ROVs. From an earlier RAND study in 2009, the potential for UUVs to accomplish mission sets such as mine countermeasures (MCM), intelligence, surveillance, and reconnaissance (ISR), and payload delivery" was highlighted, with

MCM and ISR being the top two most applicable and mature applications. (Button et al., 2009, p. xiv). This study further highlighted the potential utilization for employing UUVs in denied areas and captured the most significant current shortfalls: power duration and endurance.

ROVs also conduct this range of tasking but at a much more finite scale. Instead, they are utilized for follow-on tasking after a UUV platform completes the search and detect tasking. ROVs are used more to confirm targets and then follow-on specified actions such as disruption, delivered using capabilities provided from various configurations and tool capabilities. ROV employment is limited to launch and tether to a craft with EOD operators and power and depth limitations. The ROV provides the capability to perform actions on the identified target using a variety of configurations, such as specific tools, disruptor charges, and charge placement. The larger UUVs do not have this finish capability and are just a search and identify capability.

A significant amount of literature reports is focused on current and proposed budgets for UUV initiatives. UUVs are a considerable cost for the Navy, especially for the larger platforms. Prototypes are being developed to assess concepts of operation and mature technologies. Under PEO USC, PMS 406 Unmanned Maritime Systems leads the undersea and surface lines of effort for the larger Navy applications, outside of what PMS 408 does for the Expeditionary Unmanned Systems portfolios. Figure 10 shows the breakdown of PEO USC expeditionary efforts compared to larger undersea and surface platforms. In support of Navy EOD, PMS 408 lines of effort are the Mk18 UUV family of systems, the next-generation UUV Lionfish platform, and the MESR platform. They are all PORs. The larger PMS 408 unmanned systems lines of effort include the extra-large unmanned underwater vehicles (XLUUV), large displacement unmanned underwater vehicle (LDUUV), medium unmanned surface vessels (MUSV), and large unmanned surface vessels (LUSV). This snapshot provides a holistic picture of the Navy's unmanned systems efforts for surface and sub-surface capabilities.

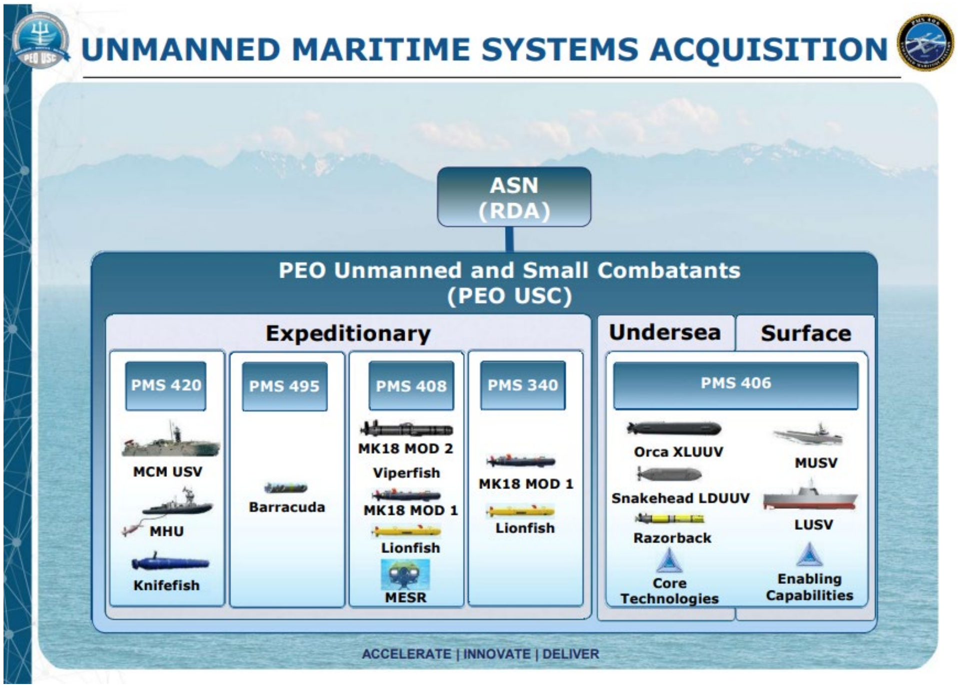

Figure 10. PEO USC Unmanned Systems Program Offices. Source: Small (2022).

According to a Congressional Research Service (CRS) report in 2023 on Navy large UUVs, due to the considerable cost of the larger UUVs such as the Orca:

> The Navy's FY 2024 budget submission programs the procurement of additional XLUUVs [extra-large unmanned undersea vehicles] through Other Procurement, Navy (OPN) account, with the one XLUUV to be procured in FY2026 at the cost of $113.3 million, another one in FY2027 at a cost of $115.6 million, and another one in FY2028 at a cost of $117.9 million. (O'Rourke, 2023)

These are significant capabilities but at a considerable expense, requiring an extensive life cycle management program to sustain them. The XLUUVs are also very limited regarding the employability of these large platforms. This is where PMS 408 and the expeditionary lines of effort for UUV and ROV come into play. These platforms provide a more employable and supportable capability than the larger PMS 406 solutions.

A Government Accountability Office (GAO) study in 2018 reviewed how the Navy and Marine Corps could better approach unmanned systems acquisition. This study analyzed the PMS 408 Mk18 UUV family of systems, the PMS 406 Snakehead large UUV, and unmanned aerial vehicle and unmanned surface vehicle initiatives. The GAO conducted this study because "the Department of the Navy has committed to rapidly grow its unmanned systems portfolio. It currently has at least 24 types of systems and has budgeted nearly $10 billion for their development and procurement for fiscal years 2018–2022" (Farrell, 2018).

Within the Defense Acquisition Innovation Repository at the Naval Postgraduate School (NPS), the Acquisition Research Program has multiple theses regarding the Mk18 UUV program. Focuses include the urgent operational need acquisition pipeline and the utilization of these UUVs to support ExMCM and SSW mission tasking. A recent NPS thesis from June 2023 by Annabelle Tiller (2023) described how PMS 408 utilized a successful program "that developed requirements accurately and on time to provide an efficient product for their end users. One such program is the Mk 18 Mod 1 unmanned underwater vehicle (UUV), which utilized the User Operational Evaluation System to inform and structure the requirements development process" (Tiller, 2023). This thesis is similar to this case study approach but focuses on the UUV rather than the ROV acquisition. The model is similar and conducted by PMS 408 for the same Navy EOD end user.

In addition to concentrating solely on UUV platforms within these mission areas, much literature focuses on technology developments such as artificial intelligence and automatic target recognition (ATR) capabilities. These capabilities are a focal point for unmanned systems. They would allow faster process time, detect and identify sequences, and reduce the current scope of responsibility for the end user to process and execute a large amount of data. This literature focuses on this capability on UUV platforms and less on ROV platforms. This case study illustrates how this ATR technology is incorporated into the VideoRay platform to provide unique applications for EOD-specific requirements.

This case study differs from previous research in that the focus is not on the UUV platforms performing the ExMCM and SSW missions but on the smaller and more specific utilization of ROV platforms by EOD to accomplish these mission requirements. Additionally, this case study highlights a unique application of MTA utilized by PMS 408 and DIU to acquire multiple commercial ROV platforms to fulfill urgent EOD requirements, prototype those platforms for unique EOD applications, field these two solutions to provide real-time operational user feedback, and then take those findings and down-select to the VideoRay platform for the MESR POR. This acquisition approach offers insight into a successful AAF strategy using the MTA pathway to provide MOTS prototype materiel solutions, simultaneously field systems for operational use, and incorporate user feedback and open systems architecture to perform iterative development and incremental fielding. The specific applications of new technologies, such as artificial intelligence and augmented reality towards an ROV application, are unique compared to the extensive literature associating these technological developments with UUVs.

III. CASE STUDY

This chapter addresses the case history of the Maritime Expeditionary Standoff Response (MESR) program of record (POR) from a case study methodology covering the background, stakeholders, central issue, requirements, iterative development and incremental delivery, and options.

A. BACKGROUND

The MESR POR results from almost a decade of remote operated vehicle (ROV) use by Navy Explosive Ordnance Disposal (EOD) forces to support operational requirements. Over this timeframe, multiple commercial-off-the-shelf (COTS) materiel solutions were purchased and prototyped into modified commercial-off-the-shelf (MOTS) ROVs to provide the initial capability for use as part of a Project Management Ships (PMS) 408 Expeditionary Missions roadmap strategy to develop COTS to MOTS and eventual POR remote operated vehicle (ROV) materiel solutions. Figure 11 shows PMS 408's MESR developmental approach for this transition.

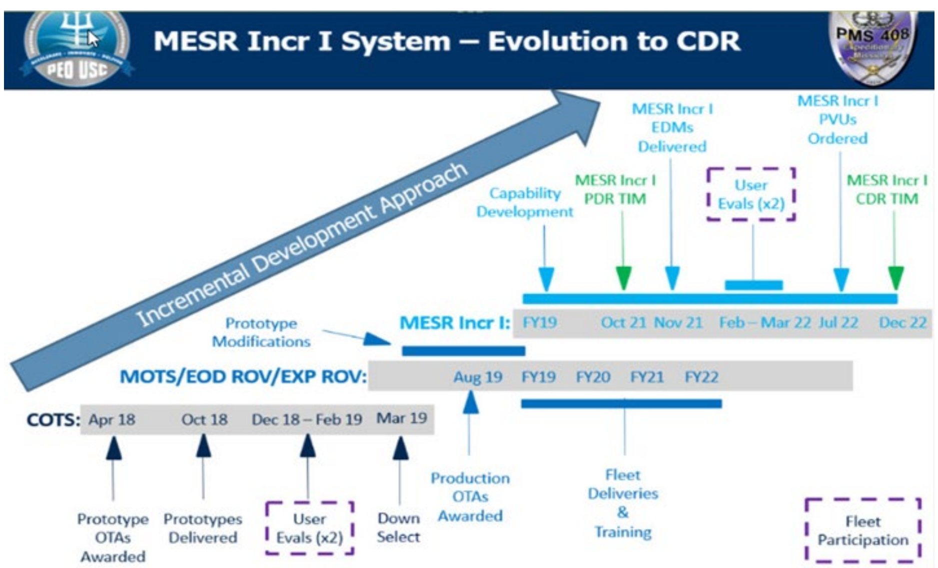

Figure 11. MESR Incremental Development Approach. Source: F. Gaghan (email to author, April 8, 2024).

These ROV platforms are required to support the operational requirements of:

> Find, fix, and finish underwater explosive-laden threats in support of maritime improvised explosive device defeat, naval mine and other unexploded ordnance render safe, neutralization, disposal and exploitation missions. Additionally, ROV systems support inspection and investigation response tasks during underwater search recovery and salvage operations. (R. Hayes, Office of the Chief of Naval Operations (OPNAV) 957, Expeditionary Unmanned Neutralization Systems Requirements Development and Strategy p. 1)

The MESR POR, through an iterative development and incremental fielding approach, provides a variety of hardware and software configurations for increased capability to accomplish Navy EOD-specific tasks. Hardware developments like additional manipulator arms, explosive charge delivery systems, and advanced sonar focus on greater capability to conduct finish-type options on desired mine countermeasures (MCM) or seabed and subsea warfare (SSW) targets. Software developments such as autonomous navigation, automatic target recognition, and interoperability with current Navy EOD applications will provide increased capability to conduct find and fix operations within the MCM and SSW domains.

B. STAKEHOLDERS

Key MESR stakeholders include the Office of the Chief of Naval Operations (OPNAV) 957 Expeditionary Combat branch resource sponsor, the PMS 408 program office, Naval Information Warfare Center Pacific (NIWC PAC) in-service engineering agent (ISEA), Defense Innovation Unit (DIU), and the Navy EOD user community.

OPNAV 957 Expeditionary Branch is the resource for most Navy EOD requirements. OPNAV N9 is the Deputy Chief of Naval Operations for Warfighting Requirements and Capabilities, OPNAV 95 is Expeditionary Warfare, and OPNAV 957 is Expeditionary Combat.

PMS 408 has six portfolios as a Systems Command for Naval Expeditionary Combat Command (NECC) and Navy EOD. One of these is Underwater Explosive Ordnance Disposal. PMS 408 is the program office managing the POR and all MESR life cycle aspects. Within the Underwater Explosive Ordnance Disposal branch, the two branches supporting Navy EOD and MESR are the Principle Acquisition Program Manager, the Fleet Product Director, and the Assistant Program Manager Manned

Systems portfolio. PMS 408 is the initial coordination point for the MESR POR and the end user.

NIWC PAC Maritime Systems Engineering Branch is the ISEA for PMS 408 and the MESR POR. As the ISEA, NIWC PAC provides technical and engineering support to PMS 408 and the end user, as well as maintenance, logistics, and training support. The MESR POR provides life cycle sustainment support through operational, intermediate, and depot-level repair support. Additionally, NIWC PAC provides sustained and incremental training to the end user for current or newly fielded configurations. NIWC PAC provides field service representatives and mobile training teams to accomplish these support functions as part of the POR.

Defense Innovation Unit served as the mechanism for PMS 408 to utilize a rapid prototyping approach for the MTA pathway and have the COTS VideoRay and SRS Fusion ROVs prototyped to the MOTS Mk 20 VideoRay Defender and Mk 21 SRS Fusion. The DIU mechanism and commercial industry relationships allowed PMS 408 to leverage various commercial technologies that could have military applications. Using a best-of-market approach, DIU provided PMS 408 with a rapid and technologically mature range of options tailored to Navy EOD-specific requirements for ROV utilization in the ExMCM and SSW mission areas.

The Navy EOD community is the end user of the MESR POR and for whom the requirements and POR was developed. Navy EOD is part of NECC with the mission of:

> Clear explosive hazards to provide access to denied areas; they employ advanced tactics and technologies to exploit and secure the undersea domain for freedom of maneuver; they build and foster relationships with the constellation of capable and trusted partners; and they protect the homeland and our American way of life. (Navy Expeditionary Combat Command, n.d)

Navy EOD is a relatively small community with a little more than 1,100 personnel (M. Guido, PowerPoint slides, 2023). The variety of complex mission tasks for Navy EOD demands a wide range of equipment and capabilities, including many unmanned systems, to accomplish these missions. The MESR POR provides the single ROV solution for the MCM and SSW mission areas.

As the end user, Navy EOD is the primary customer for the MESR POR. The MESR requirements, configurations, and prioritization of incremental developments originate from Navy EOD. The requirements for Navy EOD and the MESR POR are discussed later in this chapter.

C. CENTRAL ISSUE

Navy EOD currently utilizes a range of ROVs, from legacy systems such as the SeaBotix, to next-generation ROV systems such as the Mk 20 VideoRay and Mk 21 SRS Fusion. Figures 12, 13, and 14 illustrate the legacy SeaBotix and two PMS 408 rapidly acquired and prototyped ROV materiel solutions, SRS Fusion and VideoRay, respectively. The SRS Fusion and VideoRay were purchased as COTS items and modified to MOTS ROVs to fill emergent requirements. Currently, all three systems remain fielded. These systems provide a range of ROV capability but PMS 408, NIWC PAC, and Navy EOD currently have to manage 3 different ROV systems to execute these requirements. This scenario of having multiple platforms, some legacy and some next-generation, would drive the ultimate need and decision to down-select to a single ROV baseline platform to support MESR.

Next-generation capabilities and current EOD requirements have outpaced the legacy SeaBotix. EOD operators globally have primarily utilized the MOTS Mk 20 VideoRay and Mk 21 SRS Fusion ROV systems for the past 2 years. The Department of Defense (DOD) and Navy SSW line of efforts remain high priorities where Navy EOD and unmanned systems operate. Developed and delivered incrementally, current and future hardware and software capabilities will ensure the MESR will allow continuous improvement and employment of this capability supporting these mission areas.

Unmanned systems initiatives are one of the main priorities within the current National Defense Strategy and National Security Strategy because these initiatives represent some of the leading materiel solutions in the undersea domain of those efforts.

Figure 12. SeaBotix ROV. Source: Hydro-International (2017).

Figure 13. Mk 21 SRS Fusion ROV. Source: Sonistics (2019).

Figure 14. Mk 20 VideoRay Defender. Source: E. Ford (PowerPoint slides, November 14, 2023, p. 5).

The SeaBotix ROV system is a COTS solution PMS 408 purchased in 2011 in support of Navy EOD developing requirements for an underwater ROV to provide remote search capabilities with limited tool manipulation and configurations. At that time, Navy EOD did not have an underwater ROV capability, which was the first capability delivered to the user. In 2017, PMS 408 purchased 60 systems to provide additional capacity and capability for Navy EOD due to force growth and increasing mission requirements. The new SeaBotix systems were "fitted with a range of COTS equipment, including a crawler attachment skid, imaging sonar, tooling options, altimeter, and global position systems (GPS) navigation capability" (Haun, 2017). These systems have been fielded and utilized since 2017.

As PMS 408 realized the enduring requirement for Navy EOD utilization of ROV systems and the benefits of creating a POR to support total life cycle management for this capability, PMS 408 looked at the SRS Fusion and VideoRay Defender as alternate materiel solutions to support a Navy EOD ROV POR. From the 2017 "Navy Expeditionary Remotely Operated Vehicle System Requirements Document" document, the intent was to:

> Support accelerated acquisition, configuration control, and life cycle support of a modified-off-the-shelf (MOTS) ROV system aimed at providing a bridging solution to replace aging COTs ROVs prior to the end of their service life, until longer term, future capabilities are available to support Navy EOD and combat salvage response tasks in the undersea environment. (R. Hayes, OPNAV 957, Expeditionary Unmanned Neutralization Systems Requirements Development and Strategy, p. iii)

PMS 408 utilized the middle tier of acquisition (MTA) pathway to provide the rapid acquisition, prototyping, and fielding of the MOTS Mk 21 SRS Fusion and Mk 20 VideoRay Defender ROV systems in limited quantities to the Navy EOD community to gather user operational evaluation input to inform better which system should be the single materiel solution to provide this capability and transition into a POR. More of this acquisition strategy and decision criteria are discussed later in this case study.

D. NAVY EOD REQUIREMENTS

The originating requirements for a MOTS EOD ROV come from a top-level requirements document from OPNAV 957 to PMS 408 in March 2017. This requirement document originated at the Navy EOD commands, was endorsed by the Type Command NECC requirements branch, and was approved by OPNAV 957. The operational context of the "Navy Expeditionary Remotely Operated Vehicle System Requirements Document" document:

> Provides top-level requirements for accelerated procurement of a MOTS ROV based system with requisite life cycle and services support. The MOTS system is intended as an accelerated acquisition effort to field a "good enough" capability early, while mitigating against obsolescence with the requisite life cycle support, and then introduce technology refresh upgrades as effective, suitable, and supportable modular solutions emerge from industry and the DOD science and technology investments. (R. Hayes, OPNAV 957, Expeditionary Unmanned Neutralization Systems Requirements Development and Strategy, p. 1)

Additional requirements focused on an incremental approach that could rapidly field initial capability, supporting minimum operational requirements and continuously developing follow-on hardware and software developments to provide greater ROV capability for Navy EOD mission requirements. The minimum mission capability required was to be delivered within 3 to 5 years and to "perform standoff response to underwater explosive threat missions….and to improve situational awareness of both underwater explosive-laden targets, and the surrounding environment in which the targets are placed" (R. Hayes, OPNAV 957, Expeditionary Unmanned Neutralization Systems Requirements Development and Strategy, p. 2).

The original inventory objective for initial operational capability was 7 ROVs to start user operational evaluation and further refine requirements criteria. Figure 15 shows the MTA ROV requirements.

Parameter	Threshold (T)	Objective (O)
Key Performance Parameters (Effectiveness)		
5.1. Probability of Reacquisition/Investigation (P_R)	≥0.80	≥0.90
5.2. Probability of Identification (P_{ID})	≥0.80	O=T
Key System Attributes (Suitability and Supportability)		
5.3. Size Weight and Power (SWaP) KSAs		
(a) ROV platform max size/ weight (lbs)	≤ 88	≤ 44
(b) External module max size/weight (lbs)	≤ 88	≤ 44
(c) Topside max operational footprint (cubic feet)	≤ 27	O=T
(d) Max single component weight (lbs)	≤ 44	O=T
5.4. Adaptability for Multiple Missions	See para 5.4	Field configurable modules integrated
5.5. Supportability KSAs		
(a) Reliability (R)	≥ 0.80	≥ 0.85
(b) Operational Avail. (A_O)	≥ 0.85	O=T
(c) Material Availability (A_M)	≥ 0.85	O=T
(d) MCMTOMF (hours)	≤ 5.0	≤ 2.0
5.6. Suitability KSAs		
(a) Influence signature	Characterized	Improved designs
(b) Maximum current (knots)	1.5	5
Additional Performance Parameters		
5.7. Setup time (minutes)	≤ 30	≤ 15
5.8. Response Depth Range (FSW)	0 - 600	0-900
5.9. Standoff Range (yards)	≥ 250	≥ 2000
5.10. Single Sortie Endurance (mins)	≥ 45	≥ 120
5.11. Placement Accuracy (inches)	≤ 12	≤ 0.5

Figure 15. MTA ROV System Requirements. Source: R. Hayes (OPNAV 957, Expeditionary Unmanned Neutralization Systems Requirements Development and Strategy, p. 2).

This 2017 initial requirements document for a Navy EOD ROV system was the beginning of the Navy EOD ROV effort that would support PMS 408 acquisition of the SRS Fusion and VideoRay Defender to support this COTS to MOTS evaluation to inform the MESR POR.

The Capability Development Document (CDD) for MESR was routed from Navy EOD to OPNAV 957, validated, and sent to PMS 408 in July 2019. The inventory objective for Navy EOD was 216 systems. The MESR CDD is controlled unclassified information or higher classification and limited distribution. However, in discussion with

PMS 408, this case study can still highlight some key performance parameters (KPPs) and the key system attributes (KSAs) (F. Gaghan, email to author, April 15, 2024). The KPPs and KSAs were all broken into the MESR family of systems approach. Each KSA and KPP was broken into threshold and objective values for MESR Increment I, Increment II, and Increment III.

The KPPs are survivability, net ready, energy, and depth range. The survivability KPP focused on a family of systems approach for the MESR configuration and that any damage or loss of a single part of this configuration would not result in the system being completely non-mission capable. Net ready focused primarily on authority to operate and cybersecurity compliance. Sustainment centered on the operational availability percentages to support fleet demand and the maintenance and repair functions. Energy and power supply defined levels required for organic endurance requirements. Depth range is a KPP that is classified but in general, the ROV must be able to accomplish the full range of detect to engage tasking for MCM and SSW missions.

The parameters for the KSAs for MESR include ROV weight, payload weight, topside footprint, response mission effectiveness, mines per sortie, standoff distance, influence signature, reliability, and operational materiel availability.

E. ITERATIVE DEVELOPMENT AND INCREMENTAL DELIVERY

From the iterative development and incremental delivery approach, MESR Increments I to III plan to develop additional hardware capabilities such as advanced sonar capabilities, other manipulator arms, explosive charge delivery systems (CDSs), and onboard battery alternative power (E. Ford, PowerPoint slides, November 14, 2023, p. 9). Additional software capabilities under development include integrating automatic target recognition (ATR), automatic homing, automatic object avoidance, and advanced navigation control. PMS 408 drove to better support Navy EOD tasking in MESR Increment I with a "focus on a time-constrained mine countermeasures mission (MCM) clearance mission with platforms and payloads. This accelerates the transition of underwater EOD low/no collateral damage operations through ROV manipulation, component targeting, and advanced navigation control" (E. Ford, PowerPoint slides, November 14, 2023, p. 9).

The approach highlights the timelines associated with MESR POR to include the original COTS to MOTS prototypes delivered, the incorporation and fielding to the Navy EOD user for feedback, modifications to those fielded prototypes from user feedback, and the follow-on continuous development of MESR as a POR. The MOTS solutions utilized the VideoRay Defender as the Mk 20 and SRS Fusion as the Mk 21 and began fielding in 2019. In September of 2021, PMS 408 requested Navy EOD to determine which ROV platform, the Mk 20 VideoRay Defender or the Mk 21 SRS Fusion, should become the sole configuration of the MESR POR. Additionally, PMS 408 gathered input on the quantity and type of MESR Inc I payloads that were required to include the explosive charge delivery system, manipulator arms, ATR, and autonomous navigation.

From 2019 to 2023, PMS 408 continued to buy both the Mk 20 Defender and Mk 21 Fusion. These systems continued to support Navy EOD requirements while simultaneously gathering performance data and user input to inform discussion on follow-up courses of action for the MESR POR. Figure 16 shows the yearly Mk 20 Defender and Mk 21 Fusion purchases. The quantities and configurations purchased eventually shift towards the Mk 20 Defender.

Year	Mk 20 VR Defender	Mk 21 SRS Fusion
2019	4	18
2020	14	2
2021	19	17
2022	29	7
2023	77	0

Figure 16. PMS 408 ROV Configuration Purchases. Source: F. Gaghan (email to author, April 8, 2024).

F. OPTIONS

In 2021, PMS 408 reached out to the Navy EOD user to determine the way ahead for the MESR POR. These questions leveraged the past 2 years of user operational evaluation system (UOES) data. These questions were framed based on the triple constraints of cost, schedule, and performance using the side-by-side comparisons of the Mk 20 Defender and the Mk 21 Fusion.

The cost constraint focused on whether it was worth having two different ROV configurations that PMS 408 and Navy EOD would be responsible for sustaining. This would double the sustainment responsibilities and resources required for the ISEA and depot repairs. This also would double the requirements and limit the resources to accomplish ROV upgrades, enhancements, and configurations to develop. Each platform would have to achieve at least the threshold objectives from the same ISEA and under the same funding lines for every Navy EOD ROV requirement.

Schedule constraints focused primarily on the acquisition process burden of having to go through parallel processes for a Mk 20 Defender configuration and a Mk 21 Fusion configuration and all the life cycle requirements for a POR. The required management and contracting bandwidth would be running two separate materiel solutions under one POR.

Performance constraints were critical in comparing the Mk 20 Defender and the Mk 21 Fusion. PMS 408 compared reliability, availability, materiel availability (RAM) data, and mean time between failures (MTBF). The amount of failure analysis reports per month was also analyzed.

Comparisons of size, weight, depth rated, tether materiel, speed, maximum cargo weight, power, third-party payload capability, operator control station interface, grabber capability, and sonar configurations were analyzed between the Mk 20 Defender and the Mk 21 Fusion. Figure 17 shows the comparisons between the two platforms.

1) Which is the desired MESR ROV platform?

Characteristic	SRS Fusion	VideoRay Defender
Size	35.24" (L) x 19.13" (W) x 12.17" (H)	29.59" (L) x 15.5" (W) x 10.5" (H)
Weight in Air	64 lbs (50 lbs ROV, 6.5 lbs per Battery)	71.6 lbs (38 lbs ROV, 33.6 lbs Console)
Depth Rated	1,000ft (300m)	1,000ft (300m)
Tether	Fiber	Copper
Speed Rated	3 knots	3 knots
Max Cargo Weight	5 lbs	25 lbs
Power	Battery Onboard ROV	2 x Topside Generators (onboard batteries in development)
3rd Party Payload Capability	TBD	Yes
Operator Control Station	Handheld	Tabletop
Grabber	2 DOF (Rotate, Open/Close)	Rotating with 5 interchangeable heads (Open/Close)
Sonar	BluePrint Oculus 750D -dual freq FLS	BluePrint Oculus 750D -dual freq FLS

Figure 17. PMS 408 ROV Characteristic Comparison. Source: F. Gaghan (email to author, April 15, 2024).

Overall, both ROV platforms had positive and negative attributes for Navy EOD and in the performance of MCM or SSW missions. The collective decision for the baseline configuration between the Mk 20 Defender and the Mk 21 SRS Fusion option for the MESR POR was debated by all stakeholders.

IV. ANALYSIS

This chapter analyzes the decision of PMS 408 to select the Mk 20 VideoRay Defender as the ROV baseline configuration for the MESR POR. Through comparative analysis, decision matrix, risks and mitigations, the implementation plan, and the utilization of the MTA process for a COTS to MOTS to POR solution, this chapter highlights the comparison of the Mk 20 VideoRay and Mk 21 SRS Fusion to the MESR POR requirements, what made the MESR POR acquisition strategy a success, and how these principles can be applied throughout the DOD.

A. DECISION

The Mk 20 VideoRay Defender was down-selected by PMS 408 as the baseline configuration for the MESR POR. This decision was the result of a variety of decision criteria, including the performance factors, user preference, and programmatic efficiencies to have a single Mk 20 VideoRay Defender ROV baseline for MESR compared to having both Mk 20 VideoRay Defender and Mk 21 SRS Fusion, or using the Mk 21 SRS Fusion as the materiel solution.

PMS 408's Mk 20 VideoRay Defender selection culminated in:

> VideoRay, a rapidly growing underwater technology company, announced a $16.1 million order for Mission Specialist Defender underwater ROV and related components for the U.S. Navy's Maritime Expeditionary Standoff Response (MESR) program. This brings the Navy's total procurement of Mission Specialist Defender vehicles and accessories to $49 million since they entered into a Production-Other Transaction Agreement (P-OTA) with VideoRay. (Ocean News, 2023, p. 1)

Figure 18 shows the OPNAV 957 Fiscal Year (FY) 2026 to 2030 funding across the Future Years Defense Program (FYDP) for PMS 408 and the MESR POR.

FUNDING TYPE	FY2026 ($M)	FY2027 ($M)	FY2028 ($M)	FY2029 ($M)	FY2030 ($M)
OMN	3.263	3.341	3.368	3.442	3.518
RDTE	23.98	11.885	12.028	11.234	11.050
OPN	10.105	8.886	9.045	9.227	5.351

Figure 18. OPNAV 957 MESR Funding Across Future Years Defense Program. Source: K. Southard (email to author, April 18, 2024).

B. ACQUISITION STRATEGY

The acquisition process and baseline utilized by PMS 408 initially focused on the rapid procurement of mature COTS ROV platforms, rapidly prototyping to MOTS to support specific EOD applications, and conducting a deliberate multiyear user evaluation to inform the eventual down-select of a single platform to support the POR. An adaptive acquisition approach for this MTA, driven by urgent operational needs, initially focused on rapid prototyping: "PMS 408 and Defense Innovation Unit used the Other Transaction Authority language found in 10 United States Code subsection 2371b to carry out prototype projects that are directly relevant to enhancing mission effectiveness" (Navy Explosive Ordnance Disposal, 2020, p. 2). As the program developed, PMS 408 utilized Small Business Innovation Research (SBIR) initiatives to create additional capabilities within the industry.

The U.S. Code Title 10, Part V Acquisition, Subpart E Research and Engineering, provides the "authority to provide prototypes and follow-on production items as government furnished equipment" (Research and Engineering, 2021). PMS 408 used an incremental approach to developing and delivering vehicles, hardware, and software. The first increment focused on vehicle capacity and payload delivery. The following increment focused on additional sensors, autonomy, and artificial intelligence applications, as well as improvements in power supply. PMS 408 used small business innovative research SBIR solicitations to incentivize and canvas the industry for unique EOD applications to support these follow-up initiatives.

To address the technical data package (TDP) rights, and in forecasting the future hardware and software developments, PMS 408 with the ROV vendor went through the tasks and deliverables associated with the task order, delivery orders, reporting, commercial technical data, drawings and specifications, firmware, and manuals. It was determined that the government's rights to use, release, or disclose the above information would be restricted with limited rights. *Limited* rights mean "the right to use, modify, reproduce, release, perform, display, or disclose technical data, in whole or in part, within the government" (F. Gaghan, email to author, April 16, 2024). If the government wanted to release any of the above-restricted line items, it would have to receive permission from the organization asserting those restrictions first. These organizations include VideoRay, GreenSea Systems, and other firmware interface commercial technical data. The first MESR increment hardware and software configurations are addressed in the current limited TDP but will need to be updated with every increment based upon the specific configurations. There is potential for impact on life-cycle costs if there are a multitude of commercial organizations owning critical aspects of each increment but as this technology matures, there is also the potential for the commercial industry to utilize these technologies and technical data limitations may lessen. These caveats were primarily put in place by the vendors and subcontractors due to much of the proprietary technology, some of the first in the ROV industry, being incorporated into a specific MOTS to POR ROV platform.

This successful utilization of an MTA pathway, strategic partnering with organizations such as DIU to leverage the latest technological developments, rapid prototyping to provide multiple materiel solutions, and balance of vendor and government rights for the technical data to support broader commercial investments are successful AAF and MTA practices that should be applied across program offices. These practices allowed for a reduction in acquisition timelines, leveraging mature COTS solutions and modifying them to MOTS to support DOD-specific applications to provide fieldable prototypes that can be provided to the end user for operational utilization. End user feedback is critical for a program to provide the right capability to support the warfighter. Programmatic risks are reduced with the leverage of mature COTS solutions rather than starting a product from the ground up and a broad commercial base incentivized to continue to develop and improve their materiel solution for both DOD and commercial utilization.

Fielding two COTS to MOTS materiel solutions for a UOES and running a multiyear duration allowed the program office and user to gain valuable information and inform modifications or future requirements for the POR. This approach and associated timelines are not always possible. Still, this side-by-side comparison of COTS solutions allowed critical operational data to be gathered, such as MTBF, materiel availability, operational availability, hardware and software fulfilling mission-specific performance requirements, and what future hardware and software configurations could be developed through iterative development and incremental delivery approach.

Throughout the process, the early and frequent communication between stakeholders was critical. The routine communication between the resource sponsor, program office, ISEA, and end user allowed all parties to stay aligned and make mutual milestone decisions throughout the MTA process. Figure 19 shows the MTA framework that was executed successfully for the MESR POR. This resulted in a POR that provided a prioritized, incremental delivery of capability to the end user, executable with full-funding from the resource sponsor, and allowed the ISEA to focus on developing, training, and sustaining those incremental materiel solutions with the end user.

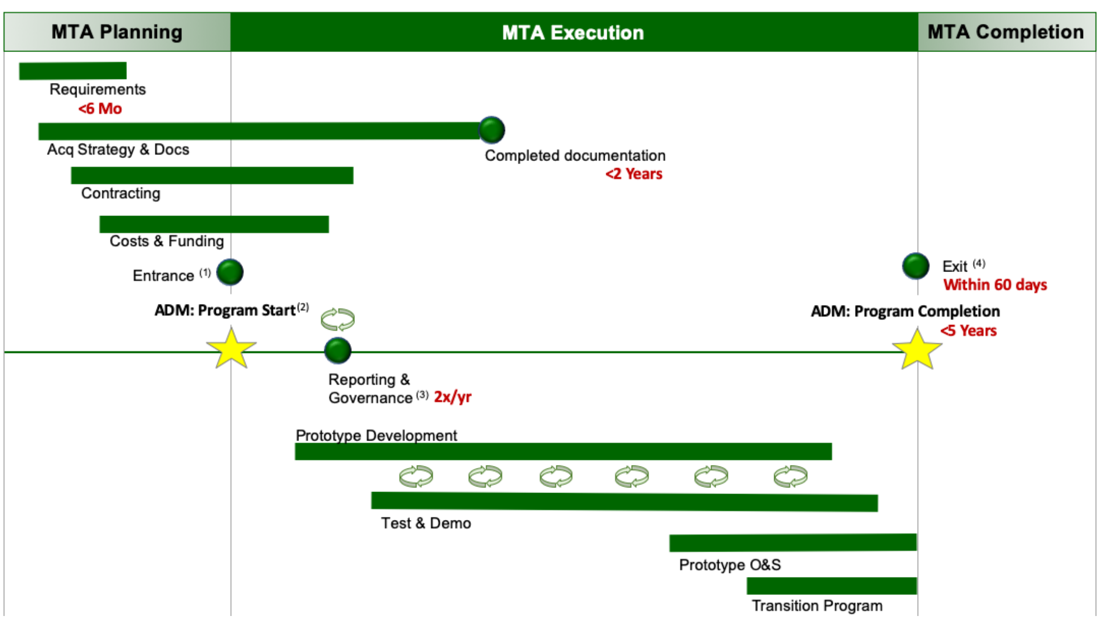

Figure 19. MTA Execution. Source: Defense Acquisition University (n.d).

C. FUTURE DEVELOPMENTS

The future of MESR and unmanned systems generally holds great potential, with current developments in both hardware and software. A POR can focus on prioritized configurations to meet immediate user needs through iterative development and incremental approach while continuously developing additional capabilities. Creative and multiple pathways, such as SBIRs, can provide some of these capabilities. In the case of MESR, there is a current SBIR for an “explosive charge delivery system to counter naval mines and maritime IEDs floating, submerged in the water column, or conducting precision placements on the seafloor. If desired, the containers could be fitted with various sensors for monitoring or recording activity in the undersea environment” (Department of Defense Small Business Innovation Research, 2016, p. 9). Additional hardware developments include dual manipulator arms, advanced sonar configurations, and alternate power sources.

Current and future software developments hold even more potential to drastically change the capability and overall concept of operations for Navy EOD utilizing MESR. Artificial intelligence and machine learning are technological developments at the forefront of strategic to tactical-level guidance for the employment in air, ground, surface, and subsurface conflicts. To provide the best MESR capability for Navy EOD, PMS 408 and parties are “rapidly developing technological advances and leveraging artificial intelligence to enable our underwater robotic systems to perform increasingly complex and hazardous jobs autonomously. Autonomous control is applied to piloting and navigation tasks and simplifies data collection, analysis, and reporting” (Gibson, 2022, p. 4).

Other efforts include augmented and virtual reality, ATR, enhanced mission planning software, and increased common operating picture interface. Different user interfaces such as:

> Custom Augmented Reality (AR), Mixed Reality (MR), and Virtual Reality (VR) Human Machine Interfaces (HMIs) or Heads Up Displays (HUDs) are proving to offer major benefits for Remotely Operated Vehicle (ROV) operators in enhancing situational awareness, decreasing task time, and at a corporate level reducing the total cost of an ROV operation. (Sapp, 2023, p. 1)

In addition to artificial intelligence, ATR improves Navy EOD capabilities. It is quickly proving to be one of the most important aspects of specific EOD applications. The ability to gather, analyze, and rapidly identify targets of interest when covering large and cluttered areas of sonar or visual data is critical to mission success. To build this capability, “SeeByte and Greensea Systems Inc. have teamed up to advance ATR of mine-like objects (MLOs) providing enhanced search, detect, and classify capabilities for underwater robots being used in maritime EOD activities” (Nguyen et al., 2022, p. 1). Figures 20 and 21 highlight future MESR iterative development and incremental deliveries such as payloads, sensors, and ATR.

Figure 20. Future Configurations for MESR Increments I and II. Source: R. Cooper, (PowerPoint slides, March 29, 2023, p. 7).

Figure 21. MESR ATR and Autonomous Software. Source: Navy Recognition (2013).

D. COMPARATIVE ANALYSIS

From Figure 17 in Chapter III, the characteristics of the different ROV platforms drove many decision criteria to support a down-select to one materiel solution over another. Critical factors such as possible hardware and software configurations, the ability to carry a significantly greater payload to support Navy EOD operations, and integrating third-party capabilities such as advanced autonomy, ATR, and other capabilities were heavily weighted. In 2021, PMS 408, in partnership with DIU, released a commercial solutions opening (CSO) to look for innovative commercial solutions that could support MESR. From that event, "67 vendor solutions submitted and all MESR relevant solutions were tailored to the VideoRay Defender; none for SRS Fusion" (S. Dentu, PowerPoint slides, September 2021, p. 11). The Mk 21 Fusion did not have any vendor solutions submitted due to not having an open systems architecture that allowed for the integration of other vendor capabilities.

Comparisons of size, weight, depth rated, tether materiel, speed, maximum cargo weight, power, third-party payload capability, operator control station interface, grabber capability, and sonar configurations were analyzed between the Mk 20 Defender and the Mk 21 Fusion.

The Mk 20 Defender has greater capability for max cargo weight, third-party payload capability, and grabber configurations. Through open systems architecture, the third-party payload capability allows the incorporation of additional configurations that can provide many additional capabilities, such as advanced autonomy, automatic target recognition, and others. The Mk 21 Fusion has lighter tether materiel and an onboard battery configuration rather than the topside generator configuration of the Mk 20 Defender.

From the user's perspective, the most significant decision factors were size, weight, power, configurations, and sustainability. Regarding the Mk 20 VideoRay Defender, user feedback included the following:

> This ROV is definitely the more capable. The VideoRay is extremely robust and capable. It can carry heavy weight. This is an enormous pro for MCM operations. In summary, the VideoRay is the platoon's favored robot over the Fusion and the Seabotix. It is more reliable, can carry more

> weight, and ultimately is more suited for EOD operations beyond just reacquire and identification. (S. Dentu, PowerPoint slides, September 2021, p. 10)

The legacy Seabotic ROV configuration is still fielded as a capability and was viewed by the end users in some of the ROV comparisons.

Some negative feedback on the Mk 20 VideoRay included the larger power footprint requiring topside generators and a larger tether, which created more drag underwater.

For the Mk 21 SRS Fusion, positive user feedback included the following: "This ROV is very intuitive. We planned a mission in less than 30 minutes without extensive training. User interface nearly allows anyone to be able to pick up the system and perform to an acceptable level with very minimal instruction" (S. Dentu, PowerPoint slides, September 2021, p. 8).

Some of the negative user feedback on the Mk 21 SRS Fusion included an insufficient load-carrying capability for certain explosive charges and a fragile tether composition.

Both platforms had positive and negative attributes from the user's perspective. The process of PMS 408 acquiring and modifying these ROV systems to support Navy EOD mission requirements and allowing a multiyear user evaluation supporting training and real-world operations allowed for a realistic and in-depth data and user preference driven decision. Figures 22 and 23 show the user interface for the EOD operators, allowing a real-time, holistic, common operating picture of video, sonar, and modular tool configurations.

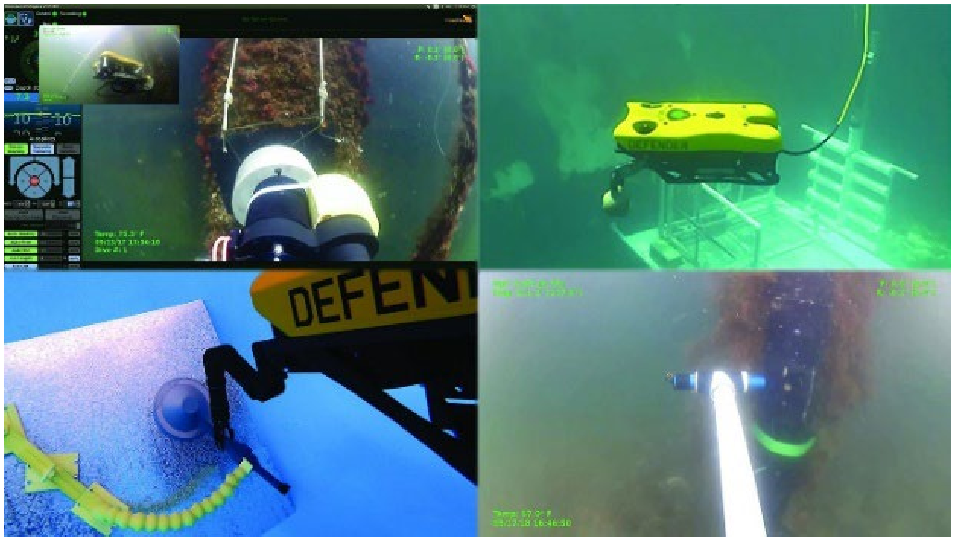

Figure 22. VideoRay User Interface. Source: VideoRay (2019).

Figure 23. User Operating VideoRay. Source: Harkins (2019).

Developments in training to address either new equipment training or building proficiency with VideoRay included augmented and virtual reality. VideoRay worked with the United Kingdom's Royal Navy divers, tasked with similar mission requirements as those of Navy EOD, to develop a mine countermeasures simulation program (MCMSim). This training tool "would subsequently demonstrate significant improvements in simulated diving performance in terms of minimized deviations of search patterns from a pre-programmed ideal identification of correct and incorrect objects and the reporting accuracy or detail of correctly identified objects" (Stone et al., 2016, p. 48). Additionally, VideoRay emphasized a common user interface with existing Navy EOD software programs to streamline the incorporation of VideoRay capabilities. Navy EOD utilizes Common Operator Interface Navy (COIN), Navy Mine Warfare Environmental Decision Aid Library (MEDAL), and Mine Warfare Tactical Command Software (MINTACS) to conduct mission planning and execute missions. The ability to rapidly process and understand the information provided, utilizing an interface already familiar to the user pushed, meant that the "creation of Pro 4 allows for a common operational picture and visualizes data in a way that can be quickly understood and easily shared by multinational forces" (VideoRay, n.d, p. 3). Figure 24 is a screenshot of the virtual reality MCMSim program.

Figure 24. Mk 20 VideoRay VR MCMSim Program. Source: Stone et al. (2016).

Sustainability at the user level is critical to prevent downtime and maximize operational usage. Keeping the lowest common denominator in mind, the Mk 20 Defender ROV is designed around being easily repaired in the field. Its components are modular and designed to be easily swapped out by the end user. Modular assembly affords the ability to plug and play different configurations of sensors and manipulator attachments as well as the rapid diagnosis and, if necessary, replacement of an item during troubleshooting or repair. This allows for the ability to isolate and rapidly address issues. An operator is presented with a suite of options that can provide enhanced capability, resulting in higher confidence and mission performance. The user can "quickly and easily integrate tooling, sensors, and payloads in the field to meet mission objectives and maximize uptime" (Ocean News, 2022, p. 6). The ROV was designed to be supported at the user and intermediate maintenance levels; it is not a sealed system that must be sent back to a depot for diagnostics and repair. Additionally, VideoRay has a robust support infrastructure through the ISEA, NIWC PAC, and PMS 408. Mobile training teams and field service technicians are located at Navy EOD command locations to provide additional experience to the fleet. Figure 25 depicts the spares kit supplied with each VideoRay system, allowing for easy repair and high sustainability.

Figure 25. VideoRay Module Spares Kit. Source: Trauthwein (2019).

The Mk 21 Fusion did not provide a spares kit and had limited user level repair options for replacement or troubleshooting. The SRS Fusion required the user to send the SRS Fusion back to the depot for diagnostics and repair. This model and supporting infrastructure could lead to increased repair and return timelines, resulting in the loss of a high demand and low inventory type capability for the end user. The Mk 21 SRS Fusion does have a mobile training team that supports new and sustained training requirements.

E. DECISION MATRIX

Each stakeholder provided a different perspective for the MESR ROV materiel solutions and contributed to the overall decision to down-select to a specific materiel solution. The performance and ability to have a single platform that can accomplish various tasks to support a range of operational requirements was most important for the user. The schedule was the second most crucial factor for the user as the inventory required to support requirements was only partially fulfilled with MOTS solutions and not a POR. Non-cost factors, when combined, were significantly more important than cost and price. The end user was not as concerned with costs.

Figure 26 illustrates the data element comparisons of the Mk 20 VideoRay Defender, Mk 21 SRS Fusion, a combination of both platforms, and the MESR POR. Many of these data elements originate from a combination of the requirements document, funding profiles, and data gathered during the 2 year UOES. The data elements combined, create a holistic snapshot for the capabilities and limitations of each ROV platform. The Mk 20 and Mk 21 data are from the current MCOTS configurations, while the MESR POR column and elements would incorporate the iterative development and incremental delivery strategy discussed throughout the case study.

Source Data / Data Element	Mk 20 VideoRay Defender	Mk 21 SRS Fusion	Mk 20 VideoRay Defender and Mk 21 SRS Fusion Dual Acquisition Solution	MESR POR Threshold (T) / Objective (O)
Size (L" x W" x H")	29.59 x 15.5 x 10.5	35.24 x 19.13 x 12.17		Topside max operational footprint (cubic feet) T= ≤27 / O=T
Weight (ROV lbs)	38	50		T= ≤88 / O= ≤44
Power Configuration	2 x Topside Generators	Battery Onboard ROV	Combined Overall Capabilities	Single Sortie Endurance (minutes) T= ≥45 / O= ≥120
Max Cargo Weight (lbs)	25	5		Dependent on Increment and Configuration
Payload Development and Integration	Charge Delivery System, Disruptor tools	Multi-function Manipulator, Disruptor tools	Combined Overall Capabilities	Increment I-III Adaptability for Multiple Missions Field configurable modules integrated
Sensor Development and Integration	Image Enhancement	Side Scan Sonar, Image Enhancement	Combined Overall Capabilities	Increment I-III Adaptability for Multiple Missions Field configurable modules integrated
Third-Party Integration/Open Systems Architecture	Open Systems Architecture	Closed, SRS Internal Only	Mk 20 VideoRay Defender Only	CSO APR21, 67 Vendors Tailored To VideoRay Baseline
Training	NIWC PAC ISEA Mobile Training Team	NIWC PAC ISEA Mobile Training Team	Double Training Requirement For ISEA, Same Resourcing Levels	ISEA Mobile Training Team, Program Office Funded Each FY, Augmented Reality Development
User/Operator Level Repair	Issued Module Spares Kit	N/A	Mk 20 VideoRay Defender Only	Module Spares Kit, FST Co-Located At Fleet Concentration Areas
Acquisition Unit Procurement Cost ($)	$320k	$290k		CUI
Schedule (Delivery and Repair Capabilities)	Greater Inventory, Field Diagnostics, User/Operator, Intermediate, Depot Level Repair	Smaller Inventory, Intermediate, Depot Level Repair	Double Requirement For ISEA, Same Resourcing Levels	FYDP Fully Funded, Operator, Intermediate, and Depot Level Repair Infrastructure, Field Service Representative and Technicians
Risk (TRLs, MRLs, Sustainment)	High TRL, High MRL, Robust Sustainment Infrastructure	High TRL, Moderate MRL, Moderate Sustainment Infrastructure	Combined Overall Capabilities, Double Sustainment Requirement	High TRL, High MRL, Robust Sustainment Infrastructure
End User UOES Feedback (Positive)	Robust, Reliable, Larger Cargo Capacity	Intuitive, Good User Interface, Minimum Platform Footprint, Ease of Use/Setup		N/A
End User UOES Feedback (Negative)	Topside Generator Footprint	Camera Imaging, Manipulator, Limited Cargo Weight		N/A

Figure 26. Data Elements Comparison Table

For the following comparison matrixes, *Performance* is defined as the ability to support the performance related data elements and incorporation of positive and negative user feedback from Figure 26. The performance of each individual system to support immediate capabilities, third-party future integration support, and an overall materiel solution to the problem resulted in one option outperforming another. These performance characteristics were highlighted in Figure 17 as well as Figure 26 with comparisons of size, weight, depth rated, tether materiel, speed, maximum cargo weight, power, third-party payload capability, operator control station interface, grabber capability, user feedback, and sonar configurations.

The ability of the platforms to meet the Navy EOD requirements is incorporated into the performance criteria. KPPs are survivability, net ready, energy, and depth range. The survivability KPP focused on a family of systems approach for the MESR configuration and that any damage or loss of a single part of this configuration would not result in the system being completely non mission capable. Net ready focused primarily on authority to operate and cybersecurity compliance. Sustainment centered on the operational availability percentages to support fleet demand and the maintenance and repair functions. Energy and power supply defined levels required for organic endurance requirements. Depth range is a KPP that is classified, but in general, the ROV must be able to accomplish the full range of detect to engage tasking for ExMCM and SSW missions.

The parameters for the KSAs for MESR include ROV weight, payload weight, topside footprint, response mission effectiveness, mines per sortie, standoff distance, influence signature, reliability, and operational/materiel availability.

Cost is defined as the acquisition unit procurement cost (AUPC) of each platform. The AUPC and associated MESR program life cycle cost estimate are classified as confidential unclassified information by PMS 408. However, the average unit procurement cost (AUPC) of the Mk 20 VideoRay configuration is $320,000, and the Mk 21 Fusion AUPC is $290,000. Additional costs as part of the MESR POR include produce procurement costs for ROV vehicles supporting end user, training assets, new equipment training, consumables, shipping costs, testing, engineering change proposals, and maintenance and repair costs. The overall life cycle management and total ownership cost for having a single configuration ROV as the POR and the performance data for reliability, sustainability, and supportability were determined to be more sustainable than having two ROV configurations for the POR and having to divide resources for ISEA life cycle support.

Schedule is defined as the ability to deliver systems to the end user, resource sponsor funding profile, and the repair capabilities for each platform. The repair capabilities include current support infrastructure, such as field service representatives, field service technicians, and the ability to support user, intermediate, and depot level repairs.

Risk is defined as the technology readiness levels, technological maturity levels, open systems architecture, iterative development and incremental delivery levels of effort, and the sustainment and supportability of the ISEA for each platform.

Figures 27 to 31 show the baseline and weighted decision matrix for each of the courses of action that PMS 408 could take for the MESR POR: use the Mk 20 VideoRay Defender, Mk 21 SRS Fusion, or have both ROV platforms be part of MESR. Figure 27 shows the baseline, unweighted comparison with the following figures illustrating the matrix with different criteria weights. Figures 28 to 31 show the different matrix from differently weighted performance, cost, schedule, and risk.

Criteria / Options	Performance	Cost	Schedule	Risk	Total* (Lower Better)
1: Mk 20 VR Defender	2	2	1	1	**6**
2: Mk 21 SRS Fusion	3	1	1	2	**7**
3: Mk 20 VR Defender and Mk 21 SRS Fusion	1	3	3	3	**10**

Figure 27. Baseline MESR Comparison Matrix

Criteria / Options	Performance (Weight x 2)	Cost (Weight x 1)	Schedule (Weight x 1)	Risk (Weight x 1)	Total* (Lower Better)
1: Mk 20 VR Defender	2 (4)	2 (2)	1 (1)	1 (1)	6 (8)
2: Mk 21 SRS Fusion	3 (6)	1 (1)	1 (2)	2 (2)	7 (12)
3: Mk 20 VR Defender and Mk 21 SRS Fusion	1 (2)	3 (3)	3 (3)	3 (3)	10 (11)

Figure 28. Performance Weighted MESR Comparison Matrix

Criteria / Options	Performance (Weight x 1)	Cost (Weight x 2)	Schedule (Weight x 1)	Risk (Weight x 1)	Total* (Lower Better)
1: Mk 20 VR Defender	2 (2)	2 (4)	1 (1)	1 (3)	6 (10)
2: Mk 21 SRS Fusion	3 (3)	1 (2)	1 (1)	2 (2)	7 (8)
3: Mk 20 VR Defender and Mk 21 SRS Fusion	1 (1)	3 (6)	3 (3)	3 (9)	10 (19)

Figure 29. Cost Weighted MESR Comparison Matrix

Criteria / Options	Performance (Weight x 1)	Cost (Weight x 1)	Schedule (Weight x 2)	Risk (Weight x 1)	Total* (Lower Better)
1: Mk 20 VR Defender	2 (2)	2 (2)	1 (2)	1 (1)	6 (7)
2: Mk 21 SRS Fusion	3 (3)	1 (1)	1 (2)	2 (2)	7 (8)
3: Mk 20 VR Defender and Mk 21 SRS Fusion	1 (1)	3 (3)	3 (6)	3 (3)	10 (13)

Figure 30. Schedule Weighted MESR Comparison Matrix

Criteria / Options	Performance (Weight x 1)	Cost (Weight x 1)	Schedule (Weight x 1)	Risk (Weight x 2)	Total* (Lower Better)
1: Mk 20 VR Defender	2 (2)	2 (2)	1 (1)	1 (2)	6 (7)
2: Mk 21 SRS Fusion	3 (3)	1 (1)	1 (1)	2 (4)	7 (9)
3: Mk 20 VR Defender and Mk 21 SRS Fusion	1 (1)	3 (3)	3 (3)	3 (6)	10 (13)

Figure 31. Risk Weighted MESR Comparison Matrix

From a sensitivity analysis using the above Figures, the Mk 20 VideoRay Defender was the better materiel solution if performance, schedule, and risk were most important to the stakeholders. The Mk 21 SRS Fusion is a better materiel solution if cost is most important to the stakeholders. Figure 32 shows the MESR decision matrix where Option 1 had the lowest overall score and was the best overall score.

Criteria / Options	Performance (Weight x 1)	Cost (Weight x 2)	Schedule (Weight x 2)	Risk (Weight x 3)	Total* (Lower Better)
1: Mk 20 VR Defender	2 (2)	1 (2)	1 (2)	1 (3)	5 (9)
2: Mk 21 SRS Fusion	3 (3)	1 (2)	1 (2)	2 (6)	7 (13)
3: Mk 20 VR Defender and Mk 21 SRS Fusion	1 (1)	3 (6)	3 (6)	3 (9)	10 (22)

Figure 32. MESR Decision Matrix

For the decision matrix, from the OPNAV 957 resource sponsor perspective, cost and schedule are the most critical criteria for the MESR POR. The ability to allocate and fully fund across the FYDP to provide the full capability required for the end user is their primary function. Additionally, OPNAV 957 was able to leverage Navy EOD and the more significant DOD unmanned systems initiatives to support prioritized funding for this line item over other program elements. Keeping this funding on schedule for award and safe from other programming is as essential to OPNAV 957 as cost. Performance is assumed to meet the minimum requirements for threshold and objective values, not the primary criteria the resource sponsor is concerned with.

From the PMS 408 perspective, all three criteria are equally important as the conduit between the resource sponsor, ISEA, and fleet. PMS 408 supported the decision for ease of programmatic support across the entire life cycle and acquisition baseline to have one ROV materiel solution rather than multiple to maximize the development, fielding, and sustainment support for MESR to the fleet.

For the ISEA, NIWC PAC, like PMS 408, having one ROV platform to provide technical, sustainment, repair, and training support is optimal. All three constraints are relatively equal for PMS 408 for the ISEA.

F. RISKS AND MITIGATIONS

The primary factor behind the overall risk reduction to this POR was an informed and holistic life cycle management planning that included all total ownership costs through acquisition, production, fielding, training, and sustainment. Using the multiyear UOES and routine, effective communication between all stakeholders allowed the POR to successfully identify and address throughout the acquisition profile a holistic picture of the requirements needed to field and maintain these systems.

The risks associated with the constraints of cost, schedule, and performance were successfully mitigated or reduced through actions by all stakeholders. For the cost, the funding profile was not at risk from the resource sponsor perspective, as it leveraged the DOD's and Navy's priorities on unmanned systems, with this specific program office and end user being at the forefront of those strategic to tactical-level operations. The prioritized unmanned and undersea domain lines of effort allowed for this unique opportunity that cannot always be applied across acquisition programs but allowed the resource sponsor to fully fund the program across the FYDP, providing programmatic stability and confidence for the program office and the POR. From the program office perspective, using the limited fielding of multiple MOTS solutions allowed for the best-informed down-select of a materiel solution to become the POR. This reduced cost risk by leveraging mature COTS solutions, conducting a limited MOTS fielding, and then taking that informed data to make the full acquisition profile for the POR initial and full operational capability levels. In addition to the inventory and production cost risk reduction, this POR's sustainment and repair model focused on a modular design coupled with spare packages that could be performed at the user level, reducing potential intermediate and depot-level repair costs. The utilization of ISEA field service technicians, field service representatives, and mobile training teams created a robust support infrastructure that the end user could leverage.

For both cost and schedule risks, the decision to down-select to one materiel solution and not have multiple materiel solutions to support as the POR created the most significant potential for efficiency and effort for the development, procurement, fielding, and sustainment of a single solution vice splitting the above to support two materiel solutions from the same support structures and resourcing profile. By not having to split efforts from the same stakeholders and infrastructure, the cost and schedule risks were reduced, and the POR could align all efforts to a specific materiel solution. Additionally, this creates a more narrowly focused industry partnership for technological developments and incorporation into the POR by allowing the industry to focus on one integration platform instead of two. This POR heavily leveraged open systems architecture and commercial partnerships, especially for software developments such as ATR and other artificial intelligence initiatives that would have been difficult to create for different platforms with multiple configurations and operating systems. Schedule risks were reduced through full resource funding and a prioritized incremental development and fielding of prioritized configurations that were most critical for the end user rather than all configurations simultaneously. Additional schedule and cost risks were reduced by the utilization of one of the vendors who was utilized for multiple years throughout the COTS to MOTS to POR process and already had the infrastructure in place to immediately support an increased production and inventory demand as well as established relationships through the program office with the other vendors supporting the hardware and software developments.

For performance risks, a heavy research, development, test, and evaluation (RDT&E) line from the resource sponsor across the FYDP and leveraging the lessons learned from a multiyear UOES allowed the program office to understand best and prioritize hardware and software developments needed to support the end user. Determining which materiel solution should continue to the POR, all stakeholders determined to prioritize the overall capability, configuration potentials, and third-party integration opportunities as the most critical aspects required for the materiel solution selected. During a side-by-side characteristics comparison, each platform had advantages over the other for specific characteristics that could benefit certain end user operational requirements. For example, the different power configurations of onboard compared to topside power were seen as one of the advantages of one system over another. To buy down that performance risk, the POR plans to develop incrementally and field different topside and onboard power configurations as part of the incremental strategy. This recognition to address a specific capability need not part of the materiel solution chosen for the POR shows a clear understanding of the user-prioritized requirements and communication among stakeholders.

G. IMPLEMENTATION PLAN

The program office utilization of a user-informed iterative development and incremental delivery strategy allowed for the prioritized delivery of capability fastest to the end user. The acquisition and utilization of additional MOTS solutions added to the initial purchase quantities created a bridging solution while the POR was developed. This allowed this capability to stay fielded to the end user to support mission requirements and receive continuous feedback and data to inform the POR. The program office developed and fielded an initial Mod 0 MOTS configuration, developed additional hardware and software capabilities for a Mod 1 MOTS solution, and then transitioned to the POR Increment I to Increment III development and fielding plan. This allowed for a clear roadmap for all stakeholders to prioritize and align efforts on those specific configurations throughout the program. Each of the increments brought all the stakeholders together to make informed and collective decisions based on the expertise and viewpoints of each. This alignment of effort creates a clear mission, goal, and priority across all parties and expectation management for when increments and capability will be provided to the end user. The end user’s ability to have insight and plan for these increments allows them to develop the best tactics, techniques, and procedures for training and employment of these capabilities to support mission requirements.

In addition to the new POR configurations being delivered, the fleet and program office gained additional capacity by retrofitting currently fielded MOTS systems to POR Increment I through a cost-effective conversion of multiple existing platforms that equaled the price of a new platform. These flexible strategies communicated and executed by the program office, ISEA, and the fleet allowed for greater capacity and capability to meet current and future operational tasks.

Additional discussions within this POR are concepts such as a family of systems approach with other configurations such as a microsystem, additional payloads and sensors, and incorporation with currently fielded or future capabilities where this POR would be part of the ExMCM or SSW mission requirements. These efforts will continue to leverage and fit into a prioritized DOD unmanned systems initiative and look at how these capabilities can continue to support the end user's critical role in those missions.

All of the actions are perfect examples of how through an MTA framework, a COTS to MOTS to POR item was implemented correctly to cover immediate requirements, developed through continuous feedback and evaluation, created using open systems architecture and modular design, and developed and delivered incrementally to the fleet with an understanding of needing to become part of the holistic solution and capability rather than a stand-alone capability that has unique requirements and life cycle management.

V. CONCLUSION

This chapter summarizes the key factors for PMS 408's successful utilization of an MTA acquisition strategy, addresses the research questions and objectives of this case history, provides recommendations on how this example could be leveraged for future acquisition programs or research and provides context to how this process and specific capability fit into the larger DOD unmanned systems battlespace.

A. SUMMARY

Primary objectives of this case history include describing PMS 408 Expeditionary Mission's MTA strategy, the use of rapid prototyping of commercial items to meet rapid operational capability gaps for Navy EOD mission requirements, comparative analysis to determine factors that made the Mk 20 VideoRay successful in selection to move forward to POR, describing iterative development and incremental fielding of hardware and software capabilities to support Navy EOD current and future mission requirements, and how MESR fits into the unmanned undersea arena.

Using the MTA pathway within the AAF, PMS 408 leveraged rapid prototyping and industry partners to provide mission-critical unmanned capabilities supporting Navy EOD requirements in the MCM and SSW mission areas. The deliberate acquisition and prototyping of two different ROV configurations, the Mk 20 VideoRay, and the Mk 21 Fusion, allowed the end user to conduct a multiyear comparative analysis of the two platforms in training and operational scenarios. This allowed PMS 408 to provide rapid, tailored capability to the end user and collect data on both platforms to inform the MESR POR configuration better.

PMS 408 leveraged Other Transaction Authorities and partnered with the DIU to allow the best of market and commercial technologies to be incorporated into the ROV prototypes. These technologies incorporated high technology level solutions that existed and tailored them to support specific military applications. They were integrated with the open systems architecture of the Mk 20 VideoRay to provide enhanced capabilities.

An iterative development and incremental delivery strategy, leveraging open systems architecture and third-party integration, allowed prioritized configuration development and fielding of hardware and software capabilities to the end user. Many of these increments incorporate leading hardware and software sensor or payload developments for undersea capabilities such as remote disruption, automatic target recognition, and augmented reality. Navy EOD worked with PMS 408 and NIWC PAC to determine the most critical capabilities to support immediate requirements, which allowed PMS 408 and NIWC PAC to focus on these requirements rather than try to deliver all requirements at once as well as continuously learn from development and fielding lessons learned.

Ultimately, after 2 years of training and operational use, Navy EOD and PMS 408 chose the Mk 20 VideoRay to become the baseline configuration for the MESR POR. The Mk 20 VideoRay and Mk 21 Fusion had capabilities and limitations that the other platforms did not, but the Mk 20 proved to be the ROV to transition to the POR. This determination was due to various perspectives from the program office, ISEA, and end users. A holistic comparative analysis between the two platforms utilized data gathered to inform sustainability, supportability, reliability, and capability. The potential for integrating third-party systems through an open systems architecture was also analyzed. Overall, the Mk 20 VideoRay was determined to be easier to sustain and support from a variety of operational, intermediate, and depot-level repair factors, had greater overall capability to conduct required EOD mission tasking utilizing payloads and sensors, and had open systems architecture that allowed integration of new or existing hardware and software capabilities. The end user and operational feedback further supported the Mk 20 VideoRay as the ROV of choice for the transition to MESR.

The future of the MESR POR will continue to utilize an iterative development and incremental approach, informed by the Navy EOD user. These increments will focus on additional hardware and software capabilities leveraging leading-edge technology such as ATR and artificial intelligence. Each increment will further Navy EOD's capabilities to execute SSW operations and play a critical role in the undersea battlespace's larger DOD unmanned systems efforts.

B. RECOMMENDATIONS

Recommendations for future research could include analyzing the follow-up MESR increments and how the POR is progressing from a cost, schedule, and performance standpoint. As this high-demand capability matures, a greater demand for capacity, additional stakeholders, and additional requirements will impact the acquisition profile of MESR, PMS 408's acquisition and contracting strategies, and potential additional funding demands across development, procurement, or operations and maintenance lines.

Additional research could address how well the MESR POR supports the growing unmanned SSW requirements and if the MESR and Navy EOD continue to be a unique materiel solution that continues to stay in the forefront of this arena, or if other capabilities and customers can employ other capabilities that make MESR too much of a niche capability.

There exists a potential for a family of systems approach for the MESR POR, and PMS 408 could develop additional configurations, such as a large or micro ROV, based on future requirements. Additional considerations include TDP for a family of systems approach similar to the current limited TDP with the first MESR increment. The demand for smaller, more powerful, autonomous capability could drive a family of systems approach for a more tailored capability rather than the current MESR that is more of a single, modular configuration based upon the VideoRay ROV.

Interoperability and integration of future unmanned systems operating in any domain will be critical for mission success. The necessity of multiple capabilities providing a real-time, common operating picture while rapidly identifying and addressing potential threats will continue to push the software and hardware developments of unmanned capabilities. Techniques such as swarming, ATR, loitering to maximize power management, and a range of kinetic and non-kinetic effects are currently in high demand for the end user and competitively worked within the unmanned systems industry.

Finally, this case study was kept at the unclassified level. Future research could include high classification levels that would allow a more detailed analysis of the acquisition profile as well as the specific performance capabilities and operational requirements supported.

C. CONCLUSION

This successful utilization of an MTA pathway, strategic partnering with organizations such as DIU to leverage the latest technological developments, rapid prototyping to provide multiple materiel solutions, and balance of vendor and government rights for the technical data to support broader commercial investments are successful AAF and MTA practices that should be applied across program offices. These practices allowed for a reduction in acquisition timelines, leveraging mature COTS solutions and modifying them to MOTS to support DOD-specific applications to provide fieldable prototypes that can be provided to the end user for operational utilization and feedback. This is critical for a program to provide the right capability to support the end user. Programmatic risks are reduced with the leverage of mature COTS solutions rather than starting a product from the ground up and a broad commercial base incentivized to continue to develop and improve their materiel solution for both DOD and commercial utilization.

DOD and Navy strategic to tactical-level unmanned systems lines of effort are prioritized within documents such as the National Defense Strategy, Unmanned Campaign Framework, Navy Advantage at Sea, the Chief of Naval Operations Navigation Plan, and the Navy's Intelligence Autonomous Systems. The ability to remotely search, detect, identify, and engage targets in all environments will be critical for future steady state and crisis operations. This POR is an essential capability utilized in the unmanned family of systems approach to MCM and SSW. This capability and Navy EOD utilization is one of those high-demand, low-density capabilities.

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