REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
21-05-2008	FINAL	

4. TITLE AND SUBTITLE

Unmanned Undersea Vehicles: An Asymmetric Tool for Sea Denial

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

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Paper Advisor (if Any): Mr. Bill Glenney

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Office of the Provost
Naval War College
686 Cushing Road
Newport, RI 02841-1207

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

Distribution Statement A: Approved for public release; Distribution is unlimited.

13. SUPPLEMENTARY NOTES: A paper submitted to the Faculty of the Naval War College in partial satisfaction of the requirements of the Department of Joint Military Operations. The contents of this paper reflect my own personal views and are not necessarily endorsed by the NWC or the Department of the Navy.

14. ABSTRACT

One of the most salient trends in military technology is the growing prominence of unmanned vehicles. Much has been written about Unmanned Air Vehicles (UAVs), and a fair amount about Unmanned Surface and Unmanned Ground Vehicles (USV/UGVs). In contrast, very little has been written about Unmanned Undersea Vehicles (UUVs). This paper contends that UUVs, currently most prominent as ISR assets and as capability-augmentation to other platforms, will come into their own as an independent combat capability, creating operational and strategic level effects. Through their inherent asymmetry, UUVs will deliver powerful capability to lower-tier navies and even non-state actors. Without anticipatory planning, and perhaps even despite it, top-tier state actors such as the U.S. will find themselves challenged in their ability to counter the threat of "sea denial" posed by UUVs. UUVs could have major effect on the operational level of war, by challenging many key assumptions around which campaign planners have based their planning.

15. SUBJECT TERMS

Unmanned Undersea Vehicles, UUVs, UCUVs, ASW, Sea Denial, Submarine Technology, Asymmetric Warfare

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			LCDR Matthew Ritchey
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED		22	19b. TELEPHONE NUMBER *(include area code)* 401.841.3220

Standard Form 298 (Rev. 8-98)

NAVAL WAR COLLEGE
Newport, R.I.

Unmanned Undersea Vehicles: An Asymmetric Tool for Sea Denial

by

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A paper submitted to the Faculty of the Naval War College in partial satisfaction of the requirements of the Department of Joint Military Operations.

The contents of this paper reflect my own personal views and are not necessarily endorsed by the Naval War College or the Department of the Navy.

Signature: _____

21 May 2008

1. Introduction- Asymmetric Undersea Warfare

For almost a century, undersea warfare has generated strategic and operational surprise for maritime planners. In World War I, the decision to engage in unrestricted submarine warfare was a key factor behind the United States' decision to enter the war. In World War II, the German U-Boat campaign almost brought Britain to its knees, and disaster was averted only through the extraordinarily rapid fielding of new technologies and operational methods; while in the Pacific, the spectacular success of American submarine commanders in their *guerre de course* against Japanese merchant shipping eviscerated the Japanese wartime economy. During the Cold War, submarines evolved into a strategic deterrent role fueling a decades-long competition for dominance in the cold waters of the North Atlantic.

If there is one constant in undersea warfare, it is its unwelcome intrusion into the carefully constructed schemes of military planners. Undersea warfare is inherently maverick, unconventional, and disruptive. There is little reason to suspect that, as conflict becomes ever more asymmetric, undersea warfare will not again demonstrate the ability to disrupt operational planning. The continued rapid evolution of technology, combined with inherent complexity and difficulty in "dominating" the undersea environment, challenge confidence in any enduring claims of "undersea superiority." Particularly threatening to such claims are the nascent capabilities of Unmanned Undersea Vehicles (UUVs).

One of the most salient military technology trends is the growing prominence of unmanned vehicles. The promising potential of unmanned technology has already reached fruition in the air domain, as witnessed in the recent wars in Afghanistan and Iraq. There is every indication that there could be similar impact in the undersea domain. This paper

contends that Unmanned Undersea Vehicles (UUVs), currently most prominent as ISR assets and as capability-augmentation to capital platforms, will come into their own as an independent combat capability, creating operational and strategic level effects and, through their inherent asymmetry, deliver powerful capability to lower-tier navies and even non-state actors. Without anticipatory planning, and perhaps even despite it, top-tier state actors such as the U.S. will find themselves challenged in their ability to counter the threat of "sea denial" posed by UUVs. UUVs could have major effect on the operational level of war, by challenging many key assumptions around which campaign planners have based their planning.

2. UUV trends and development potential

UUVs are a rapidly expanding area of investment and research across the globe, both commercially and militarily. The high price of oil and seabed minerals is driving commercial investment in UUVs for oceanographic research. Militarily, there is significant investment from at least a half-dozen European navies, in addition to the United States, and there are probable covert programs in China, DPRK, and elsewhere. Illicit activity- especially drug-running- is yet another source of investment in low-end UUVs. The primary role anticipated in today's military UUV development efforts is mine-hunting, for which purpose hundreds of UUVs have already been delivered to a wide array of international customers[1]. A notable secondary mission driving UUV development is ISR, to include hydrography and mapping. These primarily defensive and supporting missions belie the potential for offensive employment of UUVs.

[1] Richard Scott, "Unmanned Underwater Vehicles - In Harm's Way," *Jane's Defence Weekly*, June 21, 2006, 1.

Because the primary overt investment in these programs comes from NATO countries, there is less interest in offensive employment of UUVs than might be the case for potential adversaries. The operational concepts favored by dominant western navies, which generally presuppose a superior force with the objective of sea control, have less need for autonomous offensive capability delivered from a UUV. U.S. and NATO operational ideas also are heavily dependent on robust C2 arrangements, and require considerable operational flexibility[2], for which UUVs are generally are less well suited than multi-mission manned submarines. Furthermore, legal considerations and the need to remain compliant with existing legal regimes significantly complicate development by first world navies[3]. Finally, safety considerations, especially considerations associated with arming UUVs, present obstacles to the U.S. and its allied navies[4].

The trajectory of current UUV efforts, however, should not limit consideration of how developments might be leveraged by non-Western powers. The experience of asymmetric warfare has repeatedly shown that challengers will willingly and eagerly co-opt western technical developments, and modify and adapt them to suit their own purposes. UUV technologies lend themselves especially well to this approach. The UUV market is already heavily internationalized, with relatively little control over technology transfer. Most UUV development is heavily COTS (Commercial, off-the-shelf) based[5], and UUV development tends to be modular, in order to accommodate payload interoperability, a design that facilitates adaptation for offensive purposes. Compared with many other systems, UUV

[2] John Canning, *A Definitive Work on Factors Impacting the Arming of Unmanned Vehicles* (Dahlgren, VA: Naval Surface Warfare Center, Dahlgren Division, May 2005), 9.
[3] John Canning et al, "A Concept for the Operation of Armed Autonomous Systems on the Battlefield," *Proc. AUVSI 2004* (Anaheim, CA, August 2004), 4.
[4] Canning, 17.
[5] Scott, 1.

design is relatively straightforward, with fewer interoperable systems and component parts, facilitating reverse-engineering of any components that might be restricted in the commercial marketplace. All of these factors increase the likelihood that even a low tech adversary could build on western UUV R&D to field offensive, autonomous UUVs.

Three very achievable developments are especially foreboding for this future asymmetric threat. First is the arming of UUVs to create Unmanned Combat Undersea Vehicles (UCUVs). This is, in fact, already accomplished, in a sense. Torpedoes might be considered UUVs[6]- operating autonomously, in many cases, without real-time connectivity back to their launch platform. What distinguishes them from "UUVs", in common parlance, is their limited duration and operational flexibility. However, these limitations are mostly CONOPS driven, as opposed to technically driven. A simple armed UUV might be constructed around a torpedo, with the simple addition of a propulsion booster module to add range and endurance, and a basic communications package.

A second potential technology development is radically extended operational ranges for these armed UUVs. Already, the U.S. and others have invested in programs to create long-range underwater "gliders" to conduct long-range Intelligence Preparation of the Operational Environment (IPOE) missions[7]. While the technologies enabling the "glider" approach probably do not provide the flexibility and propulsion power to enable armed UUVs, such programs will significantly advance the state of UUV navigation and communications technologies. Leveraging these advancements, other nascent technologies- such as Air-independent-propulsion (AIP, e.g. Fuel Cell) propulsion or perhaps Aluminum/Vortex Combustors, could provide the propulsion power necessary to effectively

[6] Canning, 2.
[7] Otto Kreisher, "Gliders Under the Sea," *Sea Power* 49, no. 2 (Feb. 2006): 16.

deploy armed UUVs even well outside of the operating area limitations of conventionally powered submarines, indeed, even globally[8]. Divorced from the human sustainability considerations that limit manned submarines, there are few remaining constraints on the range of UUVs. Underwater navigation, when safety considerations are minimized, is remarkably easy (assuming accurate charts are available); and global communications are already a reality.

Finally, "autonomy" for these armed, long range UUVs will allow them the flexibility to conduct operations far away from the base of an adversary. Artificial intelligence (AI) based autonomous control systems are being developed at a frenetic pace, fueled principally by demand for improved UAVs. Such developments will directly contribute to UUV autonomy, but in fact, are not actually necessary for the majority of "sea denial" missions envisioned for UCUVs. Even with current state of missile seeker technology, UCUVs would only need enough autonomy to navigate to a known area of operations for U.S. forces (a port, choke point, or coastal location) and launch, and the missile would do the rest. For more complex missions, weapons could be guided by an on-site observer, for instance on a trawler or even on foot ashore, in real-time or near-real-time.

In short, there are a remarkably small number of "hard" technology barriers standing in the way of the proliferation of long range, autonomous, armed and capable UUVs. There is little reason to think that this capability will be limited to high end, state actors.

3. The threat to U.S. Operations

Even the best current Operational Art practice leaves U.S. forces with significant vulnerabilities to the dramatic new capabilities that these UUVs will introduce. While armed

[8] Dennis Bushnell, *Future Strategic Issues/Future Warfare [Circa 2025]* (NASA Langley Research Center, July 2001), http://www.dtic.mil/ndia/2001testing/bushnell.pdf (Accessed 27 April 2008), 39.

UUVs will, no doubt, make significant contributions to sea control and sea supremacy, it is in their role as a centerpiece of a sea denial strategy that their impact will be most profound. To illustrate this, consider vulnerabilities of U.S. forces in three of the six "operational functions" around which operational planning is based. *Operational Sustainment (Logistics)* is especially vulnerable, as are *Operational Protection* and *Operational Maneuver*.

Operational Sustainment is a major concern due to the risk of attack on the massive seaborne logistics train associated with expeditionary operations. Such disparate missions as Peace Enforcement, Major Combat Operations, SSTR, etc. all have in common the need for heavy sealift. Sealift requires significant footprint at Seaports of Embarkation (SPOEs), a lengthy transit, often through choke-points, and finally, significant footprint at Seaports of Departure (SPODs). At each point, the often predicable sealift train is extremely vulnerable to UCUVs, which will be difficult to counter. In historical examples of submarine threat to sealift, convoying was an effective counter, but only because of the risk to the submarine of attack against escorted merchants. This risk is not shared by expendable UCUVs.

It is also important to note that long range UCUVs can threaten operational sustainment in ways that the submarine threat, especially in recent times, has not. While German U-Boats in WWII had the range to threaten maritime logistics even into U.S. territorial waters, in the subsequent half-century no adversary submarine force other than the Soviet Navy has had the capability to threaten U.S. operations on a global scale, and especially into U.S. home waters. Most of the conflicts of the past fifty years have been "regional." In this context, a defensive Anti-Submarine Warfare (ASW) posture within the "theater of combat" has become familiar. However, planners have not had to anticipate a submarine threat in home waters, in transit in adjacent theaters, or within the protected

confines of SPODs[9]. UCUVs break this paradigm, thereby complicating sustainment planning, indeed threatening the very concept of a "regional" war, perhaps giving "regional" actors a "global strike" capability.

Operational Protection and *Operational Maneuver* are also challenged by UCUVs. Just as UCUVs can threaten sealift assets, the UCUVs could be armed with weapons systems to either attack personnel (afloat, or ashore)[10] or capital ships. Prominent commentator and analyst Robert Work of the Center for Strategic and Budgetary Assessments (CSBA) is one of the few strategists who has understood the potential of UUVs in this role. Work notes that "UUVs could determine which ships are coming out of port and move in to attack them."[11] While the mechanism of this attack (cruise missile, torpedo, etc.) and the lethality of the payload (conventional explosive or mass-effect) is not unique to the UUV, the surreptitious method of delivery and vexing ability to defend against it makes a UCUV-based attack fundamentally unique at the operational level of war.

The net effect of the threat to these three operational functions can be summarized to conclude that UCUV employment is a form of "sea denial." While UCUVs have a limited role to play in offensive operations, they can be highly effective in denying the use of the sea to a more powerful adversary. As such, they comprise a potentially powerful asymmetric tool that can "level the playing field" especially against an expeditionary adversary. The sea denial concept of a "fleet in being"- the threat posed by the mere presence of a capability- is

[9] Bushnell, 77.
[10] Bushnell, 39.
[11] Katy Glassborow, "U.S. analyst says UUVs, not submarines, are the key to maritime supremacy," *Jane's Defence Weekly*, May 03, 2006.

especially pronounced for UCUVs, which could be used very effectively as a first-strike capability due to their low operational profile.[12]

Some might disagree with this assessment of vulnerability, and counter that the U.S. already takes undersea warfare seriously, as evidenced by our standing ASW capability and history of ASW excellence. This stands in marked contrast to past wars, in which lack of preparation created vulnerabilities to undersea threat. Some would argue that despite current challenges, our ASW capability still should be evaluated as "good," by historical standards.

However, such an argument overlooks the fundamentally asymmetric nature of undersea warfare. History demonstrates that undersea warfare will adapt to attack the "seams" of an opponent's plans, whether they are strategic or operational vulnerabilities (e.g., unprotected merchants), technology gaps (e.g., acoustic vulnerabilities), or legal/ROE constraints (e.g., unrestricted submarine warfare). Current ASW practices, designed to counter manned submarines, are not sufficient to counter UUVs. Upon further examination, the ASW template breaks down completely as a method for addressing the UUV threat.

4.1. ASW- Founding assumptions and gaps against UUVs

ASW has never been an easy capability to master. However, today's U.S. Navy can claim a history of over fifty years of ASW excellence, through the exploitation of certain characteristics that make submarines vulnerable. The first of these comes in the ability to detect submarine communications. The most basic and useful information that might be gathered is location. Starting in World War II, High Frequency Direction Finding (HF/DF) was the first historical "breakthrough" in ASW. Submarines have reacted to DF by minimizing communications and employing technologies to mask the location of their

[12] Karl M. Hasslinger, telephone interview with author, March 21, 2008.

communications. However, in many cases, vulnerabilities exist despite precautions. Even highly capable submarine forces are vulnerable to techniques exploiting patterns in the communications themselves or the progression of Areas of Uncertainty (AOU) over time. These vulnerabilities are an important element of today's U.S. ASW capability.

Another key element of submarine detection and tracking is acoustic sensing. First developed towards the end of World War I, sonar became the main enabler of ASW during World War II. In response, submarine designers and operators took steps to reduce acoustic signature, both to active sonar, through the use of hull coatings, and to passive sonar, through the use of quieting techniques. Commanders learned to use the ocean environment to mask signature to both forms of sonar. Today's ASW practices remain heavily dependent on acoustic sensing. Submarine based ASW assets primarily use passive sensing, surface ASW platforms are more likely to use active sensing, and airborne ASW assets can effectively employ both. Additionally, fixed and deployable sensor arrays can be used to significant effect, but in a more limited number of scenarios.

Finally, a critical enabler of today's U.S. ASW capability is Indication and Warning (I&W). Through a wide variety of highly sensitive technologies, especially space-based SIGINT systems, U.S. ASW greatly benefits from the ability to focus ASW platforms on a manageable number of candidate submarines. Typically there is cueing that submarines have deployed from their piers, and additional intelligence information gives insight into the likely operating areas, duration of deployment, and mission of deploying submarines. While adversaries can employ countermeasures such as covering submarine piers and other OPSEC measures, the U.S. has nonetheless found effective ways to garner highly useful intelligence. This is due, in large part, to the generally manageable number of submarines employed

worldwide; even the largest submarine forces do not have more than a few dozen operational submarines in their inventories. This enables rigorous hull accountability as a technique to both enhance alertment and prescribe technical parameters for acoustic search. The I&W capability of the U.S. is a "force multiplier" for ASW forces, and helps to enable ASW forces to overcome the challenges of submarine detection.

Across each of these critical enablers of ASW, however, UUVs will undermine the credibility of current ASW practices. It has already been demonstrated that quiet, modern diesel (SSK) and AIP (SSI) submarines are incredibly difficult to detect with either passive or active sonar,[13] and their simple design and smaller size will make this even more true for UUVs. The dramatically reduced need for a large pressure hull for crew safety and operations, which in manned submarines is a major design constraint, will further reduce the complexity of the UUV and also allow it to operate at depths prohibited to manned submarines, complicating both active and passive sonar detection.

Communications from UUVs will not be markedly easier than for manned submarines, and UUVs, like manned submarines, will be vulnerable in proportion to their communications. However, because these UUVs will be "single mission" units- unlike multi-mission manned submarines, there will be less need to communicate to coordinate operations. Also, as unmanned vehicles, there will be less need to communicate for safety-of-ship reasons or crew matters. Nonetheless, for effective use, some communications will be required, even in the most cavalier Command and Control (C2) arrangements. However, in many of the asymmetric missions in which UUVs might be employed, these

[13] Dan Taylor, "Antisubmarine Warfare 'No. 1' Priority; Greenert: Navy 'Not Satisfied' With Progress In Tracking Diesel Subs," *Inside the Navy*, 31 March 08, http://www.insidedefense.com/secure/defense_docnum.asp?f=defense_2002.ask&docnum=NAVY-21-13-11 (Accessed 04 April 2008).

communications might be masked in the "noise" of commercial communications, perhaps even through the use of commercial cell phone, widely available in the near littorals, or INMARSAT. While "detectable", such a communication would be near impossible to discriminate, especially if there is little in the way of pre-alertment or an established operating pattern. For a high-end adversary employing UUVs, low-probability-of-intercept (LPI) SATCOM is just as feasible from a UUV as it is from a manned submarine.

Because of their small size and independence from crew concerns (manning, provisioning, etc.), there will be little need for UUVs to be deployed from conventional naval facilities. These UUVs could be deployed by either dropping them off the side of a commercial vessel[14], or even by dropping them from a truck into the sea, directly from any coastal location. This flexibility in deployment, coupled with the lack of any need for deployment preparations (maintenance could be done well inland, away from prying eyes), will severely challenge I&W alertment of UUV deployment.

While it is difficult to predict the specific costs of future armed long-haul UUVs, it is likely that they will be significantly cheaper to build than manned submarines. Operating costs will also be lower, from both maintenance and manning/training perspective. Because of this, it is likely that navies or irregular forces employing UCUVs will have considerably more units in inventory than is the case with manned submarines. This large quantity alone, coupled with the I&W challenges already mentioned, will critically challenge ASW practice.

4.2. Mine Warfare (MIW) paradigm challenges

Since ASW is, therefore, fundamentally unsuited to address the problem of UUVs, an alternate approach is needed. In examining the way UUVs might be used for sea denial, it

[14] Karl M. Hasslinger, telephone interview with author, March 21, 2008.

becomes apparent that the effect of UCUVs is very similar to the effect of mines.[15] The asymmetric employment of mines allows low-capability forces to effectively challenge the most powerful navies, leveling the paying field. Use of a MIW template against UUVs, however, is a culturally unconventional approach, and furthermore, the MIW template has shortcomings of its own against the kind of dynamic threat that UCUVs will present. MIW doctrine is based around several key assumptions, which UCUVs will challenge.

MIW generally assumes that mines are static in location. While some mines can use techniques such as remote detonation, floating/sinking, etc, they are still primarily "fixed" in location. While Free-floating mines exist, despite legal prohibitions to their unrestricted use, even free-floating mines can generally be "localized" to an area of uncertainty, based on currents, tides, and patterns of mine laying, enabling Tactics, Techniques and Procedures (TTPs) to facilitate operations even in spite of their presence. UCUVs, in contrast, can operate almost anywhere.

The assumption that mines are static is breaking down with technological evolution, however. Some modest "transiting" mobile mines exist, and continue to be further developed. While the range of such mines still makes them limited in effectiveness when compared to UCUVs, the similarities between mobile mines and UCUVs are unmistakable, as CBSA's Robert Work has noted. [16] Developments in mobile mine technology challenges MIW in ways that will closely resemble the challenges of UUVs.

Another assumption of MIW is that the primary function of mining is for Anti-Surface Warfare (ASUW) and ASW, and specifically, against ships in the immediate vicinity of the mines. UCUVs, on the other hand, while likely sharing ASUW as a primary mission,

[15] Canning, 23.
[16] Glassborow.

might also be used to accomplish significant effect in strike warfare or electronic warfare (EW). Employing a Land-Attack Cruise Missile (LACM) or Electronic Warfare (EW) package on a UCUV is only modestly more challenging than employing a torpedo. Indeed, strike and EW packages are already employed on manned submarines, which will facilitate efforts to employ them on UUVs.

Finally, another key assumption of MIW is that the act of mine laying can be detected. Effective MIW can be seriously challenged by covert mine laying. However, TTPs exist to address this challenge through "Maritime Domain Awareness" based on continuous observation of the operating patterns of neutral/merchant shipping that might be used for covert mining. This is resource intensive, and generates only limited freedom of action for friendly forces, but can still be effective in keeping open the sea lanes to critical SPODs. For UCUVs, such techniques will be far less effective.

While these mismatches are significant, the most serious problem with depending on a MIW approach to counter UCUVs is that, put bluntly, the U.S. is not very good at MIW, even today. Technologies to effectively detect mines are elusive, and the sheer quantity and diversity of mines on the marketplace challenges effective MIW. An unfavorable cost balance, with mine countermeasures costing far more than the mines themselves, further challenges effective MIW. UCUVs will only exacerbate the current problems of U.S. MIW. Clearly, MIW does not provide a suitable approach to address the UCUV vulnerability.

4.3. A New Paradigm- the convergence of ASW and MIW

UCUVs exploit the gap between ASW and MIW templates. The operational flexibility, low detectability, and potential quantity of UCUVs threaten to overwhelm ASW practices, while their mobility, range, and capability challenges MIW. The evolution of

UCUVs, from a submarine genesis towards resembling both submarines and mobile mines, demonstrates the convergence of the spectrum of undersea threats. This convergence calls for a synergistic, integrated undersea warfare approach inclusive of both MIW and ASW.

In what appears to be pure happenstance, a movement for organizational synchronization of these two warfare areas is indeed already underway. On 1 October 2006, the Navy's MIW (COMMINEWARCOM) and ASW commands (FLTASWCOM) were merged into the new Naval Mine and Anti-Submarine Warfare Command (NMAWC). The drivers for this merger were, however, NOT based on a sense of operational synergy between the warfare areas. Rather, programmatic synergies- in advocacy, training, and resourcing- drove the merger, which has been met with underwhelming support from both communities. Prominent naval analyst Milan Vego notes "this reorganization was generally poorly received by many mine warfare professionals, mainly because of a concern that ASW will receive far more attention and resources than MIW. Based on the Navy's traditional neglect of MIW, these fears are not ungrounded. It is also hard to see the reason, apart from saving money, for merging and thereby blurring the lines between ASW and MIW."[17]

However, as the case of UCUVs illustrates, there are benefits beyond saving money. The NWAWC merger could facilitate the closing of a looming gap in operational art. NMAWC already has a vision for the advancement of Theater ASW, as the operational-level "bridge" between tactical level and theater level success in ASW.[18] The integration of MIW into ASW at NWAWC creates the opportunity to transform this into an integrated theater

[17] Milan Vego, "Mine blindness: The Navy must reassess its shortsighted approach to mine warfare," *Armed Forces Journal*, February 2008, http://www.armedforcesjournal.com/2008/02/ (Accessed 14 April 2008).
[18] Robert J.White, "What Role Can a Theater Anti-Submarine Warfare Commander Serve in the New Maritime Strategy?" (Research Paper, Newport, RI: U.S. Naval War College, Joint Military Operations Department , 2006), 5.

ASW/MIW effort.[19] This combined effort could be much more effective at addressing the operational level actions needed to counter the challenges of ASW, MIW, and UUV threat, which are converging in their technology gaps, methods of employment, and nature of risk.

5. Recommendations for Action and Further Research

While NWAWC might serve as a focal point, much broader effort must be applied to regain superiority in the undersea environment and counter a broad spectrum of undersea threats. General awareness of acute shortcomings in both ASW and MIW has failed to generate a sustained commitment to this objective. The potential of UUVs to give an even broader range of adversaries a powerful sea denial capability provides even more urgency. The program to address this threat should include technology investment, TTP development, operational reorganization, and revision to plans and planning to take UCUVs into account.

While technology investment is not a panacea, the right investments can be of great benefit. Investment should be made into systems to detect UUVs, and to neutralize them. UUV detection is inherently challenging, and payoff of investment is by no means guaranteed. This investment should include deployable fixed-array systems that can be placed in strategic choke points, and non-acoustic ASW (NAASW) techniques. The potentially large quantity of UUVs that a potential adversary might simultaneously employ also warrants investment specifically in neutralization technology. Current ASW neutralization approaches- especially torpedoes- are ill suited to address the quantity of UCUVs that might be inbound on U.S. assets. In this respect, mine neutralization options- especially systems such as the Rapid Airborne Mine Clearance System (RAMICS) supercavitating machine gun- might be better than ASW weapons.

[19] In fact, the omission of MIW from the NMAWC's "Theater ASW" mission area seems inconsistent with other five NMAWC mission areas, which each include both ASW and MIW.

Organizational and procedural steps are as important as technology investment. Recent trends towards the establishment of a "theater ASW" commander could be broadened, from an ASW specific charter to include the entire spectrum of undersea threats- submarines, UUVs, and mines. This would improve operational-level preparedness, and better assessment of risk to the Joint Force Maritime Component Commander's (JFMCC's) forces. Intelligence functions must ensure that the JFMCC receives an assessment of UCUV quantities and capabilities in potential adversaries Orders-of-Battle (OOBs), as well as warning of adversaries' intentions for use of UCUVs to create operational surprise. HUMINT will be especially important in this respect, given the low SIGINT/ MASINT footprint of UCUVs both in development and operations.

Logistics planners will need to incorporate realistic assessment of threat posed by UCUVs into their plans and processes. Even if the technology and organizational steps are embraced, the threat of UCUVs will likely only be partially mitigated. Given the variety of actors that might employ UCUVs, and the difficultly of detecting and neutralizing them, logistics planners will likely have to make substantially more provision for combat losses of sealift assets than is currently the case. This will likely have the perverse effect of requiring *more* sealift assets, thus giving UCUVs that many more targets. The use of large maritime Pre-positioning ships (MPS)- which tend to operate in very localized areas- should also be questioned, as their operating patterns make them easier to target with low-end UCUVs. The impact of a loss of a ship of the size of a MPS would be devastating. Logisticians will also have to take into account significantly more risk in operating in "friendly" home waters and SPOEs, and likely additional time required to operate in patterns to address this risk.

Considerably more research is needed into the threat posed by UUVs. Almost the entirety of current literature on UUVs is written from a perspective of blue-force employment, with very little focused on potential asymmetric uses. This paper has limited its scope to describing the effect of UUVs at the operational level of war, it has not explicated the potential use of UUVs to attack non-military targets- notably, critical U.S. undersea infrastructure, or homeland security targets. This is not to understate these significant strategic vulnerabilities[20], which will further encourage investment in UUVs by adversaries, especially rogue states or non-state actors.

Finally, this paper has not delved into the significant ways in which ROE constraints might severely limit an operational commander's courses of action (COAs) in responding to a UUV threat. Historically, ambiguities in maritime law regarding submarines have led to costly missteps in the promulgation of ROE, and UUVs provide even more complicating factors. Current U.S. doctrinal approaches, as exemplified in NWP 1-14M[21], threaten to create significant problems by effectively treating UUVs exactly like manned submarines, instead of like mines. As this paper has demonstrated, such an assumption is ill-founded[22].

6. Conclusion

UUVs will present a formidable asymmetric threat to U.S. Operational Art in the coming decades, potentially becoming a premier tool for "sea denial." While armed UUVs- UCUVs- are not yet a prominent feature in the order of battle of potential U.S. adversaries, their arrival is only a short matter of time; few technology barriers stand in the way of the

[20] Karl M. Hasslinger, "Undersea Warfare: The Hidden Threat," *Armed Forces Journal*, March 2008, http://www.armedforcesjournal.com/2008/03/ (Accessed 14 March 2008).
[21] Department of the Navy, *The Commander's Handbook on the Law of Naval Operations: Edition July 2007*, NWP 1-14M (Newport, RI: Naval Warfare Development Command, July 2007), pp. 2-3.
[22] A more complex explication of the rationale behind NWP 1-14M is found in Andrew H Henderson, "Murky Waters: The Legal Status Of Unmanned Undersea Vehicles." *Naval Law Review* 53 rev 55 (2006).

proliferation of low cost, capable UCUVs. Because they are free of many of the operational constraints that have limited employment of manned submarines, UCUVs will introduce even more threat into the already vexing ASW problem that confronts U.S. planners. With greatly expanded operational range, UCUVs threaten to give even minor "regional" actors a global strike capability and threaten the very concept of a "regionally contained" war.

U.S. shortfalls in addressing the threat of UCUVs are similar to those it has in delivering effective MIW. Like mines, UCUVs threaten to become a highly effective tool for sea denial in the hands of low-end nations and non-state actors. These vulnerabilities across the spectrum of undersea warfare illustrate a systemic shortcoming in operational art. Particularly vulnerable to the asymmetric employment of UCUVs are supporting functions such as sealift as part of operational sustainment. The U.S.'s considerable investment, in both lives and dollars, to create a powerful maritime capability are at significant risk if the threat of UUV-enabled undersea warfare is not fully appreciated and diligently addressed.

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