ZONE DEFENSE – ANTI-SUBMARINE WARFARE
STRATEGY IN THE AGE OF LITTORAL WARFARE

A thesis presented to the Faculty of the U.S. Army
Command and General Staff College in partial
fulfillment of the requirements for the
degree

MASTER OF MILITARY ART AND SCIENCE
Strategy

by

Jason C. Pittman, LCDR, USN
Bachelor's of Music, University of Texas, Austin, Texas 1998
Master's of Education, Troy State University, Troy, Alabama, 2004

Fort Leavenworth, Kansas
2008

REPORT DOCUMENTATION PAGE					*Form Approved OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**					
1. REPORT DATE *(DD-MM-YYYY)* 12-12-2008	**2. REPORT TYPE** Master's Thesis				**3. DATES COVERED** *(From - To)* FEB 2008 – DEC 2008
4. TITLE AND SUBTITLE ZONE DEFENSE – ANTI-SUBMARINE WARFARE STRATEGY IN THE AGE OF LITTORAL WARFARE.					**5a. CONTRACT NUMBER**
					5b. GRANT NUMBER
					5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **LCDR Jason C. Pittman, USN**					**5d. PROJECT NUMBER**
					5e. TASK NUMBER
					5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Command and General Staff College ATTN: ATZL-SWD-GD Fort Leavenworth, KS 66027-2301					**8. PERFORMING ORG 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 Approved for Public Release; Distribution is Unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT Anti-Submarine Warfare (ASW) is an increasingly complex and challenging aspect of maritime warfare. Technologically advanced countries such as Germany, Sweden, and France continue to develop advances in diesel submarine technology that make these vessels more difficult to detect. As the U.S. Navy's area of operations shifts from deep-water operations to the littorals of the world, an evaluation of current ASW tactics may be required. This paper analyzes the relevance of the ASW threat to today's Navy, the inherent differences in operation between blue and brown water areas, the changing technology being used on diesel submarines, and the current ASW tactics being used by the U.S. Navy. With an understanding of the fundamental changes that are occurring in the theater of operations this paper concludes with the recommendation that a re-evaluation of current tactics must be done to ensure the most efficient use of assets for the task of ASW.					
15. SUBJECT TERMS Anti-Submarine Warfare (ASW), Diesel Submarines, Littoral ASW, Theater ASW					
16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT (U)	**b. ABSTRACT** (U)	**c. THIS PAGE** (U)	(U)	76	**19b. PHONE NUMBER** *(include area code)*

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

MASTER OF MILITARY ART AND SCIENCE
THESIS APPROVAL PAGE

Name of Candidate: LCDR Jason C. Pittman, USN

Thesis Title: ZONE DEFENSE – ANTI-SUBMARINE WARFARE STRATEGY IN THE AGE OF LITTORAL WARFARE

Approved by:

____, Thesis Committee Chair
Bob A. King, M.B.A.

____, Member
John T. Kuehn, Ph.D.

____, Member
Harold A. Laurence, M.B.A., M.P.S.

Accepted this 12th day of December 2008 by:

____, Director, Graduate Degree Programs
Robert F. Baumann, Ph.D.

The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

ZONE DEFENSE – ANTI-SUBMARINE WARFARE STRATEGY IN THE AGE OF LITTORAL WARFARE by LCDR Jason C. Pittman, 76 pages.

Anti-Submarine Warfare (ASW) is an increasingly complex and challenging aspect of maritime warfare. Technologically advanced countries such as Germany, Sweden, and France continue to develop advances in diesel submarine technology that make these vessels more difficult to detect. As the U.S. Navy's area of operations shifts from deep-water operations to the littorals of the world, an evaluation of current ASW tactics may be required. This paper analyzes the relevance of the ASW threat to today's Navy, the inherent differences in operation between blue and brown water areas, the changing technology being used on diesel submarines, and the current ASW tactics being used by the U.S. Navy. With an understanding of the fundamental changes that are occurring in the theater of operations this paper concludes with the recommendation that a re-evaluation of current tactics must be done to ensure the most efficient use of assets for the task of ASW.

ACKNOWLEDGMENTS

This thesis is not the product of one individual. It is the product of the team that inspired, guided, and supported me throughout the process of research, writing, revising, editing and submission.

First and foremost, I would like to thank the members of my thesis committee; Dr. John Kuehn, Mr. Tad Laurence, and especially my committee chair, Mr. Bob King. These gentlemen provided superb guidance and recommendations for how to best complete my project. However, the most important thing they provided me was enthusiasm for my research. Their insight and boundless excitement about the paths my thesis could take provided motivation to dig deeper into the topic.

I would also like to thank my lovely wife Victoria for her support and prompting. Always pushing to keep me on schedule and engaged, her encouragement made it easier to sacrifice family time in the name of research.

Finally, I would like to dedicate this thesis to the memory of Commander Scott Harrington. Initially a member of my thesis committee, and one of the most enthusiastic about the possibilities of this research, CDR Harrington passed away from cancer during the course of this academic year. An innovative, inspiring, and transformational leader and person, CDR Harrington did the most to inspire independent thought and a questioning attitude during the process of literature review and analysis. The U.S. Navy has lost an inspiring leader and I hope this thesis can stand as a representation of even a fraction of the innovative thinking CDR Harrington brought to the table.

TABLE OF CONTENTS

ACRONYMS

AAW	Anti-Air Warfare
AIP	Air Independent Propulsion
AOR	Area of Responsibility
ASUW	Anti-Surface Warfare
ASW	Anti-Submarine Warfare
CDR	Commander
CENTCOM	Central Command
CONOPS	Concept of Operations
FSASW	Full Spectrum Anti-Submarine Warfare
JFMCC	Joint Force Maritime Component Commander
MESMA	Module d'Energie Sous-Marin Autonome
PACOM	Pacific Command
PLAN	People's Liberation Army Navy
SSK	Diesel Electric Submarine
SSN	Nuclear Powered Submarine
SOSUS	Sound Surveillance System
TASW	Theater Anti-Submarine Warfare
USW	Undersea Warfare
VADM	Vice Admiral

CHAPTER 1

INTRODUCTION

A submarine in the water scares the hell out of people.
- ADM Kinnard McKee, USN[1]

Submarines continue to threaten surface forces, particularly in the littoral regions of the world, and are becoming extremely difficult to manage. Advanced countries such as Germany, Sweden, and Norway continue to create technologies that allow submarines to operate on their batteries for extended periods of time. Hydrogen/Oxygen fuel cells, Stirling engines, and extended life batteries are all contributing to the changing of diesel submarine operating patterns. Specifically, diesel submarines no longer need to come to surface, expose a mast, and snorkel to recharge their batteries multiple times a day. This is a fundamental change in operations that has a significant impact on current Anti-Submarine Warfare (ASW) methods employed by the U.S. Navy. This change in operating patterns, combined with improved sound isolation technology, makes the diesel submarines found in the Central Command (CENTCOM) and Pacific Command (PACOM) Areas of Responsibility (AOR's) difficult to detect. The increased danger from an unknown enemy submarine poses a significant threat to the carrier strike groups used to project forces ashore. Additionally, the Russian Federation and Germany are willing to sell these relatively inexpensive vessels to any country in the world, making the proliferation of diesel submarines a severe threat to naval operations.

Background

Anti-Submarine Warfare (ASW) has been a focal point of the maritime services since the First World War. The exploits of the U.S. Submarine Force during World War

II are legendary and stand as a testament to the devastation that submarines, acting independently, can bring to a nation. Many have argued that the battlefront existed primarily under the surface throughout the Cold War, as a cat and mouse game that was played between the fast attack and ballistic missile submarines of the United States and the Soviet Union.[2] During this period, the Navy ASW capability was arguably at its most proficient. The blue-water navies of two great nations attempted, with moderate success, to contain the submarine threat primarily through the use of anti-submarine tactics that required numerous airborne and seaborne assets.

Following the end of the Cold War, a distinct sense existed in the upper level leadership of the U.S. military that submarines were no longer a threat.[3] Indeed, funding for the SEAWOLF class was greatly reduced, and production rates of future classes were significantly lowered. As the country became involved in land wars in the Middle East, the Navy shifted its focus to supporting joint operations through power projection ashore. Consequently, the Navy experienced degradation in ASW capability. The senior leadership of the Navy has commented on this degradation as a threat to the Navy's current dominance in the under-sea battle.[4] Through such initiatives as Sea Basing and the Global Fleet Station, it has become apparent that the control of the maritime environment is still critical to mission success despite the Navy's continued focus on supporting the joint fight. Nowhere is this clearer than in Seapower 21, where then CNO ADM Vern Clark specifically cited ASW, and the need to be proficient at it, as a primary enabler for all other aspect of Sea Basing, Sea Shield, and Sea Strike.[5]

The navies of other nations improved their submarine capability as the U.S. Navy's ASW skill atrophied in the post-Cold War era. The proliferation of diesel submarines throughout the world, and particularly in the littoral regions of concern to the U.S. (i.e. the Middle East and Far East), continues at an increasing rate. Over forty countries including Russia, North Korea, India, China, and Iran, have diesel-electric attack submarines (SSKs). Diesel submarines are a cost-efficient method of ensuring localized maritime superiority, or at least guaranteeing the ability to exert some measure of sea control in the face of an overwhelming adversary such as the United States. The relative cost (compared to nuclear submarines), combined with technological advances in submarine design, are making SSKs a very real threat in the littoral regions of the world.

Technological advances in the propulsion technology of SSKs have been an area of interest for many countries. The focus on Air Independent Propulsion (AIP) has resulted in the creation of SSKs that no longer need to come to the surface for frequent battery charges to maintain their capacity for submerged operations. This capability, combined with dramatic advances in sound-silencing technology, has fundamentally changed the pattern of operations for SSK captains. These quieter submarines, with longer on-station times, are often encountered in the littoral regions of the world. To call the acoustic environment of the littorals unforgiving to the submarine hunter is an understatement at best. Diverse bottom topographies, increasing ambient noise levels, varying sound propagation paths, and increasing transmission loss all combine to make the detectability of an advanced SSK near zero.

The U.S. Navy has grown to recognize the threat of the SSK, through various international exercises and incidents, but has taken no comprehensive step toward a fundamental shift in the approach to ASW. A recent change has been the introduction of Theater ASW. Theater ASW is a concept where the Combatant Commander of a given theater (i.e. PACOM, CENTCOM) uses assets from every branch of the military, as well as the whole of government, to manage the submarine threat of countries in his or her AOR.[6] While the Theater ASW concept is a step in the right direction, involving the sister services in the fight against submarines, it is still very much focused on a defense scheme centered on knowing where the enemy submarine is at all times. The Theater ASW concept relies on two operational approaches: either keep the enemy submarine in port, through various methods of intimidation or political pressure, or, once it has left port, locate and maintain contact with it. These approaches are neither viable, nor reasonable, and are a direct reflection of the U.S. Navy relying on one paradigm for ASW--the Cold War. The Cold War ASW problem was comparatively easy. It occurred in deep water, with predictable acoustics, and a one-on-one approach for maintaining contact with the enemy. This approach was viable as long as one submarine gained and maintained track of another. The ASW environment in the shallow water of the littorals is incredibly complex, and a submarine is the only asset that is in the same location as the enemy during an ASW prosecution under the water. However, since the Cold War model is the last one the Navy used to prosecute submarines, it is trying to apply those tactics to the current problem. Theater ASW, in its present form, relies on an immense number of assets, combined with timely placement, to maintain contact with the enemy submarine. This level of equipment and manpower cannot be supported for an undetermined length of time, and removes assets from the Joint Force Maritime Component Commander's arsenal.

The current ASW tactics/operational concepts of the maritime services must be re-evaluated. The deep water, nuclear threat of the Soviet SSN is no more and the tactics used to prosecute it are no longer viable, nor are the assumptions of operation that are the basis of those tactics. To be fair, there are anti-diesel tactics that were developed during the Cold War; however, those tactics are based on a level of capability that the current enemy has far surpassed. Consequently, a reassessment of the fundamental principles that anti-submarine warfare is based on must be conducted in order to ensure continued maritime superiority for the U.S. Navy.

Primary and Secondary Research Questions

Is the paradigm under which the Navy developed its current Anti-submarine Warfare Doctrine still valid given the invention of new technologies that are making diesel submarines more difficult to locate?

1. What are the current methods of anti-submarine warfare employed by the U.S. Navy?
2. What are the technologies being introduced into submarine design and what are their effects on the detectability and operating patterns of submarines?
3. What differences in the environmental factors of operating areas are affecting anti-submarine warfare?

Definitions

The world of anti-submarine warfare is a foreign environment, even to members of the naval services. Consequently, there are terms that are specific only to this community. The following is a list of frequently used words with their doctrinal definitions. This list will aid the reader in understanding the nuances of the topic. It should be noted that some terms do not have standard doctrinal definitions but are nevertheless part of the vocabulary of anti-submarine warfare. These words are given a brief definition and all definitions are accompanied with a brief discussion to assist in clarity of meaning.

Air Independent Propulsion (AIP) – AIP is a term used to collectively describe the technologies that allow a submarine to operate without the need of oxygen from an external source. The fundamental operation of a diesel submarine is still the same, battery powered, but AIP either extends the life of the batteries or provides a method to recharge the batteries without needing to surface or snorkel to bring outside oxygen into the ship.

Anti-Submarine Warfare – As defined by Joint Publication 1-02, Anti-Submarine Warfare (ASW) is "operations conducted with the intention of denying the enemy the effective use of submarines."[7]

Atrophy – Atrophy is a common word used to describe the partial or complete wasting away of the body. This term is used throughout this paper specifically to describe the deterioration of skills due to lack of being exercised (i.e. if you do not practice using active sonar that skill will atrophy).

Detectability – Detectability refers to the ability of an object to be detected by another. In the context of this paper, the term detectability is used in reference to the relative capability of a submarine to be detected by forces that are actively looking for it. For example, a diesel submarine operating on battery power is quieter than a diesel submarine operating its diesel engine. Therefore, the submarine operating on the diesel has a higher detectability.

Littoral – Till provides the best definition of the littoral area as both the area from the open ocean to the shore and the area from the shore inland that must be "supported and defended" by assets from the sea. The size of the area from the open ocean to the shore is dependent on the amount of area the JFMCC needs to control to support operations ashore.[8]

Sound Propagation – If sound is acoustic energy caused by the vibration of an object, then sound propagation is the transmission of that acoustic energy through a medium by means of a sound wave. For the purposes of the discussions in this paper it is important to note that several factors affect sound propagation, including geometric spreading, environmental effects (temperature, pressure, salinity) and surface effects (reflections). All of these factors cause sound to no longer travel in a straight line, as it would in a vacuum.

SSK – The standard abbreviation for any class of conventionally (diesel) powered attack submarine.

Undersea Warfare (USW) – As defined by Joint Publication 1-02, USW is "Operations conducted to establish and maintain control of the underwater environment by denying an opposing force the effective use of underwater systems and weapons. It includes offensive and defensive submarine, anti-submarine, and mine warfare operations..."[9] It is important to note that ASW is one aspect of USW. These terms are often used in the same context due to the subset nature of ASW; however, it should be noted that USW also includes aspects of warfare such as mining, torpedo use, undersea nets, and awareness of the subsurface tactical picture.

Limitations

There are two major limitations to the scope of this paper. First, submarine warfare by its very nature is a highly classified endeavor. A nation's ability to conduct submarine and anti-submarine warfare is directly linked to its level of technological advancement in the field. Consequently, many technical aspects of ASW are classified. Corresponding to the secrecy surrounding the equipment used for ASW, the tactics used to effectively employ the technology of ASW is similarly classified. This paper will address current ASW methods and equipment as can be identified through open source research in an attempt to maintain the level of classification of this paper at the lowest level possible.

Delimitations

This paper is meant to examine ASW from a strategic perspective with the occasional foray into the operational level. Consequently, there will be no discussion of the specific tactics or technology needed to conduct successful ASW prosecutions at the tactical, ship-on-ship level. Discussions of tactics will be kept at a broad, strategic level, and will not include the tactical methods of submarine tracking. Discussions of technology that do occur will be focused on the ability of technology to overcome the forces of nature that affect ASW and will be kept at a very general level to avoid the previously mentioned classification discussions.

Significance

The purpose and focus of naval warfare has changed. As the U.S. Navy has shifted its focus to supporting the Joint Forces operating on land, it has increased its level of operations in the littoral regions of the world. With this decreased distance from land comes an increase in the need to ensure some measure of maritime superiority is achieved and maintained. Naval operations in the littorals are no longer short-lived events where amphibious forces are landed on shore and the ships can then back out to deeper waters to maintain naval gunfire support. The U.S. military is focusing on concepts such as Sea Basing, where U.S. military forces operate from ships off shore in the absence of any land-based staging area. The direct follow-up to this concept is the need to maintain security in the maritime area of operations, as well as the sea-lines of communication to the sea base. As will be discussed in the literature review of chapter 2, one diesel submarine can create extensive havoc throughout a surface fleet conducting littoral operations.

The U.S. Navy's skill in ASW has atrophied following the end of the Cold War but there are efforts underway to improve the capabilities, technologies, and methods used to conduct ASW.[10] A primary focus of current ASW improvement is methods in which the U.S. Navy can leverage its technological prowess against submarines in the littoral regions. The Littoral ASW Concept paper put out by Navy Doctrine Command gives much discussion to different technologies being utilized to create a common operational picture of the undersea environment and the necessity to have streamlined information flow between units.[11] There is, unfortunately, very little discussion given to the need to revise the doctrine of ASW outside of the need to have doctrine change to align it as new technology becomes available. This represents what may be a fundamental issue in updating how ASW is conducted. Doctrine represents the basis from which operational concepts are developed and if there is no evaluation of the foundation for a sound theory then the re-definition of the operational concept is simply an exercise in conducting change for the sake of change, with no real evolution in the conduct of war.

The literature concerning ASW is varied, ranging in topic from the need for a joint warfare approach to creation and implementation of new technology to overcome the inherent difficulties of littoral ASW. The literature review of Chapter 2 will examine the body of work regarding anti-submarine warfare, from past lessons learned to current trends, in an effort to determine underlying themes of approach to the ASW problem. Additionally, a review will be made of the current advances in submarine technology as it has a direct impact on the efficacy of submarine hunting methods. Subsequent chapters of this paper will determine what, if any, changes need to be made to the current U.S. Navy approach to dealing with the littoral submarine threat.

Chapter 3 of this thesis will briefly discuss the methods used to gather information for research to include an analysis of the strength and weaknesses of the research and possible effects on the veracity of this thesis. Chapter 4 will analyze the current ASW problem based on the reality of the submarine threat, the technology of new diesel submarines, the effects the littoral environment have on detecting sounds through sonar, and the U.S. Navy's current attempts to combat the ASW problem. Chapter 5 will summarize the analysis of Chapter 4 in order to determine the underlying mindset of the ASW efforts currently undertaken by the U.S. Navy. Some strategic recommendations will be provided in an effort to direct further research and action regarding the future of ASW in the U.S. Armed Forces.

---

[1] Kinnard McKee, "McKee Sees Different Mission for Future Attack Submarines," *Proceedings* [September 1990]: 82.

[2] Sherry Sontag and Christopher Drew, *Blind Man's Bluff.* [New York: PublicAffairs, 1998], xv.

[3] Ivan Eland, “It’s time to Mothball Unneeded Nuclear Attack Submarines,” *USA Today*, September 1, 1999, http://www.encyclopedia.com/doc/1G1-56459107.html [accessed 11 May 2008].

[4] Norman Polmar, “Back to the Future,” *Proceedings* [April 2006], http://www.military.com/forums/0,15240,94621,00.html [accessed May 9, 2008].

[5] ADM Vern Clark, “Seapower 21,” *Proceedings* [October 2002], http://www.navy.mil/navydata/cno/proceedings.html [accessed March 27, 2008].

[6] Patricia Kime, “Navy Should Bolster Crisis Planning for Theater ASW,” *Seapower* [September 2003], http://findarticles.com/p/articles/mi_qa3738/is_/ai_n9272050 [accessed March 4, 2008].

[7] Department of Defense, “Department of Defense Dictionary of Military and Associated Terms,” http://www.dtic.mil/doctrine/jel/new_pubs/jp1_02.pdf [accessed March 4, 2008], 39.

[8] Geoffrey Till, *Seapower: A Guide for the Twenty-First Century*. [London: Frank Cass, 2004], 255.

[9] Department of Defense, 572.

[10] Owen Cote and Harvey Sapolsky. “Antisubmarine Warfare after the Cold War.” *MIT Security Studies Program.* http://web.mit.edu/SSP/Publications/confseries/ASW/ASW_Report.html [accessed July 7, 2008], 3.

[11] Naval Doctrine Command, “Littoral Anti-Submarine Warfare Concept,” http://www.fas.org/man/dod-101/sys/ship/docs/aswcncpt.htm [accessed April 21, 2008] 9.

CHAPTER 2

LITERATURE REVIEW

There is an extensive amount of literature pertaining to anti-submarine warfare and its current state within the U.S. Navy. For the purposes of a literature review, it will be necessary to delve into the information regarding the four main areas of interest detailed in Chapter 1; the current state of ASW, the new technologies being introduced into conventional submarines, the aspects of ASW that are different between the Cold War and today, and a historical review of the modern ASW problem. Many of these topics are so interrelated that it is nearly impossible to discuss them individually. Consequently, literature will be reviewed in this chapter as a function of the type of document, such as Naval Warfare Publications, or as a function of the broader topic it discusses.

The Current State of ASW

To gain an understanding of the U.S. Navy's current approach to anti-submarine warfare, it is necessary to start at the top by looking at the documents dictating Navy policy. The new maritime strategy titled "A Cooperative Strategy for 21st Century Seapower" was released in October 2007. This strategy is a first of its kind because it is signed by all of the maritime services. The new strategy is much like U.S. Naval Strategy documents of old, such as "…Forward, From the Sea", because it makes the obvious assertions that the US military operates on a global scale and that freedom of action on the seas is a necessary prerequisite to successful global operations. Where the new maritime strategy differs is that it no longer assumes blanket control of the sea. In fact, it specifically addresses the need to ensure U.S. Naval forces are capable of controlling the seas when needed. Furthermore, it specifically addresses the problem of submarine proliferation throughout the world but does little to specify the actions to be taken to counter the threat other than to continue to develop tactics and technology.

While the new Maritime Strategy was signed in October 2007, its attitude towards ASW is symbolic of an ongoing trend in U.S. Navy policy to improve ASW capability. The Naval Doctrine Command released the *Littoral Anti-Submarine Warfare Concept* paper in 1998. This concept paper delineates how the U.S. Navy plans to mitigate the risk of submarines in the littorals by using new technologies to create a multi-platform ASW network that will be able to rapidly share information on enemy submarines in an attempt to eliminate them.[1]

Then Chief of Naval Operations ADM Vern Clark directed the formation of a new fleet level ASW command in 2003.[2] The Fleet ASW Command, created in conjunction with a Task Force ASW and a specific ASW office at Naval Sea Systems Command, sought to re-invent ASW for the 21st Century. Task Force ASW published *Anti-Submarine Warfare: Concept of Operations for the 21st Century* in 2005. While the document itself is very brief, it clearly echoes the intention of the U.S. Navy to leverage its technical superiority to create a network of sensors that was previously discussed in the 1998 ASW Concept paper.[3] An interesting note about the goals of Fleet ASW command is that when it was created, the command was given the specific task of changing how ASW is conducted but "with the technology that is currently available."[4]

There are more specific manuals and Naval Warfare Publication documents that further clarify the method of ASW being employed by the U.S. Navy; however, due to their classification, they were unable to be used for the purposes of this research study. However, the national Maritime Strategy and the Littoral ASW Concept papers, combined with other open source analysis documents, are sufficient to demonstrate the current mind-set of those conducting ASW today.

The analysis of maritime strategy by those in academia is certainly not a foreign concept. There are numerous papers and monographs on ASW written by students of the U.S. Naval War College and the U.S. Naval Post-Graduate School. As a whole, these papers also acknowledge the proliferation of diesel submarines as an increasing danger to the maritime supremacy of the United States. However, also as a whole, these papers focus on the need for ASW to become an effort of all the branches as a Joint Operation. The overarching theme in these papers is that the number of ships and planes able to conduct ASW is dwindling, and those ships that remain are increasingly called to perform multiple missions. As such, it is argued that all services have something to contribute to the conduct of ASW.

In his book, *Sea Power: A Guide for the Twenty-First Century*, Geoffrey Till also acknowledges the need for limited maritime superiority for the successful completion of expeditionary military operations.[5] Mr. Till provides a rather bleak assessment of the need for ASW however, as is clear in his statement that while diesel submarines are a problem, most countries will be unable to mount a successful submarine attack on surface forces.[6] Mr. Till essentially discounts the very real threat that even the most basic of submarines poses to a surface vessel simply because most countries cannot afford to purchase new submarines. This opinion does not take into account the fact that even one submarine, poorly manned and operated, can cause an indefinite pause in operations by conducting only one attack. Even if the attack is not successful, the prudent Joint Force Commander will not risk placing ships into harm's way without some measure of action being taken against the enemy submarine. Mr. Till's opinion is vital as it underscores a possible systemic disbelief in the true severity of the conventional submarine problem.

While some academics merely discount the issue of submarines offhandedly, others are certainly taking a more concerted look. The Massachusetts Institute of Technology Security Studies Program conducted a study in June of 1997 regarding ASW after the Cold War. Bringing together numerous luminaries in the world of maritime strategy, the study aimed to determine the course of ASW in the post-Cold War environment. The study determined that not only is ASW still a vital mission for the U.S. Navy, it is a mission that presents the Navy with a growing challenge in the increasing numbers of modern, conventional submarines available on the world market.[7] The study report is perhaps the first mention of many prominent themes in ASW today: it is a joint operation, current ASW efforts are under-funded and have been since the end of the Cold War, a single submarine presents an unacceptable threat to maritime superiority, and that conventional submarines are better equipped, better designed, and manned by better trained crews than ever before. An interesting point of the paper is that "ASW systems do not equal ASW capability."[8] This point is of note, because it seems to have been lost during the following decade of ASW development, which is an issue we will address in later chapters of this paper.

The Current Diesel Submarine Problem

Numerous authors make mention of the growing threat of conventional submarines in the world, but few provide any concrete data to support their assertion.

John R. Benedict, in his article *The Unraveling and Revitalization of U.S. Navy Antisubmarine Warfare*, provides the most comprehensive analysis of the ASW problem, from capabilities of new ships to lack of capability of current submarine hunters. A specific case cited by Benedict is the Falklands war of 1982. As the only occurrence of ASW in a wartime scenario against a modern SSK, the Falklands scenario provides a clear, if limited, view into the difficulties of locating a submarine in the littoral operating areas. The Falklands war, as it relates to ASW, will be discussed later in this chapter, but it should be stated now that the war demonstrated that a poorly trained crew in one aged submarine can cause significant distress for one of the world's greatest navies. The conclusions drawn by Benedict are supported by numerous researchers, to include the Cote and Sapolsky study from MIT, the previously mentioned Geoffrey Till, as well as CDR Karl A. Rader in his School of Advanced Military Studies monograph *Forward…from the sea into the Torpedo Danger Zone: Blue Water ASW Doctrine in Shallow Water*.

The Falklands war provides an example of the havoc a conventional submarine can cause in a sea war, but we must remember that the Argentinean submarines involved were not the highest quality. Their fire control systems malfunctioned at critical times and there is one documented case where the torpedoes they fired failed to detonate.[9] However, they were still able to cause a great deal of consternation for the Fleet Admiral while not being prevented from recharging their batteries when necessary. Add to this consideration the fact that they did not possess the equipment of choice among newer submarines, Air Independent Propulsion, or AIP.

AIP is a term used to collectively refer to any system on a conventional submarine that enables it to run longer without having to bring in outside air to run its diesel engine. This can encompass anything from more efficient batteries, to hydrogen fuel cells such as in the German Type 212, to a Stirling engine that uses liquid oxygen to enable the diesel to run, such as in the Swedish GOTLAND class SSK.[10] AIP systems enhance the capability of the conventional submarine greatly because these systems create a reduction in what is referred to as "discretionary time" or time that a conventional submarine CO must make noise to recharge his batteries. The obvious conclusion is that if a submarine is able to stay submerged, with no masts exposed, for longer periods of time then any tactic that is heavily reliant on visual or radar detection is going to suffer a drastic reduction in efficiency. The increase in submerged staying power does not place the diesel submarine on the level of the nuclear submarine, as opined by CDR Rader[11], because it is not a limitless power supply. While the conventional submarine can now stay submerged for longer periods, its speed is still quite slow. Slow speeds must still be maintained to charge a diesel battery, even if you are able to run the diesel underwater.

AIP technology is not a quantum change in the type of submarine that littoral commanders must deal with; it is merely a facet of the enemy's capability that reduces the size of the needle in the haystack. This underscores the need to evaluate the methods used to counter the threat of the diesel submarine, not just the technology onboard those submarines.

Cold War vs. Shallow War

Current ASW tactics are rooted in the tactical maneuvers most effective during the Cold War prosecution of Soviet submarines. This fact has been discussed briefly in this chapter and will be further evaluated later in this paper. More important than the idea that the U.S. Navy is trying to apply Cold War ASW tactics to the current threat are the reasons why it will not work. Chief among these is obviously the difference in the enemy. Today's conventional adversary is quiet, slow, limited in range, and extremely difficult to locate when not operating the diesel engine. Some of the aspects of conventional submarine design that further exacerbate this problem (AIP, etc) have already been discussed and will be evaluated later, but almost as troubling as what type of ship the enemy is, or what equipment it is running, is the environment the enemy is operating in.

The Cold War took place in the deep water of the Atlantic and Pacific oceans. Sound propagation in the deep waters of the Pacific and Atlantic Oceans is predictable. The primary factor in determining whether or not a submarine will be detected is a comparison of the submarine's noise emitted against the surrounding environment. Simply put, if you are trying to find something that is quiet it is easier to do so when the surrounding environment is quiet as well. The noise levels of the deep ocean are extremely low when compared with those of the coastal regions. This is due primarily to the proximity to noise sources. There are no factories in the middle of the ocean, no huge fishing fleets, no rivers, no off shore oil platforms. There is, compared to the relative bustle of the shore, nothing out there. This environment lends itself well to the tactics of localization and monitoring.

The Cold War cat and mouse games played by the US and Soviet submarine fleets are well documented, such as they can be in an unclassified manner.[12] The asset heavy tactics used to identify submarines and follow them were very useful because it was not difficult to pick out the sound of the submarine against the surrounding background. In today's era of littoral warfare, the playing field has changed but the game plan has not.

Over 70% of the world's population lives near the coast.[13] With population comes industry and with industry comes noise. Off shore oil platforms, coastal factories, fishing fleets, commercial and recreational boating, and even the sounds of waves crashing on the shore serve to increase the overall noise level in the water such that relative whisper of the diesel submarine is lost in the crowd of background noise. Norman Polmar points out that Cold War tactics relied heavily on the use of passive acoustic detection of submarine sounds, but when the sound is one among many, the utility of passive detection shows its limits.[14]

As if the simple loss of exploitable sound signals into the background did not make the ASW difficult enough, the issue of sound propagation is equally important. Sound travels in waves, much like light. As sound reaches a barrier, the surface, the ocean floor, or even a region of water with a different temperature, it will reflect in a different direction. An unfortunate side effect of this reverberation is a decrease in the strength of the sound. That is to say, the more a sound reverberates, the quieter it gets. In the deep ocean a sound can be generated and travel for thousands of miles because there will be little attenuation, or fading, of that signal due to reverberation. In the littorals, the bottom and surface are much closer together causing a dramatic increase in reverberation and attenuation in sound.[15] Nicholas Pace and Finn Jensen have compiled an exhaustive collection of essays and research reports dealing with the impact that littoral environments have on acoustic predictions, but the most cogent to this discussion is a report by Zurk, Lee, and Tracy titled, "Robust Adaptive Processing in Littoral

Regions with Environmental Uncertainty".[16] Zurk, Lee and Tracy define the problem with detection of quiet targets in the littorals as incredibly complex due to the sound propagation paths in shallow water combined with the prevalence of noise from nearby surface ships.[17] Zurk, Lee and Tracy accurately describe the complexity of the acoustic situation in the littorals, but a follow on article in the same collection highlights the main adversary in detection apparatus development: the changing environment.[18] A primary detriment to the development of accurate sonar detection equipment, as stated by Warren Fox and numerous other colleagues, is that the sonar environment of the littorals is prone to rapid change based on numerous factors such as temperature and salinity.[19] What this means in the grand scheme of ASW is that the sonar operators must not only be constantly searching for the target submarine, but also constantly evaluate the environment to ensure that the sonar system they are employing is set at the most optimal equipment settings. This does more than increase the workload of the sonarman onboard a ship; it renders any hope that the U.S. Navy places in an autonomous sensor field as useless. A static detection apparatus, such as a sonobuoy, will be useless if it cannot detect and adapt to changes to the surrounding environment on its own.

The Modern ASW Problem

When discussing the modern ASW problem it is useful to look to recent history for any and all examples of conflict at sea involving submarines. Unfortunately, there have not been many hostile engagements between surface and submerged combatants since World War II. While a review of World War II submarine battles may provide some level of input into the mindset of the surface sailor when dealing with a hidden enemy, the sheer difference in technologies between the submarines of today and yesterday render such discussions obsolete.

The Falklands war is an extremely useful tool for our discussion as it is the only major naval engagement involving submarines, both nuclear and diesel, in modern war. The 1982 Falklands campaign between Great Britain and Argentina over control of the Falkland Islands revealed several lessons on maritime strategy but the most useful is in regard to the effect of a diesel submarine.

Many maritime strategists, such as Geoffrey Till, believe that the diesel submarine threat is minimal because "the number of countries able to mount and maintain such a challenge is not great."[20] The Argentinean Navy possessed only two diesel submarines in 1982.[21] The British fleet was under the command of Admiral Woodward, who had a keen understanding of submarine tactics, as he was a senior submarine officer who had taught the infamous Perisher Course, the most rigorous step in command qualification for submarines in the Royal Navy. CDR Karl Rader gives an excellent description of the Royal Navy's challenges in dealing with a submerged threat in his monograph "Forward…From the Sea into the Torpedo Danger Zone" but it is best summarized by John Benedict when he states that the ASW campaign of this naval engagement was more of a "crap shoot than an exercise in sea control."[22] The reasons for this assessment are varied but the end result is that the Royal Navy, keenly aware of the submerged threat, allowed a Type 209 diesel submarine to stay in the operating area for over a month while expending over 150 depth charges and torpedoes on false sonar contacts and never held contact with the actual submarine.[23] Additionally, the Royal Navy could do nothing to stop two documented attacks from the Argentinean submarine that failed to sink British ships only due to onboard technical difficulties and defective weapons.[24]

The failure of the Argentine submarine to successfully carry out any attacks seems to support Till's assertions that the diesel threat is limited based on the capability of countries to actually maintain a useful force. However, in the Falklands war we see that the submarine does not need to successfully attack any ships to create a problem for the operational commander. When the force is offensively minded concerning ASW (i.e. focused on detection, location, and elimination) by merely surviving the diesel submarine creates doubt in the crew of the surface ships and more importantly a drain on the assets available to the Joint Force Commander. The British required over 20 helicopters and 10 surface ships to deal with the threat of the Argentine submarine.[25] While many ships in the U.S. Navy serve as multi-mission platforms, capable of simultaneously executing numerous tasks, the theater commander can ill afford to allocate a similar number of resources as the British and have no result to show for it.

The U.S. Navy continues to decrease in size and therefore the sheer number of assets available for what has traditionally been an asset intensive form of ASW will continue to decline. Furthermore, the assets utilized by the Royal Navy in the Falklands were only tasked with ASW and conducting an Anti-Air War. Two tasks that are certain to be the bare minimum expected of any U.S. Navy task force in charge of force projection ashore.

Trends

ASW has always been an asset intensive undertaking. The research indicates that, while there is no specific declaration by the U.S. Navy, key personnel within the organization realize the asset intensive nature of ASW and are working to leverage perceived superior communications capability and technology against the diminishing number of assets to increase the overall capability of ASW within the fleet. A majority of the literature available indicates that the current trend in ASW is to detect a submerged contact, identify it, and track it utilizing new technology such as some form of distributed sensor field.[26] In Benedict, Rader, and the Cote and Sapolsky report it is acknowledged that technology is the path to success in littoral ASW operations. As Benedict points out, all technology being utilized for ASW, as of 2004, was originally designed for the Cold War and is therefore likely to be ineffective in the new environment of the littorals.[27] This is a true statement but only highlights half of the potential problem. As pointed out by the sound propagation studies of Zurk and Fox, the sound of the diesel submarine may not be detectable regardless of what new equipment is developed to do so.

Significance of Thesis in Relation to Existing Literature

Current literature on ASW is quick to identify the difficulties of operations in the littoral environment. However, the literature fails to identify any new methods of approach when dealing with threat of the diesel submarine. New technologies are often discussed and are, in fact, often the central theme of discourse in current ASW literature. However, there is very little discussion on new methods of employing that technology. Rather than finding new ways to employ new detectors, the U.S. Navy appears to focus on how to build new sensors to do old jobs. For example, the MIT Security Study of Cote and Sapolsky highlights the possibilities of using off-board sensors to detect and track enemy subs to lower the number of manned assets required to track.[28] This reveals the underlying basis of all thought regarding the enemy in ASW: The need to know the enemy's location at all times. This paper evaluates the current ASW problem and its proposed solutions while keeping in mind the scientific studies that show that the enemy submarine may not be detected regardless of the technology or number of assets utilized simply because of the nature of the environment. It is possible that this research paper may generate thought on the possibility of utilizing the new technology being developed not to identify where the enemy submarine is but, more importantly, where it is not.

This review has shown that the U.S. Navy does identify ASW as a continuing threat that must be addressed. It has also reviewed the extensive literature on the advancing technology being used on diesel submarines and the difficulties inherent to ASW in the littoral environment. Finally, a review of the most pertinent ASW engagement to date demonstrates that a diesel submarine need not be proficient to create difficulty for the theater commander. However, the experience of the British in the Falklands highlights the trend of current ASW doctrine towards maintaining a constant track of the enemy.

---

[1] Naval Doctrine Command, "Littoral Anti-Submarine Warfare Concept," http://www.fas.org/man/dod-101/sys/ship/docs/aswcncpt.htm [accessed April 21, 2008] p. 4

[2] Eric Beheim, "New Command to Integrate Navy's ASW Mission," *All Hands* [August 2004], http://findarticles.com/p/articles/mi_m0IBQ/is_/ai_n6361582 [accessed March 23, 2008].

[3] U.S. Department of the Navy, *Anti-Submarine Warfare: Concept of Operations for the 21st Century,* by Task Force ASW, 2004, http://www.navy.mil/navydata/policy/asw/asw-conops.pdf [accessed April 28, 2008],

[4] Kreisher, Otto. 2004. "As Underwater threat re-emerges, Navy renews emphasis on ASW." *Sea Power.* October. http://www.military.com/NewContent/0,13190,NL_ASW_100404-P1,00.html [accessed June 28, 2008].

[5] Geoffrey Till, *Seapower: A Guide for the Twenty-First Century*. [London: Frank Cass, 2004], 246.

[6] Till, 257.

[7] Owen Cote and Harvey Sapolsky. "Antisubmarine Warfare after the Cold War." *MIT Security Studies Program.* http://web.mit.edu/SSP/Publications/confseries/ASW/ASW_Report.html [accessed July 7, 2008], 3.

[8] Cote and Sapolsky, 7.

[9] Joseph Allen McCullough, "The Falklands War: The Air and Sea Campaigns," *Suite101.com* [March 2007], under "History," http://modern-british-history.suite101.com/article.cfm/the_falklands_war [accessed April 28, 2008].

[10] Edward C. Whitman, "Air Independent Propulsion: AIP Technology Creates a New Undersea threat." *Undersea Warfare.* [Fall 2001] http://www.navy.mil/navydata/cno/n87/usw/issue_13/propulsion.htm [accessed June 15, 2008].

[11] CDR Karl Rader, "Forward…From the Sea into the Torpedo Danger Zone: Blue Water ASW Doctrine in Shallow Water" [master's thesis, United States Army Command and General Staff College School of Advanced Military Studies, 1994], 21.

[12] Sherry Sontag and Christopher Drew, *Blind Man's Bluff.* [New York: PublicAffairs, 1998].

[13] Till, 241.

[14] Norman Polmar, "The ASW Shift" *Proceedings* [June 2000], 87.

[15] Charles W. Holland, "Intra- and Inter-Regional Geoacoustic Variability in the Littoral," in *Impact of Littoral Environmental Variability of Acoustic Predictions and Sonar Performance*, ed. Nicholas Pace and Finn Jensen [Bruxelles, Netherlands: Kluwer Academic Publishing, 2002], 73.

[16] Lisa M. Zurk, Nigel Lee and Brian Tracey, "Robust Adaptive Processing in Littoral Regions with Environmental Uncertainty" in *Impact of Littoral Environmental Variability of Acoustic Predictions and Sonar Performance*, ed. Nicholas Pace and Finn Jensen [Bruxelles, Netherlands: Kluwer Academic Publishing, 2002], 515.

[17] Ibid.

[18] Warren L.J. Fox et al. "Environmental Adaptive Sonar Control in a Tactical Setting." in *Impact of Littoral Environmental Variability of Acoustic Predictions and*

Sonar Performance, ed. Nicholas Pace and Finn Jensen [Bruxelles, Netherlands: Kluwer Academic Publishing, 2002], 595.

[19] Ibid.

[20] Till, 257.

[21] Rader, 14.

[22] John R. Benedict, "The Unraveling and Revitalization of US Navy Antisubmarine Warfare" *Naval War College Review.* [Spring 2005],100.

[23] Ibid.

[24] Ibid.

[25] Rader, p. 17.

[26] Benedict, p. 106.

[27] Benedict, p. 100.

[28] Cote and Sapolsky, p. 5.

CHAPTER 3

RESEARCH METHODOLOGY

The secondary questions posed in Chapter 1 can be summarized as a simple question. What aspects involved in ASW are different now, if any? In order to answer this question, a wide variety of topics are analyzed, to include the environmental aspects of littoral operations, the new technology introduced into diesel submarines, the new technology being developed for ASW, and a brief look into history to determine both the difficulty of the diesel submarine problem as well as searching for a glimpse of a solution.

The research methods used for this paper will be discussed shortly, but first it is relevant to determine how the information was obtained and what criteria were used to determine the value of available information. Following the completion of the methodology description, an analysis must be conducted of the strengths and weaknesses of the approach in order to gain an appreciation for the validity of this study.

Steps taken to obtain information

Limiting this study to the use of unclassified publications consequently limits the pool of information to those documents found through open source, such as available theses on relevant topics available at the U.S. Army Command and General Staff College, the U.S. Navy War College, and the U.S. Naval Post Graduate School.

Numerous online sources were used to collect information from a variety of sources. The Combined Arms Research Library at the U.S. Army Command and General Staff College provided access to numerous academic databases for searching the published theses of the service war colleges. Standard, publicly available Internet searches through Google and Yahoo were done to procure articles from the Naval War College Review and publications from other esteemed institutions such as the Massachusetts Institute of Technology and Johns Hopkins University.

Research Criteria

The ASW problem is a complex, multi-faceted issue that must be looked at from numerous angles in order to determine the fundamental mindset utilized in the further development of tactics and techniques. In order to discern the root of the current paradigm for thinking in ASW, research was conducted in the areas of current diesel submarine technology and proliferation, current U.S. Navy advances in ASW including technology and tactics, environmental factors of the littorals that might affect ASW, and a review of historical engagements involving submarines and surface ships, specifically the Falklands War.

The Falklands War is specifically researched due to its having occurred in the Cold War and that it concerned a modern diesel submarine against a surface action group that was aware of its presence. Initial research looked into the lessons of World War II as the last incident of large-scale submarine warfare. While this research provided many anecdotes regarding the mental effect the presence of a submarine could have on the crews of surface ships, these battles occurred using equipment that is vastly inferior to that used today. World War II sonar technology, number of warships available, and design of submarines themselves were all in their infancy during the battles of World War II. The Germans had developed the Type XXI submarine, the forebear of modern hull design, by the end of the war but it saw no significant action. The disparity between technology available to the navies of World War II and today make any comparison regarding tactical uses a matter of academics with no real, viable application to the ASW battle of today.

Research Methodology

To answer the questions posed in Chapter 1 and therefore the ultimate question of this paper, four main areas of discussion are analyzed: the current state, as well as the derivation, of ASW tactics in the U.S. Navy, the changes in diesel submarine technology, and the changes in the operating environment for the U.S. Navy. Finally, an analysis of the current techniques of ASW against the capabilities of the enemy and the effects of the environment is conducted with the purpose of determining if any changes in the current approach to ASW are needed, and if so, what they may be.

Strengths and Weaknesses of Methodology

The methodology utilized in this paper is sound, but possesses both strengths and weaknesses. The strength of this methodology is in its analysis of all aspects of conducting ASW, from technology to tactics, while keeping perspective of all players. This paper will maintain an unbiased approach, neither trying to prove surface capabilities or submarine capabilities as the superior weapon.

The primary weakness in this method is the need to keep source documents at the unclassified level. By limiting the amount of source documents, the paper is by default not taking into account the most up-to-date advances in technology and tactics utilized by the U.S. Navy. This weakness is overcome by the use of numerous open source documents that identify the mind-set of the people developing the technology and tactics. This understanding of mind-set is the key for this analysis because this paper is not meant to be a thorough discussion of the ship-level tactics employed in ASW. Instead, this paper is an analysis of whether or not the beginning steps of ASW development are occurring from the correct frame of mind. A second weakness to this paper is the lack of empirical evidence available. Again, due to the classification levels required there is simply no data available to quantify whether or not the current tactics employed by the U.S. Navy are effective or not. There is a risk that the recommendations that come out of this paper may already be widely known by the ASW development community and already be placed in action. However, this risk can be considered minimal because, although the specifics of the tactics, techniques, and procedures used by the U.S. Navy may be classified, the guiding principles of ASW are not. That is to say that the direction that ASW is taking can be determined through unclassified reports and commentary on the state of the U.S. Navy as seen in publications such as the Naval Institute Review and others.

The research methodology of this paper takes place in four parts. Current ASW tactics of the U.S. Navy are analyzed, to include the basis of current tactics and the emphasis of development for future tactics. A brief case study of the Falklands War is conducted in order to provide the reader with a reference point for the follow-on discussions of submarine and surface vessel capabilities. Advances in technology for diesel submarines are discussed as well as the environmental factors that will affect both diesel submarine operations and the ability of other forces to detect those operations. The remaining chapters of this paper will answer the primary and secondary questions of Chapter 1. Conclusions will be drawn by analyzing the answers to these questions to determine the need to change the fundamental view for conducting ASW operations and the recommendations for future design of ASW operations within the U.S. Navy.

CHAPTER 4

THE REALITY OF THE CURRENT ASW PROBLEM

As the world focuses on land centric warfare in Iraq and Afghanistan, it is easy to dismiss the ASW threat as minimal in an era where sea superiority is all but assumed in every engagement. However, superiority on the water is all but assured and the relative dominance of the United States Navy may be weaker than previously thought, as evidenced by the inability to curtail pirate activities in the Gulf of Aden.[1] Continuing the assessment of the current state of ASW will require reversing the order of discussion from previous chapters. In this chapter we will first discuss the actuality of the ASW threat in the modern operating environment, and then discuss the technology and characteristics of the environment that make the problem what it is. Finally, we will evaluate what is currently being done to mitigate the ASW threat and its effectiveness.

The Falklands War

The 1982 Falklands War erupted in a small island chain 400 miles east of Argentina. British rule of the Falklands had been in dispute for over 150 years, and when the Argentine government landed a small force on the East Falklands, the United Kingdom responded by sending a strike force 6000 miles south to reinforce their claim to the island.[2] It is an engagement useful to our study because it is the last sea battle in which torpedoes were fired in combat and effectively demonstrates the havoc a singular diesel submarine can wreak during littoral operations.

The Argentines developed a sound strategy based on a strike from carriers, surface ships, and submarines. Unfortunately for the Argentine Navy, weaknesses in hardware for both surface and submarine weapons and fire control led to their resounding defeat. The British submarine threat was comprised of three SSN's and a conventional diesel submarine.[3] The numbers of submarines used by the British were never discovered at sea by the Argentines. Instead, they discovered the presence of submarines through the press, as Prime Minister Margaret Thatcher made a public announcement of what assets Great Britain was sending to defend the Falklands.[4] The Argentine Navy was never able to detect a British submarine until the HMS Conqueror sank the cruiser General Belgrano with two torpedoes.[5] Concerned by the loss of a cruiser from an enemy they could not detect, the Argentine Navy was recalled to Argentine territorial waters and rendered ineffective for the remainder of the conflict.[6]

The British held the upper hand in submarine operations with 3 SSNs to Argentina's two SSKs, with one confirmed kill, but the UK did not fair any better in the ASW war. This submarine comparison of the two navies is important to note because conventional wisdom states that the best asset to hunt a submarine is another submarine. This is certainly true given the difficulties of sound propagation in the littorals but the numerical advantage of three to one did nothing to aid the British fleet in curtailing the efforts of the Argentine SSK.

Admiral Woodward, an experienced submariner, was the commander of the British Expedition to the Falklands. His arsenal consisted of over 10 frigates and destroyers, each equipped with a helicopter, and two carriers carrying 18 Sea King helicopters.[7] His threat was one diesel submarine. The Argentines had two operating diesel submarines, the Santa Fe and the San Luis, but the Santa Fe was damaged when she ran aground while being used to ferry fuel to South Georgia Island.[8] This left only the San Luis to fight the British fleet.

Admiral Woodward, a career submariner, was obviously familiar with the capability of any submerged threat and focused the ASW effort of his fleet in keeping enemy submarines from interfering with the Anti-Air Warfare (AAW) screen his ships needed to maintain to support troops on the island.[9] This juggling of missions is indicative of the requirements of today's Joint Force Maritime Component Commander (JFMCC). Fleets do not operate in areas to hunt submarines. They operate to project power ashore and assist in defending those forces once they are ashore. However, as Admiral Woodward discovered, when threatened by an unseen enemy, ship commanders will default to the ASW missions and shoot anything that looks like it might be the enemy in an effort to strike first. For example, after the HMS Sheffield had been hit by an Exocet missile, the HMS Yarmouth broke off assisting in the firefighting to track down a sonar contact that was believed to be a torpedo in the water.[10] Admiral Woodward clearly relates the confusion of the moment:

> "*Yarmouth* thought they heard a torpedo in the water and broke off to try and find the submarine that had fired it. [They found nothing]. Then it happened again. And again. All together they detected nine torpedoes that afternoon. Sometime later we deduced that the propeller noises they kept hearing on the sonar had been from the outboard motor, which was buzzing around *Sheffield* helping to fight the blaze. *Yarmouth's* commander could not believe this at the time."[11]

This rash action to an unconfirmed sonar contact is indicative of the British approach to ASW for the duration of the conflict. All together, it is estimated that over 200 pieces of ASW ordnance, including depth charges and torpedoes, were fired during the Falklands campaign. The San Luis was never destroyed. Some may point to the fact that the British lost no ships to submarine attack as vindication that the aggressive pursuit tactic of ASW is effective. This vindication would be misplaced because the San Luis actually fired upon British ships three separate times.[12]

Weapons malfunctions and faulty fire control systems are all that kept the British from losing four ships. There is more to learn from this engagement than the fact that the British owe the lives of numerous sailors to faulty, aging Argentine equipment. Following each attack by the San Luis, the British counter-attacked with vigor, utilizing depth charges and torpedoes. Following each attack, the San Luis was able to escape unharmed and operated for a total of 36 days off the coast of the Falklands.[13]

The lessons from the Falklands are numerous, including: the utility of the diesel submarine in coastal defense, the ineffectiveness of current sonar sensors for accurately identifying submarines in shallow water, and the devastating effect of one successful submarine attack.   The answer to the question, "Is the diesel submarine still a viable threat to a surface fleet?" is a resounding, "Yes!" The next, and most obvious, question is then, how many countries have diesel submarines that might be considered a threat to *the U.S. Navy* surface fleet?

Is there really a threat?

Over 40 countries, excluding the United States, operate submarines, both nuclear and conventional.[14] The total number of submarines this represents is somewhere between three and four hundred. However, of this number over seventy-five percent are estimated to be modern design with technology of the 1970's or later integral in the design.[15] The submarines themselves are not the threat the U.S. Navy is concerned with. The concern is that those countries doing the selling, such as Germany, France, and

Sweden, are increasingly willing to sell cruise missile systems as part of the deal.[16] The threat of a missile attack from an unseen opponent can, as seen in the Falklands, have an incredible effect on operational planning of any fleet commander. In addition to the conventional threat of a cruise missile to a surface fleet, there is the possibility of fitting missiles with WMD or, as is reportedly being done by Israel, fitting cruise missiles with nuclear tips for attacks on land-based targets.[17] Finally, to end all doubt as to the capability of the diesel submarine against a surface fleet, the U.S. Navy has engaged in numerous exercises with diesel submarines since the mid 1990's. South African Daphne-class, Chilean Type 209's, Australian Collins Class, and other conventional submarines have acted as enemies against surface strike groups with great effect, often penetrating defenses and conducting simulated attacks on high value targets, including aircraft carriers, often without being detected until signaling their attack. [18] However, as enlightening as this information is, it does not necessarily answer the question of who might threaten the U.S. Navy, given that all our practical data points are, of course, against allied adversaries that benefit to some extent from training provided by the U.S.

Geoffrey Till opines that the diesel threat is minimal because not many countries can afford to maintain a credible submarine threat.[19] The analysis of the Falklands War, as well as the discussed exercise data, demonstrates that any country with a diesel submarine, even a poorly maintained one, can cause significant damage. To point to the failures of the Argentine fire control as a case-in-point justification of Till's statement that it's expensive to maintain an effective submarine forces is to rely on a crapshoot to determine the success of an operation. However, Till's statement is not without merit because maintaining the training, equipment, and personnel of a submarine force is an expensive proposition that not many countries can reasonably afford. The issue is not that most countries cannot afford it. The issue is that the countries that *can* are in the areas considered as the current operating environment for the U.S. Navy.

The U.S. Navy is arguably the only force capable of global presence and consequently the operating environment can reasonably be called anywhere in the world. While the U.S. Navy may need to maintain a global presence, the chance for a global conflict is remote. More likely than not, intervention will be required in isolated areas of historic conflict between the U.S. and other Nation states. In this perspective, the largest threats to the U.S. would be North Korea, China, Iran, and a resurgent Russia.[20] All of these countries have a formidable naval presence and all of them have a submarine force. As Admiral Fargo once testified to Congress, "250 submarines call the Pacific home – but only 30 percent of these submarines belong to allied nations."[21] In their MIT Security Studies conference, Cote and Sapolsky provide a clear answer to how a conventional submarine could possibly pose a threat to American ASW power: diesel subs are better now then they have ever been.[22]

How good are the new subs, really?

Russia's submarine force decreased dramatically following the end of the Cold War in coinciding fashion with the implosion of the Russian economy. Recently, the Russian economy has shown a resurgence and it has coincided with a resurgence in shipbuilding, not just for Russia's own fleet but for export to virtually any country willing, and able, to buy. Russia's most capable KILO submarine, the Project 636 Class, is among the quietest submarines in the world.[23] It is capable of firing heavyweight, wake homing torpedoes as well as submerged launch, anti-ship cruise missiles.[24] It is capable of 20 knots when submerged and has an estimated endurance of 45 days at sea. The capability of this submarine is a concern in and of itself; however, of more concern is that as of 2006, the Chinese PLAN has acquired 8 of these submarines.[25] The Type 636 is a formidable enemy but it is not equipped with Air Independent Propulsion (AIP) technology, which makes it susceptible to the normal operating patterns of most conventional submarines. Namely, the battery must be recharged at regular intervals by using a diesel engine that requires air from the outside world for combustion. Although the battery capacity of the Type 636 is certainly better than previous generations, which would allow it to run longer between charges, the requirement to recharge with outside air means that the Type 636 is still detectable, and vulnerable to attack, at frequent, regular intervals.

Although the Type 636 is currently not configured with AIP technology, Russia does have an AIP design capability. In the fall of 2006, Russia's Rubin Design Bureau, in conjunction with an Italian design firm, announced plans for the S1000: a 1,000-ton, 56-meter, fuel cell powered submarine capable of carrying both heavyweight torpedoes and cruise missiles.[26] It can be assumed that as demand for AIP-enabled submarines increases, the likelihood that Russia will begin exporting this technology will also increase in order to maintain market share as one of the world's largest suppliers of submarine technology.

Fuel cell technology is only one of several forms of AIP utilized in submarines today, but it is the most popular. Fincantieri, the Italian firm that worked with Russia on the S1000, also worked with Germany's ThyssenKrupp Marine Systems in development of the Type 214, an export version of Germany's Type 212.[27] The Type 212 and 214 fuel cell system uses a fuel cell system that combines pressurized hydrogen and liquid oxygen to create heat, electricity, and water.[28] This fuel cell system is similar to what ThyssenKrupp uses in the Dolphin-class submarines they are building to deliver to Israel. Eight Type 212's have been ordered or delivered to Italy and Germany and Type 214's are currently being, or have been, sold to Greece, South Korea, Pakistan, and Turkey.[29] Fuel cell technology does not improve overall speed of a submarine, but it does provide an increase in the amount of time that a submerged submarine can run at higher speeds. This is significant when one considers the fact that energy demands for high-speed operations are over 50 times greater than they are for normal cruising speeds of 2-3 knots.[30] A submarine with old fuel cells could evade at 20 knots for only an hour or two but a newer submarine with new fuel cells may be able to run for 4 hours, greatly increasing the overall search area that must be covered by the hunter if contact is not maintained with the evading submarine.

Fuel cell technology is currently the AIP method of choice, but it is followed closely by the MESMA system designed by the French company DCNS.[31] The MESMA system (Module d'Energie Sous-Marin Autonome) is a closed-cycle steam engine that generates electricity from a turbo-alternator powered by steam that is generated by burning diesel oil and stored oxygen.[32] This system is currently offered by DCNS on the Scorpene and Agosta-90B class submarines, which have been exported to Portugal, Spain, Chile, India, Pakistan, Malaysia, and South Africa.[33] The advantage of the MESMA engine over fuel cell technology is the capability to recharge batteries while still submerged. This obviously changes the tactics for hunting a submerged conventional submarine because now batteries can be recharged while on the run. If the search area was difficult to calculate with just fuel cell technology, it is now almost impossible to effectively determine, or search, an area when the need to slow and recharge cannot be estimated or identified. The MESMA system provides an additional rub when evaluating threats to U.S. Navy dominance because it is a modular system that is capable of being retrofitted to any class of submarine.[34] DCNS is specifically looking to market the MESMA technology to South American and Asian countries whose submarines are coming due for overhaul.[35]

The last, and least popular, of AIP designs is the Stirling cycle used by Sweden in its Gotland and Sodermanland-class submarines. The Stirling system burns liquid oxygen and diesel fuel to either recharge the ships batteries or power the main engine outright.[36] The Stirling system can extend the submerged time of a submarine from days to weeks because the system burns liquid oxygen and diesel in a combustion chamber that is at a higher pressure than the sea thereby allowing it to exhaust overboard while submerged.[37] The nearly impossible search area created by submarines using of extended life fuel cells is now incomprehensible with the use of Stirling AIP. Fortunately for the U.S. Navy, Stirling AIP is relatively new, and expensive, to the AIP marketplace and has only been used on Swedish and Japanese submarines.

These AIP technologies greatly increase the submerged stay time of a conventional submarine, but to what effect? The short answer is that these technologies provide countries with the type of submarine capability that they need. Take the example of Israel, who purchases AIP enhanced Dolphin class submarines from Germany. Israel is not a global maritime power and does not need the ability to send a submarine across oceans to exert its maritime influence, so a nuclear vessel is an impractical choice both in terms of cost and in performance capability. A nuclear submarine is large, the Virginia class is 100 meters long and weighs 7800 tons, and incapable of performing the missions Israel needs, which is to come in extremely close to shore to drop off special forces, conduct reconnaissance, support land operations, and hide on the bottom if need be.[38] For this purpose, a conventional submarine is exactly what is needed and no more. The difficulty this submarine presents to the surface ASW force is an enemy capable of long periods of slow speed operation, irregular requirements for recharging batteries, and enhanced technologies in sound silencing when they do recharge. ASW forces still have at least one aspect working in their favor: the enemy still has the issue of maintaining high speeds for long periods during an evasion, but that is supposing the ASW force can force the evasion by finding the enemy in the first place. This can be a daunting task depending on the location the surface fleet is forced to look in.

Did someone turn up the stereo?

The current operating environment of the U.S. Navy is not specifically defined in the Cooperative Strategy for 21st Century Seapower, but two specific areas are highlighted: the Western Pacific and the Arabian Gulf/Indian Ocean.[39] The U.S. Navy is being asked to operate in a littoral region in order to effectively support the joint mission. The littorals of the world are a decidedly different environment than the open ocean, deep-water environs of the Cold War ASW battlefield. Specific features that are different include physical, geospatial, and biological parameters. However, a brief description of basic sonar theory must be given before the differences in environment can be appreciated.

This paper is not meant to give the reader an in-depth understanding of sonar, how it works, and how best to employ it, but a few of the basics of sonar, and submarine detection, are necessary to appreciate the difficulties faced by navies operating in the littorals of the world. First, let us make the assumption that submarines do not use active sonar. This means that the only noise a submarine makes is from the operation of equipment onboard the ship resonating through the hull. Consequently, there are only two ways to detect the submarine when submerged, either by hearing the sound the submarine emits or by hearing the return of an active sonar signal transmitted in the water "pinging" off the hull, as is often depicted in movies. If the ocean were completely uniform in temperature and salinity, as well as very quiet, hearing either one of these sounds would be very easy. As was discussed in Chapter 2, the basic ability to detect something is based on how much louder the source, either the submarine or the return ping, is compared to the surrounding environment. In addition to environmental noises, there is the aspect of environmental effects on sound propagation to consider. Sound waves travel faster in water than they do in air because the molecules of water are closer together, but much like air, they are affected by things like temperature and salinity. As water temperature increases, sound travels slower. When there are definite, sudden changes in temperature, the "layer" often referred to in movies, sound will bounce of the temperature change and travel back into the region from whence it came, much like a ball bouncing off a wall. A similar effect is seen when looking at salinity, but on a smaller scale. With this basic understanding of sound properties in water complete, an examination of the littorals can begin.

The littorals of the world are drastically different from the open ocean, but no more so than in regard to its physical features. The littorals are close to shore and this causes an increase in environmental noise due to waves breaking on the shore, waves crashing on man-made structures, surface noise from waves reflecting off the bottom, and the passing of commercial and recreational craft. This causes an increase in the environmental noise that the singular signal emitted by the submarine must be detected in. The comparative shallowness of the ocean bottom creates a high incidence of bottom reflection that attenuates any signal from a submarine at a much faster rate than the open ocean where the signal can travel for miles before interacting, and being absorbed by, the bottom or any other object.[40] Conversely, any active sonar signal employed to detect a submarine operating in the littorals would suffer from the same rapid degradation in signal strength resulting in a limited range and effectiveness of active sonar.

The littorals also possess the unique characteristic of mixing fresh and salt water at the mouth of rivers and streams that empty to the ocean. This mix of fresh and salt water creates a dynamic salinity that affects the speed of sound traveling in water, causing it to reflect away from changes in salinity much the same way that it reflects away from temperature changes. There is also a temperature change that often accompanies these salinity changes, magnifying the effect that mixing sources of water has on sound propagation.

Geospatial concerns in the littorals are concerned about the effects of the topography of the bottom. There has already been a brief discussion of the effect that a shallow bottom has on sound propagation but that is not the sole concern of geospatial effects. Differences in bottom make-up, such as clay or soft sand, will affect how much, or how little, sound reflects off the bottom. In a sandy bottom, a submarine may make a noise and that noise will never be heard because the bottom, instead of reflecting the sound outward, absorbs it. While this presents a difficulty in detecting submarines, it is something that could be accounted for if the make-up of the bottom is known. Unfortunately, the amount of data required to accurately account for bottom make-up is not something the U.S. Navy currently has for a world wide operation, and the time required to collect accurate data for modeling is prohibitive in the short-fuse operational environment of the military.[41]

Marine life is sparse in the open ocean, deep-water environment of the Cold War ASW problem. By necessity, marine life lives closer to shore, in the shallow, warm water of the littorals. This presents another series of challenges to the ASW problem, aside from the numerous issues regarding the use of active sonar and its possible effect on marine mammals. Chief among these (and the only point to be discussed in this paper) is the effect on environmental noise caused by marine life. Simply put, almost every living creature makes some sort of noise either for communication or simply through the act of living. Every sound adds to the total level of background noise the ASW force must now try to detect the quiet submarine signal through. The room of people analogy most accurately portrays this problem. In a room full of people, the louder everyone is the harder it is to hear the one person whispering, even if he's standing right next to the person listening.

The myriad of difficulties presented by attempting aural detection of a submarine in the littorals presents a daunting task to the ASW forces of the U.S. Navy. In the next section, the actions the U.S. Navy is taking to overcome these challenges will be more thoroughly discussed but for the present we must acknowledge the compiled effect of these difficulties. Consider an audible signal generated by a machine with sound quieting technology inside, which is coated with a sound absorbent material, and operating in an environment that is significantly louder due to interference from the environment, marine life, and man-made machinery. The paths that signal travels is then subject to natural factors of bottom topography and composition, which are subject to change from location to location, as well as factors of temperature and salinity which are subject to daily if not hourly change. To be able to accurately detect that signal would require an advanced sonar system of superior capability and computing power. The sonar system needed to detect a signal would need to be able to accurately detect a discrete signal coming from a submarine while constantly measuring the surrounding environment and making calculations to adjust its modeling of sound propagation in order to accurately provide a bearing and range. Add on to this requirement the fact that in order to be of use to the surface fleet commander all of this must occur rapidly enough to exploit a sound transient from a submarine that often occurs only once in order to cue assets to the location of the submarine. This technological requirement will be discussed further in the next section, but suffice to say that it does not exist at this time. Consequently, detecting a submarine through the sounds it generates only is almost impossible. However, the easiest way to overcome this would be to open your eyes, which is why visual detection is still considered one of the primary methods of detecting submarines.[42]

Visual detection relies on the submarine being at periscope depth or surfaced. For the purposes of this paper, we will not evaluate visual detection of a surfaced submarine because when considering how to best defend a surface group from submarine attack you must realize that no submarine will attack while surfaced because it negates its chief advantage, that of surprise. That being said there exists numerous ways to detect a submarine visually. Chief among these is detection of the periscope or other masts above the horizon. Despite all the surface action caused by waves, the horizon line of the ocean is relatively flat and a periscope or other mast extending 5 to 6 feet above the surface is readily visible to the naked eye or, even better, to the scan of radar in the area. In calm seas, masts going through the water leave a "scar" on the surface that can trail behind the submarine for miles. In water that is clear enough, such as the Caribbean, submarines can be plainly seen at periscope depth from overhead. While a submarine at periscope depth is very vulnerable, to exploit that vulnerability requires two things, a searching vessel with enough persistence to stay in the area to catch the submarine at periscope depth and an enemy submarine that needs to come to periscope depth. With the previously discussed use of AIP technology, the need for submarines to come to periscope depth is dramatically lessening. The U.S. Navy certainly has the persistence, and the mission, to stay in a given area long enough to detect a submarine, but whether it has the capability to actually detect the submarine is another issue altogether.

<u>How do you fight an enemy you cannot see with equipment that cannot hear?</u>

To identify how the U.S. Navy intends to fight the undersea war one need only to go to their website and view the 2004 ASW Concept of Operations. The ASW CONOPS, as it is often referred to, is designed to provide a loose road map for the fleet to follow as it develops capabilities to maintain the advantage in the ASW war anywhere in the world.[43] It also reveals the fundamental mind-set of the U.S. Navy regarding how to find submarines.

> "As we sail deeper into the 21st century, Anti-Submarine Warfare (ASW) will remain a core mission area for the United States Navy. Execution of that vital mission will be critical to protecting the strategic speed and operational agility of

> joint and coalition forces across the largest maneuver space in the world – the sea. The ASW capabilities we possess today when confronting potential enemies are based largely on skills developed during the Cold War. To sustain our operational advantage, we must develop additional skills, implement them in an innovative manner, and rapidly leverage advanced technologies to swiftly defeat enemies wherever they may be found."[44]

There are two important facets of the previous statement: current ASW capabilities are based on those developed during the Cold War and the need to leverage technology to defeat enemies.

The ASW capabilities of the U.S. Navy, from technology to doctrine, are all based on lessons learned from the Cold War.[45] This is to be expected since the Cold War was largely waged through the submarine forces of the United States and the Soviet Union. Following the collapse of the Soviet Union, and their submarine force with it, the U.S. Navy no longer had an identifiable submarine threat to prepare for but they had a database of lessons learned and masses of equipment designed to hunt their old foe, so it only makes fiscal sense to find ways to use the equipment available to fight the new enemy, the diesel submarine. The problem begins once it is determined that the fact that both enemies are submarines is the sole common trait between them. Equipment can only be updated, processing algorithms altered, and tactics modified to a certain extent before the square peg is destroyed by the repeated attempts to push it through the round hole.

The U.S. Navy has had success against diesel submarines with its Cold War technology in some exercises, but this could be attributed more to the relatively high levels of noise emitted from the subs than from the skills of U.S. operators using old technology. In fact, as late as 1998, one U.S. submarine commander noted that using tried and true passive detection methods from the Cold War were ineffective against quiet, diesel-electric submarines.[46] The use of active sonar has been proven effective against diesel submarines, but only when the conditions are favorable to the use of the system, and the analysis of whether the conditions are favorable or not is one that must be continually evaluated by the operators.[47] The U.S. Navy has responded to the increase in diesel submarine capability by investing in technological development for new detection devices.

As previously discussed, the ASW CONOPS is clearly centered on the need to leverage technological capability as a means to defeating the diesel threat. This is in direct contrast to the findings of the Cote and Sapolsky Security Conference study of 1998 where it was determined that having capable ASW systems does not mean you have an effective ASW capability.[48] ASW capability comes from effective training of operators who can rapidly assess the data provided them to make a coherent, accurate judgment. The ASW CONOPS recognizes the need for training to be a cornerstone of establishing capability but the CONOPS is flawed in its very foundation. The CONOPS is fundamentally based on the idea that commanders in an area will get accurate, almost continuous, information on enemy submarines from the network of sensors that the CONOPS states may number in the thousands.[49] Access to information of this volume and at this rate is unprecedented, and currently unavailable. Consequently, the current tactics of ASW are similar to those of the Cold War.

In the mid 1980's, the enemy was the quiet Soviet SSN. ASW prosecution would often begin with a cueing event, either a satellite photo showing the boat as missing from the pier, or the detection of a transient from the sub by an ocean surveillance system like the Sound Surveillance System (SOSUS). Maritime patrol aircraft would then be scrambled to located the sub and stay in contact until control could be handed off to a more persistent platform such as a submarine or surface ship. An all-hands effort would then commence wherein the Soviet submarine would be hounded by friendly submarines, surface ships and helicopters until the enemy returned to homeport. The core of this tactic can be identified as locate and keep contact.[50] The main difference between this tactic and current diesel tactics is the idea that we will locate and destroy, hopefully in a rapid manner.

The rapid manner in which the ASW CONOPS hopes to dispatch enemy submarines is not just a hope of those who created it; it is a necessity of the U.S. Navy if they are to effectively support joint operations. Regional conflicts the U.S. Navy will find itself in are likely to be time-late events with little time for preparation of the battle space. The U.S. Navy must be ready to rapidly deploy to any location in the world and establish sea control of the region in a rapid fashion in order to support the larger effort of the joint force. The old adage is that ASW stands for “awfully slow warfare” because it simply takes time to effectively search an area for a submarine and declare it sanitized. The new CONOPS hopes to use a veritable sargassum of networked, unmanned sensors that will relay data back to the fleet so they can quickly establish dominance in an area, hopefully before the enemy diesel can even arrive.[51]

In an interview, Adm. John Nathman, Vice Chief of Naval Operations, described the differences between old and new ASW methods as being the difference between the attrition warfare of the Cold War and a new method where “we don’t necessarily have to kill submarines. We just have to be able to operate in the environment to our satisfaction."[52] What exactly is required to meet the satisfaction of the U.S. Navy is not clearly defined, but all indication in open source point to it being the ability to destroy any enemy submarine that threatens operations whenever the ASW commander decides to do so. This desire to destroy on command is, once again, predicated in the idea that the ASW commander will have continuous positional data of all enemy submarines and highlights the distance between doctrinal idea and technological reality.

The Doctrine-Technology Gap

The last page of the ASW CONOPS defines the operational principles and capabilities that the U.S. Navy intends to develop to bring their vision of 21st Century ASW to fruition. The first of these is "Battle Space Preparation and Monitoring" where the fleet will develop a comprehensive understanding of the undersea environment, to include a thorough understanding of enemy capabilities, tactics and vulnerabilities.[53] This skill will provide the most dividends for winning the ASW battle. Supposing that the technology to provide constant contact of the enemy submarine is developed, unless the commander has the good fortune of an unlimited resource of said sensors it does him no good unless he knows where to best place them for maximum effect. As Sun Tzu said, an understanding of your enemy's practices is essential to maximizing the use of your resources.[54]

The second capability defined is one of "Persistent Detection and Cueing." The capability of sensors to autonomously adjust to the environment, detect and relay information at the rate and volume required has yet to be developed, much less the network to actually relay the data. This is arguably the largest hurdle to successful implementation of the CONOPS. The next capability is listed as "Non-Traditional

Methods" but the definition accompanying it does nothing more than discuss the new technologies that will be needed to complete the second capability. To further highlight the reliance on non-existent technology, two more principles, "High Volume Search and Kill Rates" and "Defense-in-Depth", are also defined by the use of "agile technology" and integrated, networked sensors.[55]

"Combined Arms Prosecution" is the last principle of the CONOPS, and the one that seems the most promising, after understanding the enemy. At first glance, it does not seem apparent how the Army or Marine Corps could contribute to the ASW fight however they can be immensely helpful in removing the support base of enemy submarines. Regardless of how long submarines can operate based on fuel cells or Stirling AIP, they must bring on supplies of food, water, and diesel fuel. By isolating the source of these supplies, or even taking over bases before submarines can get underway, the land forces can almost negate the effectiveness of their submerged stealth.

The principles of combined arms and battle space preparation are the pieces of the ASW CONOPS that point to a solution that may be more viable in the near term. When the concept of operations has six principles of which four are dependent on a technology that does not exist, there is a danger that the U.S. Navy may find itself in a similar position as the U.S. Army is with the Future Combat System, dedicating billions of dollars to develop unproven technology while its troops go into combat without the equipment needed to win the current operation. This is not to say that the required technology should not be developed. If the capability can be created it would place the U.S. Navy at an almost insurmountable advantage in ASW. However, until that technology is developed, the U.S. Navy must do something other than rely on Cold War tactics in the hopes that the sensors will arrive in theater before the enemy torpedoes do.

This chapter has highlighted the effectiveness of the diesel submarine as a combat platform. The Falklands War demonstrated that even a poorly manned, poorly maintained diesel submarine can have a tremendous effect on operations for a fleet commander and that, even without actually sinking a ship; by simply remaining undetected the submarine affects the fleet commander's ability to exert sea control. The proliferation of diesel submarines, combined with the advances in AIP technology highlighted the very real threat that diesel submarines pose to the U.S. Navy's dominance in the maritime domain. The inherent difficulties of detecting an advanced submarine due to the environmental features of the littorals were thoroughly examined, as well as the U.S. Navy's current path to overcoming these difficulties through the use of technologically advanced sensor networks. In the final chapter of this thesis all of the data will be summarized in an attempt to identify if the U.S. Navy is on a path towards successful maintenance of ASW dominance and if not, what may be done about it.

---

[1] Barbara Starr, "U.S.warship can't stop pirates off Somalia," CNN.com, http://www.cnn.com/2007/WORLD/africa/06/06/pirates/index.html [accessed April 28, 2008].

[2] Joseph Allen McCullough, "The Falklands War: The Air and Sea Campaigns," *Suite101.com* [March 2007], under "History," http://modern-british-history.suite101.com/article.cfm/the_falklands_war [accessed April 28, 2008].

[3] CDR Karl Rader, "Forward…From the Sea into the Torpedo Danger Zone: Blue Water ASW Doctrine in Shallow Water" [master's thesis, United States Army Command and General Staff College School of Advanced Military Studies, 1994], 12.

[4] McCullough.

[5] Rader, 12.

[6] Ibid.

[7] Ibid.

[8] Lawrence D. Freedman, "Reconsiderations: The War of the Falkland Islands, 1982," *Foreign Affairs* [Fall 1982], http://www.foreignaffairs.org/19820901faessay8299/lawrence-d-freedman/reconsiderations-the-war-of-the-falkland-islands-1982.html [accessed April 28, 2008].

[9] Rader, 14

[10] Ibid., 15

[11] ADM Sir John Woodward, *100 Days: The Memoirs of the Falklands Battle Group Commander* [Annapolis: Naval Institute Press, 1992], 17.

[12] Rader, 15-16.

[13] Ibid, 13.

[14] John R. Benedict, "The Unraveling and Revitalization of U.S. Navy Antisubmarine Warfare," *Naval War College Review* [Spring 2005]:102.

[15] Ibid.

[16] James Clay Moltz, "Global Submarine Proliferation: Emerging Trends and Problems," Nuclear Threat Initiative, http://www.nti.org/e_research/e3_74.html [accessed May 13, 2008].

[17] Ibid.

[18] Benedict, 100.

[19] Till, xx.

[20] Benedict, 103.

[21] Benedict, 100.

[22] Owen Cote and Harvey Sapolsky. "Antisubmarine Warfare after the Cold War." *MIT Security Studies Program.* http://web.mit.edu/SSP/Publications/confseries/ASW/ASW_Report.html [accessed July 7, 2008], 8.

[23] Naval Technology, "SSK Kilo Class (Type 636) Attack Submarine, Russia," http://www.naval-technology.com/projects/kilo/ [accessed July 7, 2008].

[24] Benedict, 102.

[25] Sino Defence, “Kilo Class (Project 636/877EKM) Diesel-Electric Submarine,” sinodefence.com, http://www.sinodefence.com/navy/sub/kilo.asp [accessed July 7, 2008].

[26] Michael Dumiak, “Lurking in the Littorals,” *Defense Technology International* [May 2007]: 27.

[27] Ibid., 25.

[28] Ibid.

[29] Naval Technology, “U212/U214 Attack Submarines, Germany,” http://www.naval-technology.com/projects/type_212/ [accessed July 7, 2008].

[30] James H. Patton, “ASW is Back,” *Proceedings* [February 2004]: 56.

[31] Dumiak, 24.

[32] Ibid.

[33] Nuclear Threat Initiative, Submarine Proliferation: France Export Behavior,” Nuclear Threat Initiative, http://www.nti.org/db/submarines/france/export.html [accessed May 13, 2008].

[34] Dumiak, 25.

[35] Ibid.

[36] Ibid.

[37] Kockums, “The Kockums Stirling AIP system – Proven in Operational Service,” Kockums Shipyard, http://www.kockums.se/submarines/aipstirling.html [accessed October 12, 2008].

[38] Dumiak, 25.

[39] U.S. Department of the Navy, *A Cooperative Strategy for 21st Century Seapower*, by GEN James T. Conway, ADM Gary Roughead, and ADM Thad W. Allen, [October 2007], 9.

[40] Jurgen Sellschopp, et al., “Combination of Acoustics with High Resolution Oceanography,” in *Impact of Littoral Environmental Variability of Acoustic Predictions and Sonar Performance*, ed. Nicholas Pace and Finn Jensen [Bruxelles, Netherlands: Kluwer Academic Publishing, 2002], p. 26.

[41] Ibid.

[42] Royal Australian Air Force, “Art of the Hunter,” http://army.gov.au/news/raafnews/editions/4703/features/feature01.htm [accessed October 14, 2008].

[43] U.S. Department of the Navy, *Anti-Submarine Warfare: Concept of Operations for the 21st Century,* by Task Force ASW, 2004, http://www.navy.mil/navydata/policy/asw/asw-conops.pdf [accessed April 28, 2008], 1.

[44] Ibid.

[45] Benedict, 100.

[46] Steve Ross, “USS BOISE’s 1998 Deployment: SSN Operations in the 21st Century,” Global Security, http://www.globalsecurity.org/military/library/report/1998/uss_boise.htm [accessed October 10, 2008].

[47] Ibid.

[48] Cote and Sapolsky, 7.

[49] Sandra Irwin, “Shrewd Tactics Underpin Navy Strategy to Defeat Diesel Submarines.” *National Defense Magazine* [March 2005]. http://www.nationaldefensemagazine.org/archive/2005/March/Pages/UF-Shrewd_Tactics5844.aspx?PF=1 [accessed September 12, 2008].

[50] Cote and Sapolsky, 5.

[51] Irwin.

[52] ADM John Nathman, as quoted in Sandra Irwin, “Shrewd Tactics Underpin Navy Strategy to Defeat Diesel Submarines.” *National Defense Magazine* [March 2005]. http://www.nationaldefensemagazine.org/archive/2005/March/Pages/UF-Shrewd_Tactics5844.aspx?PF=1 [accessed September 12, 2008].

[53] U.S. Department of the Navy, 5.

[54] Sun Tzu, *The Art of War,* trans. Samuel B. Griffith [New York: Oxford University Press, 1963], 50.

[55] U.S. Department of the Navy, 5.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

> "While there are promising new technical developments, none of them will deliver a transparent littoral ocean or lead to a quantum leap in offshore capability soon."
>
> - VADM (ret.) Albert Konetzni[1]

The road ahead is paved with good intentions

Maintenance of maritime superiority is, and will remain, one of the core tasks of the U.S. Navy. As joint operations move further and further into the littorals of the world, the ability to maintain some measure of sea control is absolutely necessary to ensure success of the mission. One of the key tasks required for the JFMCC to maintain control of the littorals is the ability to effectively deal with the submarine threat. The previous chapters have demonstrated that, without officially stating so, the U.S. Navy recognizes that the capability they currently possess for ASW is based on old technology, old tactics, and is for an old enemy. The current enemy is a grave concern for all fleet commanders and they appear committed to finding a solution to the problem. In his 2005 article in the Naval War College Review, John R. Benedict stated that the U.S. Navy appeared to be "on the brink" of making a firm commitment to the revitalization of ASW based on the creation of a Fleet ASW Command and numerous studies being conducted into methods to leverage the technological prowess of the United States in the ASW war.[2] However, three years later there has been no appreciable increase in the technological capability of the U.S. Navy in regards to ASW. An autonomous UUV has yet to be developed and deployed, no new autonomous sensors capable of analyzing the environment and adapting its search method have been developed, and the networks needed to relay the data have not been established. This, in and of itself, is not an issue for grave concern. A weakness has been identified and a solution has been developed to account for it. The issue at hand is that the U.S. Navy is simply waiting for the production of the items needed for the solution and not doing much else. It takes time to create new technology and field test it so there should be no great rancor over the fact that identified needs have not been met yet. Indeed, based on the information available, there is no sense of urgency for dealing with the submarine threat until the technology is created. Any discussion of new ASW tactics is centered on how to use the technology once it is available in the future. The question that is not being answered is how does the JFMCC win the ASW fight right now?

The U.S. Navy is still functioning around the globe and the proliferation of diesel submarines continues at a rate estimated to double the total number of diesel submarines worldwide by 2010.[3] The U.S. Navy cannot afford to continue applying Cold War technology and tactics to the diesel threat. As VADM (ret.) Konetzni testified to the House Armed Service Committee, "… instead of instilling strict discipline in access missions of mine and anti-submarine warfare, we appear to ignore study after study regarding shortfalls in platforms, training [and] concepts of operations, and have replaced these truly 'transformational', proven methods with a desire to find a 'holy grail'."[4] The crux of VADM Konetzni's argument is that the U.S. Navy is waiting for the silver bullet of technology to arrive instead of focusing on developing new tactics and methods to prosecute submarines in the meantime.

If there were any doubt that the U.S. Navy is relying on old tactics, CDR Perry Yaw points out in a Naval War College thesis that, as recently as 2004, a prosecution of a

Chinese HAN class nuclear submarine in Japanese waters required an entire U.S. P-3 squadron, numerous JDF P-3Cs, a number of U.S. submarines and surface ships, and a T-AGOS surveillance ship equipped with towed sonar arrays.[5] The total length of time for the prosecution lasted two days. The number of assets utilized is indicative of the Cold War need to have positive location on all enemy submarines at all times. It can be argued that all of these assets were allocated by the JFMCC for the prosecution because the training opportunity to track a HAN is not something to be wasted. The issue then is if the ASW forces have had real-world training in using massive amounts of equipment and assets to track they can scarcely be expected to do anything different in the context of a war-time scenario. The adage that you perform how you practice holds true, even for military operations.

What to do then? As was discussed in Chapter 4, two concepts of the ASW CONOPS show the way to developing a CONOPS that is not reliant on technology to be successful and that is to both improve understanding of diesel technology, operating patterns, tactics, and procedures and to integrate the joint force into the ASW fight. By understanding how the enemy must operate the ASW commander can more accurately predict where the enemy **will** operate. This makes it easier for the JFMCC to understand where to place his limited ASW assets so they are in a position to be effective when trying to locate the enemy submarine. Moreover, by understanding the operating patterns of diesel submarines, the JFMCC can determine the area that diesels will likely not operate in. By determining where the enemy is least likely to operate due to tactical disadvantage, the JFMCC makes the problem of defending that much easier. The overall goal of ASW for the JFMCC should not be to know where the enemy submarine is at all times, but rather where he is not. The JFMCC, and therefore the U.S. Navy, must also learn to leverage the capability of the other branches of service when developing an ASW strategy.

The notion that U.S. naval forces can arrive off the coast of a country identified for possible combat actions before the host nation has dispatched their submarines is slightly far-fetched. Acknowledging the news cycle of the 21st century media, high-speed capability of U.S. ships, and slow speed of diesel submarines, it is still a gamble to think a country such as Iran would not dispatch their diesel submarines in anticipation of possible U.S. action. Consequently, the Combatant Commander could have the Joint Force Air Component Commander place enemy submarine bases on the target list and have the submarines, or their base, destroyed before the submarines ever leave port. The Joint Force has many capabilities, combined with the Interagency, to persuade or prevent enemy submarines from ever leaving port that must be utilized in any ASW plan. The idea that the U.S. Navy can maintain constant contact on enemy submarines once they have left port and entered the safety of familiar waters is a fallacy.

The lack of sensor nets described in the ASW CONOPS notwithstanding, the number of forces required to maintain constant contact with an enemy submarine is massive, as briefly evidenced by the story of the Chinese HAN. The JFMCC has limited resources available to him to complete a mission that is likely to be time-critical. The JFMCC can ill-afford to devote assets to the ASW mission that would compromise the ability to complete the strategic goal of the operation. Supposing the JFMCC does grant the ASW commander sufficient assets to keep continuous position data on an enemy submarine the pertinent question becomes, what if contact is lost, or worse, never gained?

Current doctrine, and anecdotal examples, would suggest that the course of action is to commence a wide area search to relocate the enemy submarine. Given the size of the operating area, the size of the enemy submarine, the previously discussed difficulties of identifying a submerged contact in the littorals by aural signal and the possibility that AIP technology will prevent the enemy from risking visual exposure, the chances for a wide area search conducted with limited assets available being successful is minimal at best.

Recommendations

The ASW problem is incredibly complex and this paper is not designed to solve it. This paper is merely intended to engender discussion in the naval community about how to best apply the assets currently available to the problem at hand. The ASW CONOPS is not a foolhardy document whose success hinges on the creation of impossible technology. Quite the contrary, the ASW CONOPS provides a clear vision of the future and rightly determines that technology will give the U.S. Navy the greatest advantage in the fight. However, the technology required will take an inordinate amount of time to invent, test, and field, if it is ever successfully developed at all, and the U.S. Navy is placing its hold on maritime security at risk by not making a concerted effort to determine how to deal with the ASW problem in the meantime.

Clearly, Cold War tactics of identifying the enemy at sea and maintaining constant contact are no longer realistic or feasible. The difficulty of the acoustic environment in the littorals, combined with the limited amount of ASW assets available to the JFMCC, demands that new tactics and doctrine be developed. The JFMCC can no longer afford to keep contact of a submarine that is not an operational or tactical threat to his forces. Rather than attempting to determine where the enemy submarine is at all times, the JFMCC should focus on maintaining a certainty of where he is not. The area of concern should be an envelope around the strike group inside of which enemy submarine weapons cannot reach the U.S. vessels. It is not that the U.S. Navy does not already employ this tactic to some level, but it is recommended that this safety envelope be the focus of the fleet ASW plan, not just one aspect. Abandon the idea of trying to maintain contact on the enemy through the use of a porous surveillance net and instead focus resources and platforms on creating a veritable wall through which the enemy submarine cannot pass undetected. To do this will require fewer assets and an increased knowledge of how diesels operate and what their weaknesses are will enable the JFMCC to determine where best to employ them. Additionally, by understanding the best practices of the adversary, the JFMCC can determine where to best locate his fleet to maximize advantage. It is not enough to simply build a wall around the fleet. The JFMCC must know where to build that wall and by having a foundation of ASW tactics based on understanding the enemy's operations (vice the current method of just finding the enemy) the fleet can be placed on top of the proverbial hill that maximizes the effectiveness of the ASW wall. By learning to maintain security with fewer assets, the ASW commander will be doubly efficient once the technologies being developed under the ASW CONOPS are fully integrated into operations.

By creating a ring of defense the JFMCC, can focus his efforts on completing the task at hand. After all, the JFMCC's responsibility is not to conduct ASW; it is to support the Joint Force in achieving the goals of the Combatant Commander. Consequently, if the JFMCC never has contact with the enemy submarine, either passively or through a submarine attack on his forces, then he has successfully completed his ASW task. ASW, from the JFMCC perspective, should not be about locating and destroying enemy submarines; it should be about ensuring his control of the seas is not adversely affected by the mere existence of diesel submarines.

Conclusion

Anti-Submarine Warfare is a core competency of the U.S. Navy. It has been since submarines were first used as weapons of war and will remain so for the foreseeable future. As the characteristics of the enemy changes, so should the tactics used to prosecute them. The U.S. Navy has defined a clear vision for the future of ASW but the road to achieving that vision is indeterminably long, and something must be done to ensure the maintenance of the maritime superiority that is increasingly an assumption in all theater contingency plans. As the cost of ships, planes, and submarines increases, the number of assets available will decrease. The U.S. Navy will be asked to do more with less but with the same measure of effectiveness, which is never losing a ship to enemy actions. In order to complete this task against a formidable enemy in an unforgiving environment, a fundamental change in how the U.S. Navy approaches ASW must occur. The enemy does not need to be kept from operating undetected at sea. He simply needs to be kept from operating in such a manner as to be able to adversely affect friendly operations.

The U.S. Navy no longer has the assets available, in capability or number, to gain and maintain contact with enemy submarines over long distances for indefinite periods of time. The current enemy will be difficult to find, if at all, and when they are found contact may be fleeting. To this end the current direction of ASW is correct in that forces must be ready to execute rapid attacks once contact is achieved. The conclusion of this paper is that the U.S. Navy can no longer afford to expend assets in a wide-area search of an enemy that cannot be found with any degree of reliability. The current acquisition programs are a step in the correct direction but tactical focus should not be on searching wide areas of ocean in a hope of gaining contact, but instead be on focused areas of denial where the technological superiority can be leveraged to create barriers no submarine can pass through undetected. Instead of attempting to cover the entire ocean, the Fleet Commander needs only to protect the waters around his assets at such a range as to keep them invulnerable to attack from a submerged enemy.

---

[1] VADM(ret) Albert Konetzni as quoted in Michael Bruno, "Retired Admirals Press Littoral Dominance Needs," *Aerospace Defense & Daily Report*, vol. 216, no. 32 [November 15, 2005], http://www.bl.uk [accessed June 25, 2008].

[2] John R. Benedict, "The Unraveling and Revitalization of U.S. Navy Antisubmarine Warfare," *Naval War College Review* [Spring 2005]: 94.

[3] Andrew Krepinevich, "Navy Strike Operations in the 21st Century," Strategic and Budgetary Analysis Online, http://www.csbaonline.org/ [accessed October 12, 2008].

[4] Konetzni.

[5] CDR Perry D. Yaw, "ASW…Not just a Navy sport. The Need for Joint ASW" [master's thesis, Naval War College, 2006], 11.

BIBLIOGRAPHY

Books

Fox, Warren L.J., Megan U. Hazen, Chris J. Eggen, Robert J. Marks II, and Mohamed A. El-Sharkawi. "Environmental Adaptive Sonar Control in a Tactical Setting." In Pace and Jensen, 595-602.

Holland, Charles W. "Intra- and Inter-Regional Geoacoustic Variability in the Littoral." In Pace and Jensen, 73-82.

Pace, Nicholas and Finn Jensen, ed. *Impact of Littoral Environmental Variability of Acoustic Predictions and Sonar Performance*. Bruxelles, Netherlands: Kluwer Academic Publishing, 2002.

Sellschopp, Jurgen, Peter Nelson, and Martin Siderius. "Combination of Acoustics with High Resolution Oceanography." In Pace and Jensen, 19-26.

Sontag, Sherry and Christopher Drew. *Blind Man's Bluff.* New York: PublicAffairs, 1998.

Sun Tzu. *The Art of War.* Translated by Samuel B. Griffith. New York: Oxford University Press, 1963.

Till, Geoffrey. *Seapower: A Guide for the Twenty-First Century*. London: Frank Cass, 2004.

Woodward, ADM Sir John. *100 Days: The Memoirs of the Falklands Battle Group Commander*. Annapolis: Naval Institute Press, 1992.

Zurk, Lisa M., Nigel Lee and Brian Tracey. "Robust Adaptive Processing in Littoral Regions with Environmental Uncertainty." In Pace and Jensen, 515-522.

Periodicals

Beheim, Eric. "New Command to Integrate Navy's ASW Mission." *All Hands* [August 2004]. http://findarticles.com/p/articles/mi_m0IBQ/is_/ai_n6361582 [accessed March 23, 2008].

Benedict, John R. "The Unraveling and Revitalization of US Navy Antisubmarine Warfare." *Naval War College Review* [Spring 2005]: 93-120.

Bruno, Michael. "Retired Admirals Press Littoral Dominance Needs." *Aerospace Defense & Daily Report*, vol. 216, no. 32 [November 15, 2005]. http://www.bl.uk [accessed June 25, 2008].

Clark, ADM Vern. "Seapower 21." *Proceedings* [October 2002], http://www.navy.mil/navydata/cno/proceedings.html [accessed March 27, 2008].

Dumiak, Michael. "Lurking in the Littorals." *Defense Technology International* [May 2007]: 26-29.

Eland, Ivan. "It's time to Mothball Unneeded Nuclear Attack Submarines." *USA Today*, [September 1999]. http://www.encyclopedia.com/doc/1G1-56459107.html [accessed 11 May 2008].

Freedman, Lawrence D. "Reconsiderations: The War of the Falkland Islands, 1982," Foreign Affairs [Fall 1982]. http://www.foreignaffairs.org/19820901faessay8299/lawrence-d-freedman/reconsiderations-the-war-of-the-falkland-islands-1982.html [accessed April 28, 2008].

Irwin, Sandra. "Shrewd Tactics Underpin Navy Strategy to Defeat Diesel Submarines." *National Defense Magazine* [March 2005]. http://www.nationaldefensemagazine.org/archive/2005/March/Pages/UF-Shrewd_Tactics5844.aspx?PF=1 [accessed September 12, 2008].

Kime, Patricia. "Navy Should Bolster Crisis Planning for Theater ASW." *Seapower* [September 2003]. http://findarticles.com/p/articles/mi_qa3738/is_/ai_n9272050 [accessed March 4, 2008].

Kreisher, Otto. "As Underwater threat re-emerges, Navy renews emphasis on ASW." *Sea Power* [October 2004]. http://www.military.com/NewContent/0,13190,NL_ASW_100404-P1,00.html [accessed June 28, 2008].

McKee, ADM Kinnard. "McKee Sees Different Mission for Future Attack Submarines." *Proceedings* [September 1990]: 82.

Patton, James H. "ASW is Back." *Proceedings* [February 2004]: 55-56.

Polmar, Norman. "Back to the Future." *Proceedings* [April 2006]. http://www.military.com/forums/0,15240,94621,00.html [accessed May 9, 2008].

Polmar, Norman."The ASW Shift." *Proceedings* [June 2000]: 87-88.

Whitman, Edward C. "Air Independent Propulsion: AIP Technology Creates a New Undersea threat." *Undersea Warfare* [Fall 2001].

http://www.navy.mil/navydata/cno/n87/usw/issue_13/propulsion.htm [accessed June 15, 2008].

Government Documents

U.S. Department of Defense. *Department of Defense Dictionary of Military and Associated Terms.* http://www.dtic.mil/doctrine/jel/new_pubs/jp1_02.pdf [accessed March 4, 2008].

U.S. Department of the Navy. *A Cooperative Strategy for 21st Century Seapower,* by GEN James T. Conway, ADM Gary Roughead, and ADM Thad W. Allen. Washington, DC: Government Printing Office, 2007.

U.S. Department of the Navy. *Anti-Submarine Warfare: Concept of Operations for the 21st Century,* by Task Force ASW. 2004. http://www.navy.mil/navydata/policy/asw/asw-conops.pdf [accessed April 28, 2008].

U.S. Naval Doctrine Command. *Littoral Anti-Submarine Warfare Concept.* http://www.fas.org/man/dod-101/sys/ship/docs/aswcncpt.htm [accessed April 21, 2008].

Other Sources

Cote, Owen and Harvey Sapolsky. "Antisubmarine Warfare after the Cold War." *MIT Security Studies Program.* http://web.mit.edu/SSP/Publications/confseries/ASW/ASW_Report.html [accessed July 7, 2008], 3.

Kockums. "The Kockums Stirling AIP system – Proven in Operational Service." http://www.kockums.se/submarines/aipstirling.html [accessed October 12, 2008].

Krepinevich, Andrew. "Navy Strike Operations in the 21st Century." Strategic and Budgetary Analysis Online, http://www.csbaonline.org/ [accessed October 12, 2008].

McCullough, Joseph Allen. "The Falklands War: The Air and Sea Campaigns." *Suite101.com* [March 2007], under "History," http://modern-british-history.suite101.com/article.cfm/the_falklands_war [accessed April 28, 2008].

Moltz, James C. "Global Submarine Proliferation: Emerging Trends and Problems." Nuclear Threat Initiative, http://www.nti.org/e_research/e3_74.html [accessed May 13, 2008].

Naval Technology. “SSK Kilo Class (Type 636) Attack Submarine, Russia.” http://www.naval-technology.com/projects/kilo/ [accessed July 7, 2008].

Naval Technology. “U212/U214 Attack Submarines, Germany.” http://www.naval-technology.com/projects/type_212/ [accessed July 7, 2008].

Nuclear Threat Initiative. “Submarine Proliferation: France Export Behavior.” Nuclear Threat Initiative. http://www.nti.org/db/submarines/france/export.html [accessed May 13, 2008].

Rader, CDR Karl. “Forward…From the Sea into the Torpedo Danger Zone: Blue Water ASW Doctrine in Shallow Water.” Master’s thesis, United States Army Command and General Staff College School of Advanced Military Studies, 1994.

Ross, Steve. “USS BOISE’s 1998 Deployment: SSN Operations in the 21st Century.” Global Security. http://www.globalsecurity.org/military/library/report/1998/uss_boise.htm [accessed October 10, 2008].

Royal Australian Air Force. “Art of the Hunter.” http://army.gov.au/news/raafnews/editions/4703/features/feature01.htm [accessed October 14, 2008].

Sino Defence. “Kilo Class (Project 636/877EKM) Diesel-Electric Submarine.” sinodefence.com, http://www.sinodefence.com/navy/sub/kilo.asp [accessed July 7, 2008].

Starr, Barbara. “U.S.warship can’t stop pirates off Somalia.” CNN.com. http://www.cnn.com/2007/WORLD/africa/06/06/pirates/index.html [accessed April 28, 2008].

Yaw, CDR Perry D. “ASW…Not just a Navy sport. The Need for Joint ASW.” Master’s thesis, Naval War College, 2006.

INITIAL DISTRIBUTION LIST

Combined Arms Research Library
U.S. Army Command and General Staff College
250 Gibbon Ave.
Fort Leavenworth, KS 66027-2314

Defense Technical Information Center/OCA
825 John J. Kingman Rd., Suite 944
Fort Belvoir, VA 22060-6218

Mr. Bob A. King
DJIMO
USACGSC
100 Stimson Ave.
Fort Leavenworth, KS 66027-2301

Dr. John T. Kuehn
Dept. of History
USACGSC
100 Stimson Ave.
Fort Leavenworth, KS 66027-2301

Mr. Harold A Laurence
DJIMO
USACGSC
100 Stimson Ave.
Fort Leavenworth, KS 66027-2301