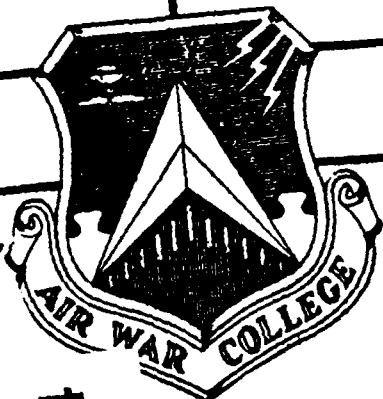


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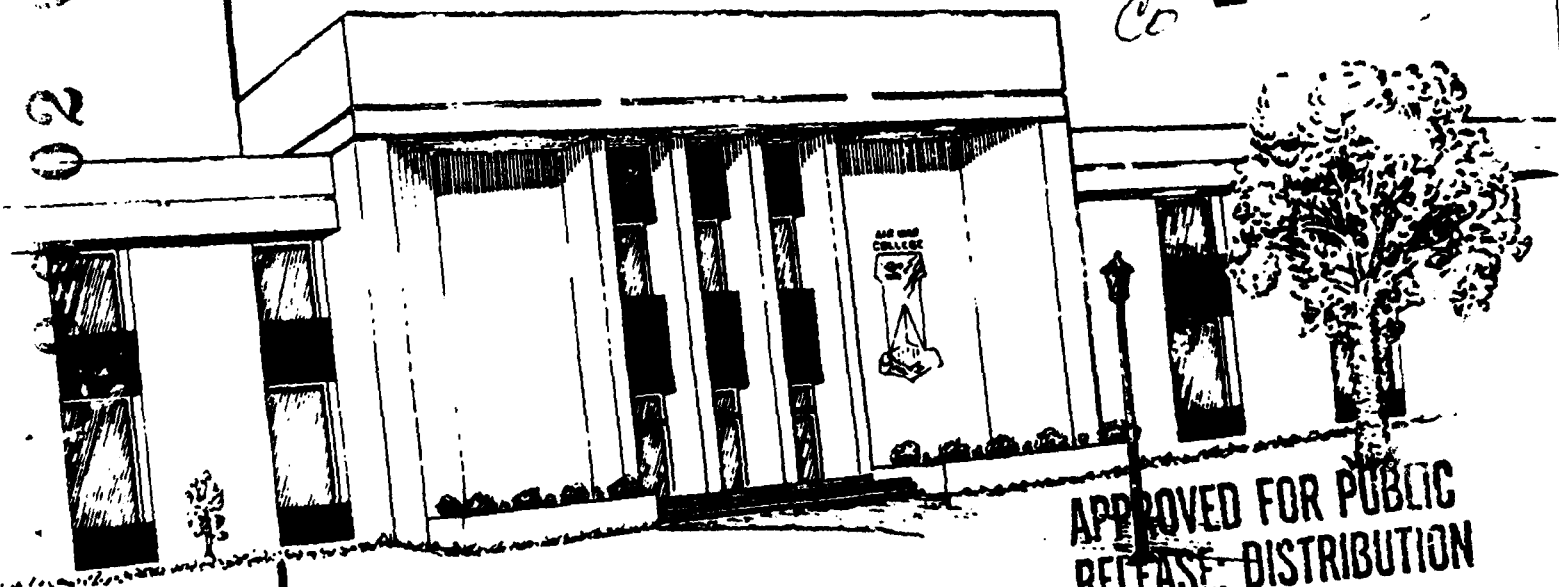
ANTI-SUBMARINE WARFARE
ON THE CONTINENTAL SHELF

COMMANDER BRUCE H. BRUNSON, USN

1989

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UNITED STATES AIR FORCE
MAXWELL AIR FORCE BASE, ALABAMA

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ANTI-SUBMARINE WARFARE ON THE CONTINENTAL SHELF

BY

BRUCE H. BRUNSON
COMMANDER, USN

A DEFENSE ANALYTICAL STUDY SUBMITTED TO THE FACULTY
IN
FULFILLMENT OF THE CURRICULUM
REQUIREMENTS

ADVISOR: CAPTAIN RICKY K. MORRIS

MAXWELL AIR FORCE BASE, ALABAMA

MAY 1989

PREFACE

The Soviet submarine threat off the east coast of the United States is a joint service problem and requires a joint service effort to combat the threat. When the Army or Air Force is sitting in Europe waiting for his supplies and men from the states and the Navy officer says there are Soviet submarines on the continental shelf, he needs to understand the basics of the problems the Navy and Coast Guard are having. This paper is written not to make Air Force and Army officers experts in Anti-Submarine Warfare, (ASW), but to make them aware of a real world problem that could disrupt the forward depolyed war fighting strategy of all the services.

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EXECUTIVE SUMMARY

TITLE: Anti-Submarine Warfare on the Continental Shelf

AUTHOR: Bruce H. Brunson, Commander, USN

The challenge of conducting Anti-Submarine Warfare (ASW) against the Soviet Submarine threat on the continental shelf of the east coast of the United States is addressed. Basic shallow water acoustics are explained to assist in the understanding of ASW sensors, weapons, and platforms. The United States' Maritime Strategy of forward deployment may leave the east coast of the United States vulnerable to Soviet attack and missile submarines. By presenting the difficulties of shallow water ASW on the continental shelf and the limited number of United States assets that will be available for coastal defense, it will be shown that the target rich environment provides incentives for deploying Soviet submarines there to strangle NATO supply lines.

BIOGRAPHICAL SKETCH

Commander Bruce H. Brunson graduated in 1974 from the United States Naval Academy with a B.S. in Operations Analysis. He has had three operational tours as a pilot in Anti-Submarine Warfare (ASW) helicopter squadrons. He also had a tour in an ASW operational test and evaluation squadron and in the Pentagon working in the area of international research and development. He has gained many years of operation ASW experience while flying SH-3Hs off aircraft carriers and SH-60Bs off small combatants in the Atlantic Ocean and Mediterranean Sea. Commander Brunson is a graduate of Air War College, class of 1989.

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The Royal Navy, long believed to be the best equipped and trained Navy in the free world in the field of shallow water ASW, was unable to successfully localize and destroy the Argentine submarine San Luis, known to have been operating in the vicinity of the (British) task force for a considerable period. The Falklands experience clearly demonstrated the difficulty associated (with ASW) in shallow water, an aspect of Naval warfare which requires increased emphasis in the U.S. Navy. (8:47)

CHAPTER 1

INTRODUCTION

The United States has been formulating its wartime strategy to defeat the Soviet Union for many years. The key features of the United States maritime strategy are to fight forward deployed and to use the oceans as a defensive barrier. For the Atlantic Theater, the Atlantic Ocean has provided the United States with a defensive barrier against conventional weapons. In the past two world wars and during the subsequent years, the Atlantic Ocean served the maritime strategy well. Except for the German submarines sinking merchant vessels off the coastal United States during World War II, the major threat to the North American mainland has been the introduction of nuclear intercontinental ballistic missiles (ICBMs) that can be launched from the Soviet Union or from their ballistic missile submarines operating in the Atlantic or the Pacific. A significant threat from Soviet nuclear attack submarines operating in the Atlantic far from the Soviet homeland has developed and its importance is growing daily.

The United States Navy fleet is capable of fighting both a nuclear or conventional war while forward deployed in blue water

(open ocean, deep water) as required by the U.S. Maritime Strategy. As the threat of nuclear war decreases and with the technological improvements in conventional weapons, the continental shelf of the United States' east coast may be the Achilles heel for the United States and its Allies during a war with the Soviet Union. Success or failure of the Anti-Submarine Warfare (ASW) efforts in the coastal areas of the United States will have an important effect on a war overseas. The same ocean that provides a defensive barrier for the United States, also handicaps us with a long supply route to support overseas operations and an extensive transit time for military forces. More than 2,000 maritime shipments per month could be required to transfer supplies and combat troops to meet the NATO worst case defense plan against the Soviet Union. (17:168) This paper will look at the ASW challenge the United States has in defending its east coast against Soviet submarines and maintaining the ability to send the men, equipment, and supplies to Europe.

CHAPTER II

THREAT

Many theories have expressed opinions on how the Soviets and the United States will fight the next war. For many years the dominant opinion was that a war between the Soviet and United States would escalate quickly to the use of nuclear weapons. The Soviet's doctrine of defense of the motherland requires a large submarine fleet of diesel-electric and nuclear powered ballistic missile and attack submarines to support it. Soviet maritime strategy for the use of their submarines is primarily in close defense of the maritime approaches to the motherland and to use their attack submarines to provide defense for the strategically important ballistic missile submarines. As the Soviet submarine-launched ballistic missiles (SLBMs) range increased over the years from 300 to 4,500 miles, their ballistic missile submarines and supporting attack submarines have deployed closer to the motherland into a more defensible disposition in the Norwegian Sea and farther north. (6:544) The Soviets have continued building more attack submarines to have enough to conduct anti-shipping campaigns outside their defensive bastions. Containing these extra submarines becomes extremely important as the number of excess Soviet attack submarines continues to increase. The United States Maritime Strategy in the Atlantic Ocean has been to prevent the Soviets from getting to the United States coast and to Allied shipping by closing the Greenland-Iceland-United Kingdom (G-I-UK) Gap to transit by Soviet submarines and surface ships. Further plans call for United

States Naval forces to go north from the G-I-UK Gap and attack the Soviet submarine and surface forces in their own waters. The United States strategy assumes that large numbers of Soviet submarines will not be deployed when hostilities begin and the U.S. Navy can get into position prior to a large number of Soviet attack submarines passing through the choke points. The initial level of hostilities and the early rules of engagement (ROE) may not permit the U.S. forces to attack Soviet submarines when they are first detected and allow more to reach the open ocean, however. Once the attack submarines reach the vast area of the Atlantic Ocean, the problem of ASW area search is greatly increased. Predeployed submarines and submarines that get through the G-I-UK Gap will be a threat to the United States' east coast and Sea-Lines-of-Communications (SLOCs) to Europe.

If a war quickly escalates to a global nuclear war, the submarines that get through the G-I-UK Gap will not have a major effect on the war since a short war will not require extended resupply. Since theorists are downplaying this scenario and increasingly postulate that a war into a nuclear scenario and a war in Europe could go on for an extended duration. The SLOCs will then become extremely important to NATO. This scenario is based on the theory that the nuclear arsenals of the United States and the Soviet Union are so large and survivable that their use by either side would be suicidal. To avoid nuclear war, ballistic missile submarines of each country will not be allowed to come under attack. Since these submarines are strategic defense platforms, sinking them would trigger a severe

response by their governments which would thus enhance the threat of nuclear escalation. Neither country would want this nuclear strategic capability eliminated. Excluding a nuclear attack against the United States, the Soviets' attack submarine force is the only conventional weapons delivery platform that remains a threat to the continental United States. The Soviets will have to use their attack submarines to stem the flow of men and supplies to Europe. Two World Wars proved how critical the SLÜCs are to a war effort in Europe and would represent a primary strategic target for the Soviets. Also, submarines could be used if Soviets wanted to make a tactical conventional strike against a target on the continental United States. Submarines can be used for several missions. They can: Launch submarine long range cruise missiles (SLÜMs) at targets like vital bridges, vessels, ports, command and political centers, etc.; Torpedo Naval and merchant vessels; Lay minefields in harbors and along SLÜCs; Deploy covert operation teams who could close harbors by destroying bridges, port facilities, mining channels, and conduct terrorism , etc.; Act as intelligence collectors; Attack offshore oil and gas platforms. Even minor delays in supply support to the European theater caused by submarine action would be critical to the NATO war effort. The Soviets can get a better return on their effort by attacking a port and delaying multiple vessels rather than trying to attack individual ships and convoys. Also, the search area for targets is much smaller close to a port than in the vast area of the Atlantic Ocean.

The Soviet submarine force consist of a wide variety of

types. Not all would be capable of deploying to the continental shelf. With the large number of platforms available, the ones with lesser capabilities like the diesel-electric and older nuclear boats would relieve the newer more capable submarines to deploy. The Soviet submarine fleet consists of:(6:544)

Ballistic-missile submarine (nuclear propulsion) (SSBN).....	62
Ballistic-missile submarine (diesel-electric) (SSB).....	13
Guided-missile submarine (nuclear) (SSGN).....	49
Guided-missile submarine (diesel-electric) (SSG).....	16
Fleet attack submarine (nuclear propulsion) (SSN).....	80
Submarine (diesel-electric) (SS).....	125

Total active Soviet submarines.....345

The Soviet submarines assigned to the Northern Atlantic fleet are:
(6:544)

SSBN.....	38
SSB.....	0
SSG.....	7
SSGN.....	30
SSN.....	55
SS.....	40 (In addition about 70 believed in reserve)

total active ... 170

The Soviets are currently constructing Typhoon and Delta IV class SSBNs and Oscar, Sierra, Akula and Victor III attack submarines. Their production averages five to six nuclear and one to three diesel-electric submarines per year. (6:123)

The Soviets' technological improvements in submarines is best demonstrated by the addition of the Akula Class SSN with a speed of over 42 kts. submerged while carrying torpedoes and land attack cruise missiles. The Oscar Class SSGN with a speed of 30 kts and capable of carrying torpedoes and 24 cruise missiles has also been recently added to the Soviet Fleet.(6:550) These new submarines are much quieter and faster than their older attack

submarines which further decreases the United States tactical advantage.

The weapon systems of the Soviet nuclear and diesel powered submarines consist of ballistic and cruise missiles as well as torpedoes and mines. Their ballistic missiles have ranges out to 4,500 miles and their antishipping cruise missiles have ranges out to 340 miles. The SS-N-21 land attack cruise missile under development will have a range from 1,100 to 1,600 miles. Their torpedoes are the acoustic homing Type 53 which has a range of 11 miles and the Type 65 wake homing torpedo with a range of 55 miles. (6:550)

Even though the Soviets have the largest submarine fleet in the world with the capability of attacking targets in the coastal waters of the United States, some theorist do not feel there is a coastal submarine threat. Distance from home base, shallow water, the proximity of land ASW resources, and United States Naval ASW forces comprise a formidable ASW defense. However, the shallow water coastal environment (favorable to submarines because ASW is much harder there) combined with forward deployment of the United States ASW surface, subsurface, and air assets (leaving th United States coastline undefended) are conditions favorable to the Soviet submarine force. Because of these factors, as well as the Soviet Navy's clearly stated intention to interdict Allied SLOCs in time of war, the Soviet submarine threat to the U.S. coast is significant and cannot be discounted.

CHAPTER III

DETECTION

Acoustic detection using active and passive sensors is the primary means of detecting, classifying, localizing, tracking, and attacking a submarine. An elementary discussion of underwater acoustics is required to address the submarine threat.

Taken from the book Naval Orientation: (9:436)

The principal method of submarine detection is sonar (sound navigation and ranging). This is the name applied to the electronic device that can either detect the sounds originating under water (passive sonar) or transmit a sound wave through the depths that, upon striking an object, will reflect (active sonar).

To understand how sonar works you must first understand sound. Sound is the physical cause of the sensation of hearing. It travels in the form of waves away from the point of origin, just as ripples travel out in all directions when a pebble is tossed into a pond. Echoes are created when the sound waves strike an object of varying density in the surrounding sea water. The waves will not travel through these objects, and are reflected back to the surface.

The substance through which sound travels is called a medium. All types of matter are sound mediums of varying efficiency. The denser the medium, the more rapidly sound travels through it. Therefore, steel is a better medium than water, and water is a better medium than air.

Let's take a look at what happens to a sonar impulse after it leaves a transducer (the transmitting antenna). The transducer introduces the sound wave into the water by converting the equipment's electrical energy into sound vibrations. The impulse travels at a rate of between 4700 and 5300 feet per second, depending on the temperature, salinity, and pressure of the water. This is four or five times faster than the speed of sound in air but the hazards of travel take their toll on this speed and signal strength. Some of the sound is absorbed by currents, bubbles, or wakes, and it is further weakened by scattering as it passes through water containing foreign matter, i.e., sea weed, silt, animal life, or air bubbles. Also, like a searchlight beam, the sound wave spreads out as it travels farther and farther away from the transducer

and thus becomes weaker and weaker.

Once the wave does strike an object such as a submarine that portion of the impulse which is at a right angle to the object is reflected back to the sonar receiver. Again it is acted upon by absorption, scattering and spreading, but a signal will be received indicating a possible target, provided it is not drowned out by reverberations, self-noise and a high surrounding noise level. These are the multiple reflections or echoes which can come from many sources.

Sound waves bouncing off small objects such as fish or air bubbles produce small echoes. Sound reflected from the sea surface and bottom also echo, and the sea mass itself causes still unexplained reverberations. These reverberations appear on video display and come in over the audio receiver in the form of a roar. Reverberations from nearby points may be so loud that they interfere with, or completely mask, the returning echo from the target.

This explanation of active sonar waves in water also explain the use of passive sonars. In this case the sound source is the target submarine or surface ship and the sound is affected only by one way transmission loss and not in both directions as in the case of active sonars.

The ocean has very many different types of acoustic environments which present different problems for ASW units. One of the most complex consists of fifteen percent of the world's oceans and is classified as a shallow water ASW environment.

(10:i) Appendix 1 depicts the areas of the world classified as shallow water and Appendix 2 shows the east coast of the United States. The Chief of Naval Operations defines shallow water as:

Antisubmarine warfare operations in water depths 50 to 1,000 meters where acoustic propagation is dominated by boundary interactions, is reverberant and complicated by extreme oceanographic temporal and spatial variability. (4:1)

To the ASW operator shallow water is an area which restricts a submarine's operating depth. These areas include straits and

choke points, continental shelf regions and areas that include complex and variable oceanographic conditions.

The continental shelf off the east coast of the United States falls into this classification of shallow water. This area favors the submarine's defense due to sound reverberation from the bottom, the mass of mechanical and biological noise, the lack of unobstructed sound paths, and unpredictable sonar characteristics due to variable chemistry and temperature, and particulate matter that characterizes the coastal zone near the exit of bays and rivers.(5:16) The effects of ocean fronts and eddies, such as off the east coast of the United States, also cause conditions that disrupt acoustic target acquisition by searching sensors and attack weapons. Shallow water has an adverse effect on all phases of an ASW operation from detecting and tracking to attacking and weapons acquisition. Active sonar and torpedoes in the homing mode are the most effected. Currently the Navy has no sensors specifically designed for use in shallow water aboard its ASW platforms. (18:4-2) Appendix 3 gives a more in-depth explanation of shallow water acoustic factors.

The submarine threat in shallow water is not new. In World War II 39% of all ships sunk were in water depths less than 100 fathoms, Germany sank 600 ships in shallow water off the United States during a five month period in 1942. Every British battleship, cruiser and carrier was sunk in a shallow water environment. (10:1) Because shallow water acoustics favor an attacking submarine and targets are more concentrated and

predictable there, the next war will find attacks in shallow water tactically inviting.

CHAPTER IV

ASW Sensors.

Acoustic detection is and will remain the primary form of ASW for many years. Sensors for acoustic detection are classified as active or passive and stationary, mobile or deployable. All the sensors depend on sound traveling through the water and are affected by the ocean environment as discussed in Appendix 3. Passive sensors use the submarine radiated self noise for one way noise signal detection. Active systems transmit a signal that is reflected off objects and back to the ASW system. The primary ASW acoustic sensors currently in use are: The moored hydrophones referred to as the Sound and Surveillance System (SOSUS); Ship and submarine towed arrays; hull mounted sonars (Sound Navigation Ranging) on surface ships or submarines; Surface ship variable depth sonars (VDS) and dipping sonars carried by helicopters; active and passive sonobuoys. All of the acoustic systems were designed for deep water operations and some have experienced satisfactory but unpredictable performance in shallow water. The active and passive systems that have done well in one location have failed in others. System performance in shallow water is unpredictable and does not provide the operator uniformly effective operation in all the geographic areas where he operates.

Sound Surveillance System (SOSUS). SOSUS is an array of passive hydrophone receivers moored to the ocean bottom and cable-connected to shore stations for signal processing. SOSUS is

deployed in both the Atlantic and Pacific Oceans at strategic locations to optimize the long range wide area passive detection of Soviet submarines. This system covers outward from the continental shelf toward deep water. It provides early target warning, but is not considered a continental shelf shallow water sensor.

Surveillance Towed Array System (SURTASS). SURTASS is a surface ship passive towed array hundreds of meters long. T-AGOS ships tow the array at slow speeds to supplement SOSUS wide area target search and classification. The acoustic data is relayed by radio to shore facilities for processing. T-AGOS ships are small, civilian manned and noncombatant.

Rapid Deployable Surveillance System (RDSS). RDSS is a long-life, sophisticated, air-dropped sonobuoy that can provide surveillance in areas not covered by SOSUS or SURTASS. Their signals are relayed by radio to shore facilities or aircraft for processing.

Tactical Towed Arrays (TACTASS). TACTASS are long passive arrays towed behind different classes of Naval ships and submarines for long range passive search, classification, and tracking. The acoustic processing is done onboard the towing vessel.

Variable Depth Sonars (VDS) and Dipping Sonars. VDS is a towed underwater body used by various surface ships and dipping sonars are used by helicopters from a hover (helicopters do not tow sonars). Both systems are used to get the sensor below the

surface isothermal layer to the thermocline below for passive and active contact acquisition.

Hull Mounted Sonars. These sonars are used for both passive and active target acquisition. They both have the major problem of own ships noise and blind spots in their area coverage. Surface ships also have the disadvantages of not being able to get the sensor below the surface layer. Submarines have a better target detection capability than ships since they produce little self noise at slow speeds and can place their hull mounted sonar into the same acoustic layer as their target.

Sonobouys. Sonobouys are expendable buoyant tubes that contain a hydrophone and radio transmitter which are designed as either active or passive sensors. They are dropped by aircraft and helicopters or can be deployed by surface ships and submarines. Once deployed, sonobuoys lower a hydrophone to a depth set by the operator and use a radio link to transmit the sound received by the hydrophone back to an ASW platform. Most sonobouys last for 8 hours or less, but some large sonobouys are capable of working for over a week and transmitting information to ships, aircraft, and possibly satellites.

Nonacoustic Sensors

Radar. Land, surface, and airborne radars, which are the primary detection devices for submarines on the surface or with their periscopes and or masts up, are hampered by the large number of surface contacts that are in a coastal area. Fishing boats, pleasure boats, merchant ships, and military ships all look the

same on most radars. Navigation buoys and flotsam can easily be mistaken as submarine periscope with radar, night vision devices and also the naked eye. Before making an attack or deploying special forces Soviet submarines would have some surface exposure time, which if planned properly, would be difficult for ASW units to detect and classify as a submarine contact. A limitation to large area radar ASW search is that an attack periscope has a small radar cross section and under good conditions can only be detected at 15 miles or less depending on the radar system.

The use of radar does provide "hold down" capability, however. If a hostile submarine detects a radar capable of ASW search, the submarines surface exposure time would have to be limited and require a tactical decision to be made on the assumption that an ASW platform is present that can make a counter attack if the submarine makes a strike at a target.

Magnetic Anomaly Detection (MAD). MAD senses variation in the earth's magnetic field made by metallic objects (submarines, wrecks, etc...) and has a detection range of only 1,000-2,000 feet.(c:71) It is used by most ASW airborne platforms as a collaborating sensor for tracking and attacking a submarine contact. Soviet submarines can use known areas of ship wrecks as areas to mask their MAD signature and confuse the ASW problem. MAD has a high false target rate on the continental shelf due to the large number of wrecks.

Electronic Support Measure (ESM) and Signal Intelligence (SIGINT). The use of ESM and SIGINT for submarine detection

would be limited. Although Soviet submarines have discreet radar signatures and the communication systems can be detected, their radars would see very little use in a hostile environment. Submarine electronic transmissions of any type would be of short duration thus making detection and localization difficult. ESM would benefit the Soviets more in the detection and localization of the United States ASW platforms, potential targets, and shore facilities. United States search sensors detected by a Soviet Submarine could act as a deterrent to its operations.

Forward-Looking Infra-red (FLIR). FLIR systems are used by airborne platforms for passive visual day and night area search. The systems are useful for classification of surface targets picked up by other systems such as radar or sonar. FLIR is adversely affected by clouds, rain, whitecaps, and sea state.

Satellites. Currently satellites are supporting ASW by providing SIGINT, ESM, infra-red detection and imaging. These systems were not designed specifically to find submarines and until technical advances are made, satellites will not be a primary ASW detection sensor.

Chapter V

ASW Platforms.

ASW platforms for defense of the continental shelf are submarines, surface ships, fixed wing maritime patrol aircraft and helicopters. The number and types of Navy combatants that are in the Atlantic command capable of ASW are: (15:Encl(5) 1-6)

* ("N" is for nuclear powered)

Aircraft Carriers (CV/CVN).....	8
Battle Ships (BB).....	2
Guided Missile Cruisers (CG/CGN).....	17
Destroyers (DD).....	17
Guided Missile Destroyers (DDG).....	23
Frigets (FF).....	29
Guided Missile Frigets (FFG).....	33

Total active surface combatants.....128

Ballistic Missile Submarines (SSBN).....	29
Attack Submarine (SSN).....	60

The Naval Reserve has:

FF.....	4
FFG.....	8

The only USCG ship capable of ASW are 8 High Endurance Cutters (WHEC).

The number of Navy ASW squadrons on the east coast and their approximate number of aircraft are: (15:Encl (2) 9-16)

<u>Type Squadron</u>	<u># Aircraft in Squadron</u>	<u>Total</u>
12 Maritime Patrol (VP).....	9 P-3s.....	108
7 Reserve VP.....	9 P-3s.....	56
7 Air Anti-Submarine (VS).....	10 S-3s	70
7 Helicopter Anti-Submarine (HS).....	6 SH-3s..	42
1 Reserve HS.....	7 SH-3s....	7
3 Helicopter Anti-Submarine Light (HSL)..	10 SH-2s....	30
2 Reserve HSL.....	8 SH-2s....	2
3 Helicopter Anti-Submarine Light (HSL)..	13 SH-60s...	39

* These numbers do not include the training squadrons. During a war the training squadrons' aircraft and personnel would be used to keep the front line squadrons at full strength. However, they would be able to provide some ASW operations off the coast. The VS, HS, and HSL ASW aircraft are assigned to the ships that would be deployed to the Atlantic or Mediterranean.

Nuclear attack submarine (SSN). SSNs are considered to be the premier ASW platform. They are quiet, have outstanding acoustic sensing and processing and have good ASW weapons. Additionally they operate in the same environment as the enemy. However, once the enemy reaches the continental shelf, the United States submarine has to find and attack a target that is in an acoustic environment not suited for passive sensors. If the searching submarine uses active sonar, it loses one of its primary tactics - stealth - and develops an easy target solution for the enemy submarine. Friendly submarines also have the problem on the continental shelf of being identified by other ASW units as a friendly not a hostile submarine. It is not hard to imagine that during a war ASW on the continental shelf will have various types of ASW platforms with varying amounts of ability and training. The command and control of where the friendly submarines are positioned could breakdown very quickly. Since a submarine contact to most sensors does not provide classification as to type of submarine, a lot of ASW platforms will be dropping weapons on any suspected submarine contact - friend or foe.

Surface Ships. Surface ships with ASW capability for use on the continental shelf would come from both the Navy and Coast Guard. Assets that are not forward deployed or involved in convoy escort

will have capabilities that vary from platform to platform, but should have sonars for passive and active search, radars, ESM equipment and weapons delivery capability. Some ships would be capable of carrying ASW helicopters. Speed is the surface ship's primary disadvantage in ASW. It is limited to less than 40 knots when transiting, and to slower speeds (20 knots or less) when using some ASW acoustic sensors. The ships' effectiveness without VDS is restricted in different acoustic environments since it can not get its sonar below the upper acoustic layer which provides a useful sanctuary to the target. Active sonars on surface ships do provide good localization, tracking and attacking capability, but may be very limited in range when working in shallow water. When a surface ship is pinging its active sonar for use in screening other units or in an area search, it limits the hostile submarine's safe areas to operate.

Presently, ASW aircraft will primarily come from Navy assets. Other than for surface search, the Coast Guard does not have any aircraft with ASW sensors or ASW weapon stations. The Air Force can provide aircraft for radar surface search, the dropping of bombs, and the launching of air to surface harpoon missiles.

P-3 Orion. The Navy's land based P-3 maritime patrol aircraft would be the primary long range airborne ASW platform. It has radar, ESM, MAD, FLIR, carries 88 sonobuoys (mixture of active and passive sonobuoys), onboard acoustic processing and can carrier a large payload of ASW weapons. With the large sonobuoy

loadout and its 12 hour endurance, the P-3 can do large area search, classification and tracking of a target and then conduct multiple attacks. It is also capable of deploying defensive mines and firing air to surface Harpoon missiles. Like other ASW platforms that primarily use passive detection, the P-3 is handicapped in the shallow water continental shelf environment. There will also be a large demand for P-3s in other areas which will stretch the limited resources. It is one of the primary forward deployed ASW assets and will be needed for carrier battle group protection.

S-3 Viking. The Navy's S-3 is the primary long range ASW asset for the aircraft carrier. The S-3 has the same type of equipment as the P-3, but due to its smaller size, it has reduced capability in range, endurance, and buoys and weapons. Although most of these assets will be deployed on aircraft carriers, there should be some available for coastal ASW.

SH-2 Seasprite, SH-3 Sea King and SH-60B Seahawk. SH-2, SH-3, and SH-60 helicopters would be used for ASW on the continental shelf as the stand-off weapon system in support of ships or from the shore. The SH-2 and the SH-60B, which are referred to as Light Airborne Multipurpose System (LAMPS) and deploy off smaller ships (not aircraft carriers), use active and passive sonobuoys as their primary ASW sensor. They also have radar, ESM, MAD and some have FLIR. SH-3's deploy off aircraft carriers and use a dipping sonar in the active mode as their primary ASW sensor. They also have onboard sonobuoy processing and MAD. They do not

have radar or ESM capability. Due to their limited endurance, range, sonobuoy load-out and weapons, all the helicopters are used primarily in a reactive mode to other detection sources for localization, tracking and attacking. They are capable of employment as a screening unit, in small area acoustic and MAD search, and/or radar ESM search of ASW areas. Since the helicopters are deployable assets, the majority of them along with their surface platforms will not be available for coastal defense. The SH-2 and SH-60B primarily use passive sonobuoys which are not very effective in the continental shelf area. The SH-3 primarily uses active sonar which is often limited to short ranges of 2,000 yards or less under some coastal water conditions. The SH-60F will start replacing the SH-3 and will have improved capabilities. The helicopters that are deployed off the ships assigned to the coastal defense role will be important in localization and attacking of submarine contacts. Using active Sonobouys or active sonar and radar flooding of an area will restrict an enemy submarine's operations.

CHAPTER VI

ASW Weapons.

Weapons for use on the continental shelf are one of the major concerns for the defense of the coastal United States. Currently, even when a submarine is located in shallow water, smart weapons are adversely affected by reverberation, surface capture, bottom capture, sound channel effects, biologics and interference from hull sonars.

Torpedoes. Two types of acoustic homing torpedoes, the submarine carried MK 48 (wire guidance is optional) and the surface and air carried MK 46 torpedoes, are the primary conventional ASW weapons in the United States. The MK 48 has a range of 27 miles, speed of 55 knots, a depth to 2,950 feet and a warhead of 267 kg.(6:697) MK 46 torpedoes have a range of 6 miles, speed of 40 knots, and a warhead of 44kg.(6:720) Both the MK 46 and MK 48 torpedoes are considered good ASW weapons, except in the shallow water environment where the acoustic problems that plague sonars, also hamper the acoustic localization and attacking capability of torpedoes. Technology is improving the torpedoes' ability to operate in shallow water, but it will take time to modify the current torpedo inventories. The depth charges and other "dumb weapons" of past wars are gone. There are several "dumb and cheap" weapons being evaluated, but one problem is ships, submarines, and aircraft have limited carrying space for weapons and do not want to substitute weapons space for a less capable weapon than existing torpedoes.

During the Falklands war, 31 MK 46 torpedoes were launched mostly by helicopters against suspected submarine targets. Some of these hit the seabed, but most were fired at seabed wrecks and whales. The lack of depth-charges for aviation platforms was noted after the war as one of the lessons learned,. The inexpensive ship-mounted mortars played a positive role in attacking possible submarine targets which were thought to be hiding among seabed wrecks in the Falkland Sound.(11:70) All this action was against the threat of one Argentine diesel submarine. Just imagine what the Soviet submarine threat on the United States' continental shelf would cost in weapons launched against false targets!

Mines. Mines may also be used to restrict enemy submarine operating areas. The CAPTOR (or encapsulated torpedo) mine uses the MK 46 torpedo as its weapon and is restricted to the capabilities of the MK 46 in shallow water. The CAPTOR mines would primarily be used to stop enemy submarines from reaching the continental shelf. They can be sown in deep water by surface ships, ASW aircraft, and B-52 bombers. Bottom influence mines will be used in shallow water.

Antisubmarine rocket (ASROC). ASROC, a rocket-boosted MK 46 torpedo or a 1 kilo ton nuclear depth bomb with a range of 1 to 5.5 miles, is carried by several classes of Navy ships.(6:725)

Submarine Rocket (SUBROC). SUBROC is a submarine launch rocket-propelled nuclear depth charge with a range out to 30 miles.

(6:697) Being nuclear, this weapon would not be used in a nonnuclear war.

CHAPTER VII

Command and Control.

It is important to have an understanding of who is responsible for coordinating the use of the ASW platforms in the defense of the continental shelf. It is a Naval mission, but falls under the command of Commander, U.S. Maritime Defense Zone Atlantic (COMUSMARDEZLANT)(USN command, USCG Commander) and is responsible to Commander in Chief, Atlantic Fleet (CINCLANTFLT) for maritime defense and internal, inshore and coastal waters. Appendix 4 shows the command structure and the operational area of responsibility. (During time of hostilities, the Coast Guard falls under Navy command and control.) The Maritime Defense Zone (MDZ) area includes the navigable waterways, port areas, harbor approaches, and ocean areas from the coast seaward to 200 miles. (16:23) The mission of the MDZ Command is:

Plan for, and when directed, conducted, coordinate, and control operations in the area designated as the Maritime Defense Zone Atlantic, as required, in order to ensure the integrated defense of the area, to protect coastal sea lines of communication, and to establish and maintain necessary control of vital coastal sea areas, including ports, harbors navigable waters, and offshore assets of the United States, exercising both statutory and naval command capability. (12:1)

The objective of the MDZ Command, consistent with the Maritime strategy, is to ensure the success of the following:

(1) SSBNs successfully sortie in accordance with contingency plans; (2) battle groups, amphibious groups, submarines, and supply support ships deploy unimpeded from U.S. ports when hostilities are imminent; (3) reinforcement and resupply shipping in support of forward deployments safely departs U.S. ports and coastal areas; and (4) safe and secure water transportation of economic cargoes continues from U.S. ports and coastal areas. (16:23)

The MDZ Command establishment was important in combining the assets of the reserve and active units of the Coast Guard and Navy into a common command. With the Coast Guard as the lead service, the years of operational and command and control experience in working in the coastal environment can be passed to the Naval forces that have trained for blue water operations. The Navy is well versed in ASW against a submarine attempting to attack a surface unit. The Coast Guard is experienced in handling the threat in the coastal water of mines, sabotage, and terrorism. The MDZ command will be the focal point for related land and air defense interaction and optimum port use for supply and resupply for the Army, Air Force, and relevant civilian agencies.

Chapter VIII

Incentive For Coastal Attack

The Soviets know the problems of shallow water ASW and from many unclassified articles on the United States Maritime Strategy and ASW capability they must know our handicaps in defending the continental shelf. Combined with their increasing capabilities in submarines like their nuclear powered Akula and Oscar (cruise missile carrier) or their diesel-powered Tango and Kilo, the target rich environment of the east coast provides incentives for deploying Soviet submarines there to strangle NATO supply lines. Even their older submarines, by avoiding highly defended areas, would be useful in laying mines or supporting covert operations and gathering intelligence. These older, noisier submarines could be used in large numbers for saturation of the United States limited resources or to draw ASW assets away from the more capable and valuable submarines. For instance, "what if" one or two older Victor attack submarines made an approach in the area of Kings Bay, Georgia (deployment port for U.S. SSBNs) and an Oscar also made a indirect approach at the same port. The noisier and more easily detected Victors would attract a lot of ASW assets from the many surface and air ASW platforms stationed in the Jacksonville and Mayport, Florida areas. While the ASW assets went for the "easy target", the Oscar could slip into cruise missile range (up to 340 nautical miles with a SSN 12 or 19)(6:550) and depending on his intelligence and targeting data attack an SSBN, any surface ship in the channel, or the bridge

spanning the transit channel (requires little update in intelligence since it does not move). One sunken ship, submarine, or downed bridge would close the port. If the Victors do not press an attack, they may be able to avoid being attacked.

To put the ASW search area off the East Coast of the United States in perspective, consider that it has over 1,600 miles of coastline. If the search area is only out to 200 miles that provides an area of 320,000 square miles. (If the search area is extended to 300 miles off the coast to include the 300 mile range of cruise missiles, then the search area is 480,000 square miles.) Using a 10 mile circular range on a surface ships sonar, the ship covers an area of 314 square miles. It would take 1,019 ships to provide simultaneous coverage of the coast out to 200 miles. In 24 hour traveling at an ASW search speed of 10 kts, the ship would search about 7,500 square miles of ocean. That would require about 42 ships to search the coastal waters in 24 hours, but does not give simultaneous coverage. Even if the search area is cut in half since submarines would or could not transit in all the areas, the number of ASW ships required is 500 for simultaneous coverage and 21 for 24 hour coverage. Of the ships in the Atlantic the 122 DDs, DDGs, FFs, FFGs, and WHEN (active and reserve) are the primary ASW surface platforms. The majority of these assets will be assigned to support one of the eight aircraft carriers or the battleship. A notional battle force that was presented to congress for justification of a 600 ship Navy consist of: (13:33)

PEACETIME

1 CV/CVN
1-2 CG/CGN
2-3 DDG
2-3 DD
1-3 SSN

WARTIME

2-4
4-8
4-8
4-8
3-4

If seven CV/CVN and one of the BBs are able to deploy to the North Atlantic and Mediterranean in support of the Maritime Strategy, then each ship will take approximately 7 of the DDs/DDGs and FFs/FFGs. That will leave 53 Active Navy escort ships, 12 Naval Reserve ships, and 8 Coast Guard ships for other missions (This includes the ships that will be in repair). These ships would have to provide support in many areas including: amphibious groups; supply and personnel convoys; defense of bases like Roosevelt Roads and Guantanamo Bay; and meet other NATO joint force commitments. The notional Underway Replenishment Groups for both coast would contain one DD/DDG and three FF/FFGs for escorts and would require about 40 ships. (13:282) There are also plans for 7 convoy groups to support both coast that would require one DD/DDG and nine FF/FFGs. (13:282) If only half of these escorts come from the east coast it still requires 55 escorts. (These ships would also be covering the Gulf of Mexico which poses an ASW challenges like the continental shelf.) The actual number of surface ships that will be assigned to coastal defense if the currant Maritime Strategy is used will be very minimal for the task. If all the remaining 73 ships not assigned to battle group protection were assiged to coastal defense, they could divide the 320,000 square miles in to 73 areas of 4,383 square miles each.

The 60 attack submarine will also be spread very thin in their wartime missions. The Soviets have 38 SSBNs in the Atlantic which are one of the top priority missions of the U.S. SSNs. The aircraft carrier and battleship will require SSN defensive support and so will the supply and amphibious groups. There are 132 non-SSBNs submarines in the Soviets Atlantic fleet that the the U.S. SSNs will have to fight along with other ASW units. For justification of the 600 ship Navy, the Navy estimated 40 Soviet submarines would be used in the Atlantic to attack the SLOCs. (13:247) Add the "other mission" of SSNs and 60 Soviet attack submarines against our SLOCs (Some would be in overhaul) does not leave many for coastal defense.

The ASW helicopters would be deployed on ships and most of the P-3 squadrons would also forward deploy to overseas bases. The amount of ASW coverage that airborne platforms could provided would not only be limited by airframes available, but also aircrews to fly continuous operations. The P-3s, S-3s, SH-2s, and SH-60s use sonobuoys as their primary ASW sensor and they are not an unlimited resource. Also, for helicopters, the storage and resupply of sonobuoys becomes a major problem on small ships. Sonobuoy usage will have to be managed closely and will prevent continuous large area sonobuoy search. The numbers showing ASW coverage that may be provided by airborne platforms is even harder to predict than the ASW coverage of ships. However, it is apparent that the combined forces of ships, submarines and aircraft have a lot of ocean to search with limited assets.

Chapter IX

Defense in Depth

Defense in depth will be required to maximize the effectiveness of ASW sensors and weapons and to attack the enemy while he is out of range of the east coast. It is important to realize that a successful ASW operation does not have to kill an enemy submarine. ASW must ensure the enemy submarine does not complete its mission. If a convoy sails from port and reaches its destination without coming under submarine attack or if the convoy does not get bottled up in a port, then the ASW units have succeeded. The number of assets made available for coastal defense will depend on the scenario that started the hostilities. If hostilities happens quickly and the location of most of the Soviets' attack submarines are known to be across the Atlantic, then the majority of the Naval assets can be sent out to intercept the enemy at forward deployed choke points. However, if hostilities have been building slowly and the Soviets have already deployed their submarines past the choke points and maybe even have some off the east coast, then the Navy will need more ASW platforms to clear the coastal waters leaving fewer available to forward deploy. In either case the first line of defense will come from detection, classification, and tracking from the SOSUS stations, TACTASS ships and SURTASS ships in open ocean. These passive array systems will provide the early warning and initial trigger to send a submarine, surface action group, P-3, S-3, or a helicopter to prosecute the contact. The United States

submarines will also be working the outer defense zone to stop the enemy. They may not necessarily attack the contacts because once they do attack their position is revealed. The U.S. Navy works exercises in which the submarines pass their enemy contact locations to surface and air assets for localization and attack. The P-3, S-3, and shipborne helicopters will be doing passive sonobuoy, radar, ESM, FLIR and visual search. Deployable long life passive sonobuoys will also be placed in strategic areas or to replace SOSUS coverage that has failed and gaps in SOSUS coverage. A weak link in the outer defense is the vulnerability of the cables and shore station for the SOSUS and the SURTASS ships which are not combatants and can not defend themselves. Even if the passive outer defense detects all or most of the enemy submarines, there may not be enough ASW platforms to prosecute all the contacts prior to some reaching the continental shelf. Just the presence of ASW platforms in an area should disrupt or delay the enemy submarine operations. The farther and longer he is kept away, the more combatants and supply ships can sortie.

The inner zone for this paper will be defined as the area of the start of the continental shelf up to two miles off the coast. This area is dominated acoustically by the effects of shallow water and the funneling of surface vessels to ports. Passive acoustic prosecution in many areas of the continental shelf can not be used tactically and active sonar ranges are usually very short. However, experience in some areas have shown that passive ranges on a contact may be good, but the filtering of other

background contacts makes it hard for a sonar operator to prosecute for localization and attack. Most of the ASW platforms will use active sonars, radar, ESM, FLIR and visual search. The British found the shallow water in the area of the Falkland Islands was characterized by large quantities of marine life, including whales, heavy mixing of layers and a rough bottom. This difficult ASW environment forced the Royal Navy sonar operators to rely on active ASW search tactics.(8:47)

There will be an increased need in the MDZ for Coast Guard ASW platforms. The USCG only has thirteen ships between both coasts which have ASW sonars and over-the-side torpedo capability. Coast Guard search aircraft are equipped with surface search radars not designed for detecting submarine periscopes and most do not have FLIR. In this area any military ship or aircraft, whether it can carry weapons or not, will act as a deterrent to enemy submarine operations. The submarine will be reluctant to transit or remain in an area that is flooded with active sonar and sonobouys or will cause it to present a radar cross section in a radar flooded area. Theoretically even a private fishing boat could detect a submarine on a fish finding sonar. Just think of that civil defense force! The whole MDZ will not be able to be covered, but the high threat areas could have defensive mines deployed and active screening of ships in controlled shipping lanes. The direct torpedo attack on a specific surface unit will be the hardest operation for the enemy to conduct. The 11 mile range of homing torpedoes (The 55 mile range of the wake homing torpedoes would not be "selective".),

the poor passive acoustic conditions, and the high risk of counterattack should require submarines to look before shooting. After he does fire a torpedo, than he becomes a hot DATUM (last known position of a suspected submarine contact). If a surface or air ASW asset is in the area, he becomes highly vulnerable to counter attack. The time late of the ASW platform starting its search is very important. For example, helicopter search plans for prosecution of a DATUM, a 20 minute time late or more gives a low probability of detection on a submarine with estimated speeds of over 15 knots due to the large Area Of Uncertainty (AOU) (78 square miles) and the short range of ASW sensors. With a full load of 25 sonobouys on an Sh-60B in the water and a two mile detection range, the sonobuoy coverage would be 314 square miles but the helicopter can only monitor about a third of the sonobouys at one time. Also in responding to a hot DATUM it takes time to put a sonobuoy pattern into the water. By 40 minutes time late, the AOU is up to 314 square miles. An enemy nuclear submarine at 20 to 30 knots clearing a DATUM quickly presents a single ASW operator with an AOU too large for his ASW sensors to cover. While the enemy submarine is clearing DATUM at high speeds, he is easier to detect on passive sensors because he is very noisy at high speeds. However, the passive sensors must be in place and "better detection ranges" is a relative statement. Increasing detection range (in some shallow water environments) of a sonobuoy from 1,000 yards to 3,000 yards does not considerably improve the ASW search solution because of the very large AOU's (60-300 square miles) and large areas to cover

even without a DATUM.

One drawback to using active ship sonars is that the Soviets' torpedo and missile ranges will in many situations exceed the range of the ships' sonars. The ships' transmission of his sonar acts as a beacon for the enemy submarine to classify and compute a targeting solution. Sonar are like radars in that they can be used by a receiver to quickly classify the platform that is emitting the signal. The air ASW threat and nontransmitting platforms act as a deterrent in a confused ASW environment. If the enemy submarine has the time to sort out through acoustics, ESM, visual and intelligence the positions of platforms capable of counterattack, active sonar may attract a weapon. This same situation holds true for the use of any active sensors.

Missile firing submarines in the inner zone present a different problem. They can stay well outside of the quick counterattack range of the shore or ASW platforms and fire their weapons. The Soviet Charlie II and Oscar class SSGNs carry SSN-9, 12 and 19 respectively with ranges of up to 340 nautical miles and the Soviets new SS-N-21 has an estimated range of 1,100 to 1,600 nautical miles.(2:22)(6:550) A national system of sensors which can detect a submarine cruise missile launch position and develop an accurate hot DATUM is not in place nor is one planned to be operational soon. A submarine that fires a missile in an area not covered by SOSUS or SURTASS presents a real problem in detection and a very large ADU (A 300 missile would have an ADU of 282,735 square miles). There needs to be a passive acoustic,

radar, or satellite system that provides launch detection and location. After the launch, a quick response ASW system to counterattack will be required along with an effective missile warning command and control system to alert missile defense systems. The Army and Air Force all have to be concerned with the missile firing submarine. It will have to be a joint service effort to defeat the threat. The Navy and Coast Guard have to stop the submarine before it launches, but if they fail, all the services will be involved in trying to stop both the land cruise missiles and the antishipping missiles.

Covert operation will be the main threat in the area from the shore out to two miles or coastal defense zone. A covert operating team has a wide choice of targets. Bridges, ports, oil platforms and navigational aids are just a few of the many targets that a covert team could destroy without even coming ashore. The defense of this areas will require a combination of resources from both the military and the law enforcement agencies. As in the other area, saturation by active search sensors, a good command and control system, and responsive counter-special-forces groups and ASW platform will be required as a deterrent.

CHAPTER X

FUTURE ASW

The shallow water environment is receiving increased attention within the ASW community and in the Washington Area. Current ASW torpedoes, which are optimized for deep water operations, are being modified to operate in shallow water and new torpedo designs such as the MK 50 advanced light weight torpedo (ALWT) will have increased shallow water capability. The advanced capability MK 48 torpedo program (ADCAP) is increasing the MK 48 capability in several areas including shallow water. SUBROC will be replaced by the submarine launched antisubmarine standoff weapon (ASWSOW). ASWSOW will be able to carry the MH 50 ALWT or a nuclear depth bomb. Other types of weapons from bombs with hydrostatic fuses to gun projectiles are being evaluated as weapons that are cheap, meet urgent attack requirements, and can either damage a submarine or spook it from its mission. Cheap weapons are being evaluated to avoid the dropping of expensive torpedoes (that are carried in limited numbers on ASW platforms) against every suspected submarine contact.

Research in the nonacoustic detection of submarines has provided some optimism in future detection sensors. Several published areas of research are: Submarine wake detection, turbulence created by the submarines which rises to the surface astern of the boat. They are referred to as far-field or Kelvin-type waves.; Submarine waste matter detection, identifying the neutrons particles and heat that are emitted from nuclear submarines reactors.; Synthetic aperture radars (SAR) carried by

aircraft or space vehicles may be able to detect the submarines wake.; Over-the-horizon backscatter (OTH-B), shore based radars for possible wake detection and missile launch detection.; Bioluminescence, the light that is emitted by living organisms when the submarine passes through them. These areas of non-acoustic detection are "theoretically" possible. They all need more research and budget support before they become an ASW asset.

Improvements in acoustic detection is and will remain a high priority. Technologic improvements in fiber optics and superconductivity will enhance the acoustic capability of towed and fixed sonar arrays against the quieter new generation Soviet submarine both in the open ocean and in shallow water. There are also advances in long range active detection by using high power and low frequency. Low frequency active sonars may provide an active barrier for areas of the continental shelf.

The area of missile and torpedo launch detection and countering needs to be focused on by all the services. It is an area that the United States is limited in its ability. Once a land cruise missile is launched from a submarine, it becomes an Air Force problem to track and intercept it before it hits a target. This area is getting budgetary support under the Air Force and Navy directed Air Defense Initiative (ADI) Program as a joint service issue and is working in conjunction with the Strategic Defense initiative (SDI). (1:2 & 17)

The purpose of the ADI Program is to develop an air defense system to defend North America against low-observable penetrating bombers and air- and sea- launched cruise missiles. The Office of the Secretary of Defense (OSD) manages the program, which is executed by the Air

Force and the Navy.

The Navy's current ADI requirement is to track submarines carrying cruise missiles that are in range of North America to permit destruction of the submarine and/or direct the engagement of cruise missiles in flight. Detection and localization of submarines are becoming more difficult because of Soviet quieting and because of the expanded numbers and types of submarines with cruise missiles. Increased numbers of Soviet submarine-launched cruise missiles are expected to be available by late 1990's.

CHAPTER XI

CONCLUSION

The current Maritime strategy is based on the assumption that the Soviets will not send a large number of Soviet submarines into the Atlantic prior to hostilities. It is also assumed that the United States can bottle up the Soviet submarine forces north of the G-I-UK gap and the United States technological superiority will overcome the Soviet advantage in numbers of submarines. These assumptions are certainly not certainties, which leaves a lot of potential for the Soviets to have their submarines reach the SLOCs and the east coast of the United States. This is a credible possibility and with the incentive the Soviets would have to close the bridge across the Atlantic they should be expected to make a major effort to do so. The U.S. Navy and the U.S. Coast Guard must make this threat believable as they press their cases for increased funding to build up the necessary ASW capability to defend U.S. coastlines. In the area of joint service action, the congress, the Army and the Air Force may find it hard to understand how a numerically inferior force is going to sail into the Soviets home waters at the beginning of the war and survive with enough assets left to protect the vital supply line to Europe. Both the Army and the Air Force can understand what havoc "leakers" can cause in their areas of defense. The Navy needs to prepare for theirs.

SHALLOW WATERS OF THE WORLD

SOURCE: THE ODYSSEY WORLD ATLAS, ODYSSEY BOOKS/NEW YORK

DEPTHS LESS THAN 200 METERS

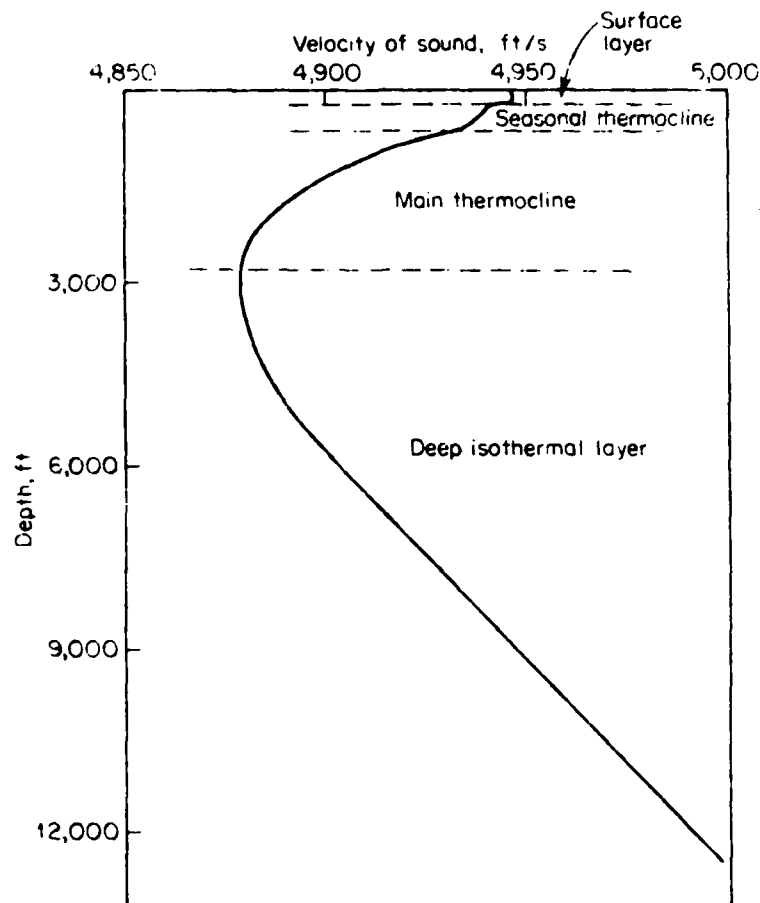


APPENDIX 3

ASW acoustic predictions are done with the aid of sound velocity profiles from areas of the ocean. ASW sensor selection and tactics are determined by these acoustic predication. Before going into the problems of shallow water acoustics, one needs to understand the basic sound velocity profile. Taken from Robert J. Urick's book Principles Of Underwater Sound:(14:117)

A typical deep-sea profile is shown in Fig. xxx. The profile may be divided into several layers having different characteristics and occurrence. Just below the sea surface is the surface layer, in which the velocity of sound is susceptible to daily and local changes of heating, cooling, and wind action. The surface layer may contain a mixed layer of isothermal water that is formed by the action of wind as it blows across the surface above. Sound seems to be trapped or channeled in this mixed layer. Under prolonged calm and sunny conditions the mixed layer disappears, and is replaced by water in which the temperature decreases with depth. Below the surface layer lies the seasonal thermocline---the word "thermocline" denoting a layer of which the temperature changes with depth. The seasonal thermocline is characterized by a negative thermal or velocity gradient (temperature or velocity decreasing with depth) that varies with the seasons. During the summer and fall, when the near-surface waters of the sea are warm, the seasonal thermocline is strong and well defined; during the winter and spring and in the Arctic, it tends to merge with, and be indistinguishable from, the surface layer. Underlying the seasonal thermocline is the main thermocline, which is affected only by seasonal changes. The major increase in temperature over that of the deep cold depths of the sea occurs in the main thermocline. Below the main thermocline and extending to the sea bottom is the deep isothermal layer having a nearly constant temperature near 39 F, in which the velocity of sound increases with depth because of the effect of pressure on sound velocity. Between the negative velocity gradient of the main thermocline and the positive gradient of the deep layer, there is a velocity minimum toward which sound traveling at great depths tends to be bent or focused by refraction. At high latitudes, the deep isothermal layer extends nearly to the sea surface.

Fig. 1



Typical deep-sea velocity profile divided into layers

Source Principle of Under Water Sound by Robert Urick

SHALLOW WATER ACOUSTIC PHENOMENA

The acoustic detection of targets, whether surface or sub-surface, in a shallow water environment is more difficult than in the open ocean. An ideal ASW shallow water environment is where there is isovelocity sound condition (sound velocity versus depth is constant), a good reflective bottom composition, nonsloping bottom, and a good reflective surface. Under these "ideal" conditions, which are not often encountered simultaneously, good target detection capability is available due to sound ducting in what is referred to as a multipath environment. As conditions vary from the "ideal", detection capability decreases.

Effect of the Bottom. The sea bottom effects sound propagation through: bottom absorption; scattering loss; vertical sound speed distribution; stratification of the bottom; bottom topography; bottom composition; bottom slope. In shallow water the sound source is closer to the bottom causing many reflections of the sound waves. Bottom composition (mud, silt, sand or rock) affects the sound wave each time it hits the bottom through scattering, reverberation, and attenuation. This causes a reduction in the sound source level and detection ranges are decreased as the source levels are decreased. Since rock and wrecks on the bottom provided an acoustic echo to an active sonar, false target are also higher where the active sonar waves are capable of reflecting off the bottom.

A sloped bottom causes unusual sound propagation that not only decreases detection ranges (disruption of the multipath) but also effects bearing and range accuracy. Not knowing what type of sea bottom operations are being conducted over, makes sonar ranges and target detection predictions difficult.

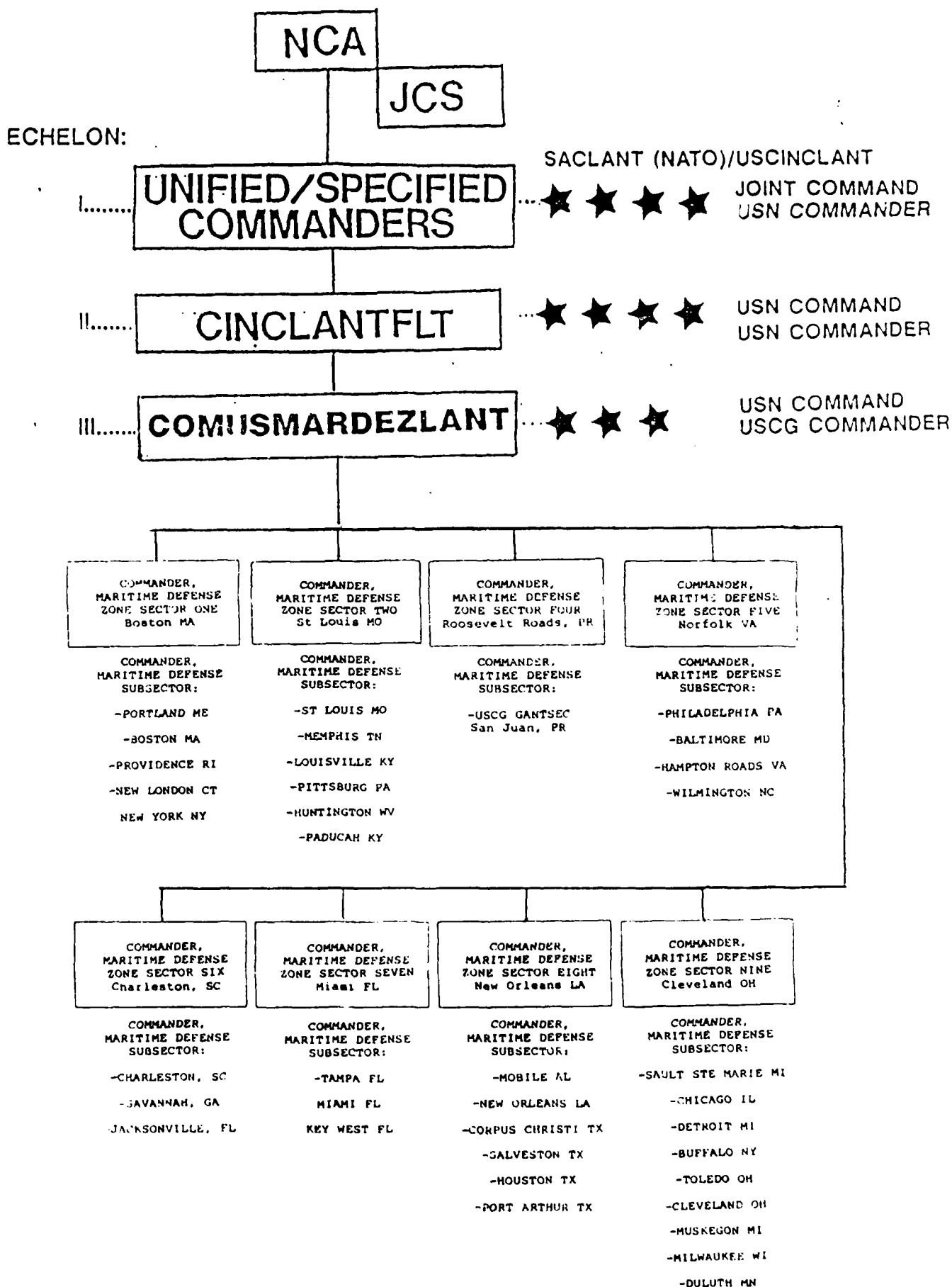
Ambient Noise. Tides, waves, biologics, shipping, fishing vessels, land based industry, and oil rigs cause very high levels of ambient noise in shallow water coastal regions. Ambient noise masks the sound produced by targets. In deep water, ambient noise is well-defined. In coastal water ambient noise is variable from time to time and place to place. This noise can greatly decrease the probability of detection and in many areas restrict the use of passive sonars and sonobouys.

Biologics. Coastal areas have a greater density of biologics (marine and plant life) than the open ocean. Biologics cause reverberation and scattering of sound waves. Plus they add to the ambient noise from their own noise and the noise of fishing vessels attracted to the area. Gaseous waste produced by the life cycle of plants and animals forms gas bubbles that also increase the sound source level loss through reverberation and attenuation.

The Water Column. Sound speed profile prediction in shallow water is very difficult due to the rapid change in water density caused by variations in temperature and salinity. These changes occur because of weather, ocean fronts and eddies, and the influence of fresh water streams and rivers. These phenomena mix rapidly and develop distinct boundary areas in shallow water. Inconsistent temperature and salinity causes sound speed profiles to change radically, resulting in variable sonar ranges in small geographical areas.

Weather. Weather causes variable thermocline, surface scattering and increased ambient noise from wave action.

The bottom line on shallow water ASW - it is not predictable for tactics using passive acoustics and current active sensor are limited in range.



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