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THE CONVENTIONAL SUBMARINE THREAT IN LITTORAL REGIONS

by

Victor G. Ristvedt
Commander, USNR

A RESEARCH REPORT SUBMITTED TO THE FACULTY

IN
FULFILLMENT OF THE CURRICULUM
REQUIREMENT

Advisor: Captain Larry Beatty, USN

MAXWELL AIR FORCE BASE, ALABAMA

April 1993

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EXECUTIVE SUMMARY

TITLE: The Conventional Submarine Threat
in Littoral Regions

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The United States Navy white paper, "From the Sea" assumes that the most likely naval confrontation in the future will be in the littoral regions of the earth. The Navy's force structure is decreasing in response to domestic fiscal constraints while countries in the very regions we may fight "From the Sea" are buying conventional submarines. The ships submarines and aircraft now being flown were designed for deep water operations. Fighting in shallow and confined waters will require a hard look at what is needed for this emerging threat.

The manufacturers of conventional submarines are rapidly improving the underwater endurance, automation, and fire power of their products and are aggressively selling them. Their relatively inexpensive price tag makes them especially appealing to nations unable to afford a surface navy competitive against U.S. forces. History is replete with examples of the dangers of being caught short of ASW assets. Current Navy direction is concentrating too much money and fire power into too few platforms to carry out the ASW effort that will be required in the littoral and in guarding the sea lines of communications essential to any future war effort.

BIOGRAPHICAL SKETCH

Commander Victor G. Ristvedt has been involved in Anti-Submarine Warfare throughout his career in the Navy. He has served in four Maritime Patrol Squadrons in the Mediterranean, North Atlantic, Caribbean, Western Pacific and Indian Ocean. He has also served on Reserve Patrol Wing Atlantic staff as Maintenance Officer and served as Officer-in-Charge of Patrol Squadron Sixty.

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INTRODUCTION

In the intervening years, since the collapse of the Soviet Union, the nations of the world (with very few exceptions) have significantly reduced their defense budgets in order to devote national resources to more pressing domestic concerns during a general world-wide recession. The defense forces of the United States are no exception as major force reductions are scheduled to continue through out the rest of this century.

With the threat of conflict with a major naval power greatly reduced, the United States Navy focused on likely regional conflict scenarios and abandoned its long vaunted deep "Blue Water" strategy that revolved around major open ocean battles with the Soviet Navy. The white paper that lays out the general re-focus of future naval effort, "From the Sea", recognizes that future threats to national interests of the United States will require the concentration of naval forces and capabilities in the littoral or coastal regions of the earth. This redirection has involved, as its centerpiece, the ability to dominate the battle space of an opponent's coastal region and to project that dominance ashore. This "battle space dominance" consists of land elements, (primarily Marine forces); air elements composed of carrier air (Naval and Marine); and sea elements that are divided into surface and subsurface platforms.

In planning the deployment of forces it is necessary to anticipate how potential opponents might counter or initiate hostile action. This paper will assess the suitability of United States Anti-Submarine Warfare platforms to operate in the littoral; the

suitability of current Anti-Submarine Warfare detection technology to detect conventional submarines in the littoral and the current capabilities of conventional submarines and trends in their technological improvement. Also to be examined will be the rate at which those changes are occurring, the possible roles and missions of conventional submarines in the future, and what is needed by United States Naval ASW forces to counter this conventional submarine threat in the littoral regions.

This paper will deal exclusively with the conventional or "non-nuclear" submarine. These diesel-electric powered boats are relatively inexpensive when compared with nuclear submarines, easier to maintain, and with developing technology, are becoming increasingly more capable of performing a host of undersea missions. In regards to countering this threat, this paper will look at projected Anti-Submarine Warfare forces in the United States Navy, new developments to counter the threat and an examination as to whether these efforts will be sufficient.

Note: Recognizing that military acronyms can make for difficult reading, this paper is devoid of them except for one--ASW. ASW or Anti-Submarine Warfare is the art of search, identification, localization, tracking and, if necessary, attacking and destroying a submarine. Its use is so prevalent in this paper that the acronym is used throughout for easier reading.

CHAPTER I

DETECTING SUBMARINES IN THE LITTORAL

The initial detection of a submarine is a very exacting and time consuming operation which ties up vast numbers of ASW assets including submarines, surface forces and fixed-wing aircraft and helicopters. Much of the effectiveness of the initial detection relies on intelligence concerning the enemy, his way of thinking, and his technological capabilities. Even after detecting and then effectively tracking and localizing a target, it still has to be attacked and destroyed, and this can be difficult.

The current technology of detecting submarines through primarily passive means is inadequate to dependably prosecute a submarine in all littoral conditions. Active sonar is the optimum tool at present but present active gear was designed for deep water where bottom bounce was no problem. The active ship sonars developed in the 1970s and 1980s expended enormous amounts of energy into the water to achieve long detection ranges. Those same systems can almost deafen a crew in shallow water as the sound is reflected off of the bottom and into the ship. Another problem associated with active sonar is using it to gain initial contact. The sonar initiator is at a disadvantage because a target can always hear an active signal from an active sonar before the signal is strong enough to be reflected back to the originator. The target submarine has two options, he can turn away from the source, or he can use the signal emanating from his opponent's sonar

as a beacon on which to aim his own torpedoes. In trying to gain contact on a submarine it is always better to know his approximate position so that when the active sonar is turned on, the submarine is already within detection range. Often times sonar is used in this manner not to detect but to deter.

The Falkland Islands War

The difficulty in finding a conventional submarine in shallow waters can perhaps best be understood by recounting the relatively recent efforts of the British Navy during the Falkland Islands War. The ASW actions conducted during this war provide a prime example of how difficult submarine detection is, the effect that a limited size threat can have on an opponent's naval operations and the effect of a limited ASW capability (Argentina's) on national war aims..

The war, fought over sovereignty issues of the Islands between Great Britain and Argentina in 1982, began with an Argentine invasion force firmly placing itself upon the islands with the British Navy 8,000 miles away. The British Royal Navy later arrived in the area with a sizable fleet of aircraft carriers, cruisers, destroyers, troop ships, submarines and an air component derived of Harrier jump-jets, Vulcan bombers and ASW helicopters. Besides its ground troops on the Falkland Islands, Argentina's military operated with Mirage fighters and a small Navy that included an aircraft carrier, a cruiser, several frigates and two submarines, one of which did not operate in the war.

Hydrographically, this was a littoral naval campaign. The continental shelf of Argentina is shallow and very broad. The shelf extends 600 miles out from Argentina beyond the Falkland Islands themselves. The conditions along the shelf are conducive to mixed sound wave propagation, uneven water temperature mixing and bottom bounce phenomenon--conditions difficult for an ASW force and conducive to protecting a submarine--especially a quiet one.

The Argentina submarine, *San Luis*, was a modern German Type-209 diesel-electric. The *San Luis* stalked British targets though out the sea campaign of the war. Although firing several torpedoes, it was unsuccessful in scoring a hit because of an inoperable fire control panel.¹ Despite this problem, the submarine continued to shadow the fleet despite repeated efforts on the part of the British to find and destroy it. The British expended over 200 ASW weapons on over 300 sonar contacts during the war without success.²

The British submarines, unlike their Argentine counterpart, did not face a serious ASW threat and effectively controlled the waters in their area of responsibility. After the political decision was made to strike beyond the previously arranged exclusion zone around the islands, a British submarine found the Argentina cruiser *General Belgrano* and sank her with the loss of over 400 men.³ The Argentine Navy, realizing its inability to counter the submarine threat with a credible ASW counter-force, was forced to abandon its attempt at using the sea to replenish ground forces on the Falkland Islands with supplies and to provide naval fire support.

Several lessons were learned from this war:

- Substantial subsurface and surface ASW defense is required when a naval task force is constrained to work in one area (the Falkland Islands littoral)

- The British under-anticipated the difficulty of detecting a diesel submarine in shallow waters. They expended ASW ordnance at a higher rate than they had planned and were close to running out at the end of hostilities.⁴

- The threat of one known enemy submarine in an area of naval operations greatly restricts the freedom of movement of those ships.

- Without a capable ASW force opposing them, submarines can effectively control a battle space area and sink targets at will.

- That the British Navy, considered by many naval experts as the best ASW Navy in the world, could not find and destroy a modern diesel submarine that was in its midst for a long period points out the potential threat of conventional submarines in any future littoral conflict.

The Battle for the North Atlantic

The effort to dominate through technological means is well established in submarine and ASW operations, both in the present and the past. At no other time has submarine and ASW technology and doctrine evolved as rapidly as during World War II. The efforts by Germany's *Unterseeboote* or U-boat fleet to shut down the Allies' sea lines of communications and the Allied ASW forces counter efforts

provide valuable insight into how future wars will be fought in littoral regions between opposing maritime forces.

At the beginning of hostilities, the German U-boat command, was undersized for offensive operations with only 39 operational U-boats. The British Navy, however, was inadequate in one area--ASW. The British Isles, dependent upon war commerce from the United States, did not have the technology nor the doctrine to stop the U-boat. Although the German Navy lost 28 U-boats during the first year of the war, they sank twelve British combatants and 438 merchant vessels totaling 2.3 million tons.⁵

A battle of rival technologies soon began with the advantage alternating between the U-boat and the ASW forces. German U-boats found their richest target environments in the shallow waters of the North Sea and to the west and south of the British Isles where merchant vessels converged to go into and out of port on their way to and from the United States and the Mediterranean. The Germans dominated the seas using the "wolf-pack" tactic of several U-boats preying on lone ships or separating and then attacking a ship out of a convoy. That changed in the Fall of 1941 when the British began extensive use of ASDIC which was an active sonar system that transmitted a sound pulse that would be reflected back to a receiver if it met some object in the water. Also at this time the British outfitted most of its ships and some of its aircraft with radar to detect surfaced U-boats. The results were dramatic as U-boats were forced to submerge and break off contact with escorted convoys.⁶

The entry of the United States into the war provided a new target rich environment (the Eastern U.S. seaboard) with little ASW capability. Germany sank 600 ships in U.S. shallow waters during a five month period in early 1942.

Between early 1942 and June of 1943 both sides leap frogged the others capabilities four times. The British developed a 1.5 meter radar which was countered by a radar detection devise known as the Biscay Cross⁷ giving German U-boats a n opportunity to escape. The British then developed a 10cm radar that the Germans could not counter and also incorporated larger fuel tanks giving ASW aircraft the range to cover the mid-Atlantic. The Germans decided to develop another approach at avoiding detection--the snorkel. A major drawback of the U-boat was its requirement to surface periodically to run its diesel to recharge the batteries. This had to occur every eight or nine hours for approximately one hour,⁸ a time of maximum danger to the submarine because it was fully exposed. The snorkel was a hollow mast that extended up from the submarine to allow air to be sucked into the diesel while the craft was still submerged and less vulnerable to attack.

The British soon countered with a tactic called "creeping attack"--one escort ship would hold the U-boat on ASDIC and position a second escort, with its ASDIC off, towards the U-boat until it was overhead and in position to fire depth-charges. Two other escorts would follow, to pick the U-boat up if it turned away.⁹ Much like the

U-boats' own famous early-war "wolf-pack" tactics, creeping attack emphasized the coordinated attack of the many against a sole target.

Table 1 illustrates the direct cause and effect relationship of this historic technological battle.

Table 1
GERMAN U-BOAT VERSUS BRITISH ASW

DATE	BRITISH DEVELOPMENT	GERMAN DEVELOPMENT	SHIPPING TONNAGE SUNK	U-BOATS SUNK
JAN '40	-----	Wolf-pack tactics	300,000	2
JUN '40	ASDIC	-----	100,000	2
JAN '42	-----	Trans-Atlantic	300,000	3
FEB '42	-----	"Milch cows"	500,000	2
APR '42	1.5m Radar	-----	400,000	4
AUG '42	-----	Biscay Cross	520,000	9
MAR '43	10cm Radar long range ASW acft	-----	318,000	17
JUN '43	-----	Snorkel	101,000	17
OCT '43	Creeping Attack	-----	69,000	26

Sources: U-Boats at War, Harald Busch
The U-Boat Wars, Edwin Hoyt
Submersible to Submarine, Jonathan Crane

The technological battle continued beyond the war's conclusion. The lessons of the battle for the Atlantic were not lost on those responsible for Cold War ASW forces. Among the many developments were; direction finding passive sonobuoys, towed arrays of passive sound receivers, helicopter dipping sonar, permanently placed passive sonar

arrays called SOSUS, and continual refinement of active sonar systems and surface radars. To counter these improvements, submarine forces on both sides advanced their own technologies to produce unlimited endurance (nuclear propulsion), quieter mechanical systems and more sophisticated fire control systems and weapons.

CHAPTER II

THE INVENTORY OF CONVENTIONAL SUBMARINES AND U.S. ASW ASSETS

Conventional Submarines

The manufacturers of modern non-conventional submarines are located in Europe, Russia and Japan where advanced industrial basis and support infrastructure exist. There is, however, a growing trend of third world nations licensing the ship building technology and implementing indigenous building programs as a cost-savings measure, and as a stimulus to building their own industrial base to ensure future independence from outside political constraints.

Table 2 lists the manufacturers who export, their country of origin, the product they produce and the buyers.

Table 2

THE CONVENTIONAL SUBMARINE MARKET

Manufacturers/Country	Product	Buyers
Dubigeon/France	Agosta	France, Spain, Pakistan
Spetsvneshtekhnika (GTD)/Russia	Kilo	Algeria, India, Romania, Poland
Thyssen Nordseewerke, Howaldtserke- Deutsche/Germany	Type-209	Greece, Brazil, Argentina, Chile, Columbia dor, Indonesia, India ekey
	TR-1700	Argentina
Kockums/Sweden	Type A-17	Australia

sources: Modern Submarines, David Miller
Submarines, Tom Clancy
Jane's Warfighting Ships of the World, 1992-93

Not all manufacturers sell to foreign clients. Some have unproved track records making it difficult to enter the market. Politics is involved in most transactions although there are interesting exceptions. Sweden, an internationally recognized and self-proclaimed "neutral", advertises extensively to sell their Stirling engine propelled submarines. Political pressure is not uncommon in preventing submarine sales. Germany's Thyssen Nordseewerke attempted to sell Taiwan ten Type-209 submarines in October of 1992 but the Chinese pressured the German government to turn the sale off.¹⁰ The Netherlands' Rotterdamse Droogdok Maatschappij Corporation attempted to sell the Zeeleeuw submarine to Taiwan in 1993 with the same results.¹¹ Governments are also wary of the political pitfalls of selling to perceived "bad actors". The Russians were contracted to

sell three Kilo class submarines to Iran and delivered two as scheduled but halted the third delivery in December 1993 over concerns of regional instability.¹² Lastly, governments will not permit the sale of weapon systems that could jeopardize their technological edge. The Germans' Type-212 submarine is not for sale nor is the Russian Tango. Table 3 lists the submarines not yet sold to international customers.

Table 3
MODELS CURRENTLY NOT EXPORTED

Manufacturer	Product	Note
Spetsvneshtekhnika, (GTD) Russia	Tango	Suspected Missile Capability
Thyssen Nordseewerke, Howaldtserke-Deutsche, Germany	Type-212	Fuel Cell
Kockums, Sweden	Type A-19	Stirling Engine
Rotterdamse Droogdok Maatschaoij, Netherlands	Walrus	Has "X" fin pattern to better sit on sea floor
Mitsubishi, Japan	Harushio	Highly Automated
Kawasaki, Japan	Yucca	Diving Depth - 3,280 feet
Italcantieri, Italy	Primo Longobardo	Advanced Fire Control
Fincantiere, Italy	Salvatore Pelosi, S-90	Sub-Harpoon capable
C.R.D.A., Italcantiere, Italy	Nazario Sauro	Holds 12 ASW Torpedoes

sources: Modern Submarines, David Miller
Submarine, Tom Clancy
Jane's Fighting Ships of the World, 1992, 1993

U.S. ASW Assets

The ASW inventory of the United States Navy is the largest in the world with over 680 ASW assets¹³ The inventory is composed of attack

submarines, surface ships, land and carrier based fixed wing aircraft, and helicopters. Table 4 gives current and projected force strength by platform.

Table 4
CURRENT AND PROJECTED ASW FORCE STRENGTH

Platform	Type	FY 1994	FY 2000
Surface Ships	Cruisers	32	22-27
	Destroyers	38	32
	Frigates	35 (24)*	0
Submarines	Attack	81	45-55
Fixed Wing Acft	P-3	144 (72)*	104 (72)
	S-3	118	118
Helicopters	SH-60B	139	191

Source: Sea Power 1994 Almanac

* denotes additional Reserve assets

CHAPTER III

UNITED STATES ASW CAPABILITIES

Attack Submarines

The United States' attack submarine fleet is composed of two classes--the *Los Angeles* Class and the *Sturgeon* Class. Attack submarines are considered the best ASW prosecution platforms because

they operate in the same environment as their chief adversary another submarine. Besides unlimited endurance and high submerged speed, they have exceptional sonar systems. One problem in littoral warfare, however, is the size of a nuclear attack submarines compared to the typical diesel submarine--6,900 tons for a *Los Angeles* class boat¹⁴ to a Type-209's 1,140 tons. The larger size presents a larger surface area for sonar to reflect off of, giving the smaller submarine the advantage of first detection in a one-on-one active sonar scenario. Another disadvantage of the larger nuclear submarines is that while it can go faster (30+ knots compared to 20 knots) it will be going slow in the search phase. If both submarines detect each other at roughly the same time, the diesel can accelerate at a faster pace than the much heavier nuclear submarine.

Surface Ships

Surface ships provide inner zone defense against a submarine threat. Usually grouped around a high value unit such as an aircraft carrier, surface vessels can use either active or passive sonar to detect and deter or attack an enemy submarine. Cruisers, destroyers, and frigates provide multiple sensors, including helicopters to ensure that the submarine does not get within striking distance.

Effective use of cruisers as ASW platforms is limited. Built with powerful sonar systems designed for deep water, these same systems are often unusable in shallow waters because of the bottom-bounce of the signal back to the hull of the ship--drowning out the return signal from a distant target. The *Ticonderoga* class cruiser and its Aegis

radar system were designed primarily for one job--protecting aircraft carrier battle groups against high-density raids from a sophisticated threat.¹⁵

Destroyers, which are slightly smaller than cruisers, have excellent active and passive ASW hardware but with the introduction of the Aegis radar system, the focus has been on moving towards offensive power projection, namely Tomahawk missiles.¹⁶ ASW helicopters will be put on the decks of these ships starting in 1994.

The frigate is the smallest of the surface combatants with only one power train versus two for the cruiser and destroyer. It is relatively inexpensive when compared to the cruiser and destroyer¹⁷ (note H.2 \$1B) and brings an effective towed acoustic array, a sonar system well suited to shallow water and two helicopters. Frigates do not bring battle force or offensive power to the sea campaign--they bring protection of shipping from submarines. They are scheduled to be phased out by the year 2000.

Land-based Maritime Patrol

The P-3 aircraft is the sole U.S. long-range ASW platform. The four engine aircraft carries advanced imaging radar, a magnetic anomaly detector, 88 sonobuoys, and a wide variety of weapons. With 12 hour endurance, P-3s can conduct ASW searches over large areas of water, however, they need external intelligence on the approximate location of the submarine to have a reasonable chance at detection. Other options include deploying sonobuoys across a choke point or area

that geographically forces a submarine through a relatively narrow passage. P-3s have relied almost entirely on passive detection but are now forced to use active sonobuoys in the search for diesel submarines in shallow waters.

Carrier-based ASW Aircraft

The S-3 is a highly capable carrier-based ASW aircraft with a four man crew, six to eight hours of endurance, and carries 60 sonobuoys. The S-3 acts as the ASW arm for the aircraft carrier and its primary mission is to ensure the safety of the carrier battle group from subsurface threats. Since it is not necessary to find the submarine to keep it away from the carrier (the act of actively searching can force the submarine to withdraw), the S-3 will normally clear the waters as the group moves through them.

Helicopters

The SH-60B helicopter is operated from surface ships to provide medium range (100-150 miles) ASW capability beyond the detection range of the ship's own sensors. The SH-60B carries 25 sonobuoys whose signals are relayed back to sensor operators aboard the mother ship to be processed and analyzed for targets. The craft carries a magnetic anomaly detector, two torpedoes and dipping sonar. The dipping sonar, if it is within range of the submarine, provides the crew the information they require to stay constantly on top of the submarine. Again, like the other air assets, cueing information is needed to have

an effective search with a reasonable chance of detection, otherwise the search is used to clear the area.

Future Capabilities

In the ongoing quest for ASW supremacy, the U.S. Navy is investigating several different leads in the area of submarine detection. The efforts can be divided into two areas--acoustic, and non-acoustic. About \$40 million was spent on this ASW research in 1993¹⁸ and the emphasis has been on inserting the technology on existing platforms as an inexpensive alternative to building new platforms from the ground up.

Among acoustic initiatives is the ongoing development of low frequency active sonars and sonobuoys. Low frequencies around the 1000 KHz range have extremely long ranges--the draw back is that the signal is difficult to focus and it is difficult to determine the direction of returning signals. If this problem can be resolved, low frequency active sonar may well be the best tool for ASW in the littoral.

One non-acoustic initiative involves using laser light to detect and determine the range of a submerged submarine. Current testing is being conducted on P-3s and SH-60s to determine the feasibility.¹⁹ The Russians are working on a similar program attaining coverage paths 100 yards wide and submarine detections down to 100 feet.²⁰ If U.S. efforts are in this range, the laser would be used much in the same way as magnetic anomaly detectors are used now--primarily for final firing solutions after the submarine has already been localized and tracked.

Another initiative involves using unmanned undersea vehicles and unmanned air vehicles as comparatively inexpensive force multipliers. The use of fiber optics and lightweight composites promises to produce interesting possibilities in stretching the reach of ASW forces. One question, however, is whether the effort and funding now being authorized will get the results needed by the year 2000 when smaller U.S. ASW forces will face a larger and more sophisticated conventional submarine force.

CHAPTER IV

CONVENTIONAL SUBMARINE CAPABILITIES

PRESENT AND FUTURE

Increasingly, other nations are coming to expect subsurface platforms capable of effectively countering the established standard of warfighting ability demonstrated by NATO forces and that of Russia. Although Russian and German submarine sales dominate the market, many of the advancements in technology are coming from the competition looking to enter the market. Attention must be given to monitoring these technical advances with the understanding that competition on the open market is as much a driver of submarine improvements as perceived military strategic requirements.

Present Capabilities

The majority of diesel-electric submarines are very similar to their World War II ancestors--using diesel engines to run generators to recharge lead-acid cell batteries. These batteries power the electric motor that drives the propeller drive shaft. Diesel-electrics depend on outside air to run their diesels to recharge the batteries. Improved batteries have reduced this time (known as the discretion ratio--time on diesel to time on batteries) to approximately 10%; so in any given 24 hour period a diesel-electric needs to surface or snorkel for about two and a half hours. Because conventional submarines are designed for shallow waters, they have no need for the deep diving capabilities of by nuclear submarines (with the exception of the Japanese).²¹

Diesel-electrics are quieter than nuclear submarines which require coolant pumps. In a shallow water environment where sound propagation is already a difficult problem to resolve, a diesel-electric surpasses the stealth capability of its nuclear cousin.

The relative cost of a conventional submarine compared to that of nuclear models is significant. The safety-redundant features required on nuclear submarines, the nuclear plant itself, the extensive training required to operate the nuclear plants, an extensive infrastructure required to support nuclear fuels replenishment, handling and disposal--all contribute to put nuclear submarines outside the fiscal means of most nations. Without factoring in infrastructure costs, a nuclear submarine can easily run one billion

dollars or more. By comparison, diesel-electrics have low intensity manpower requirements, building materials, training requirements, and infrastructure. While the typical nuclear attack submarine requires 80 to 130 crewmen, the German Type-209 requires only 31. The current price for the Type-209 (1200 model) is \$186 million and the Russian Kilo reportedly costs \$250 million.²²⁹ It would be misleading however to imply that nuclear submarines are overpriced and inferior to diesel-electrics. Nuclear submarine reach submerged speeds matching that of most surface targets and of course the ability to stay submerged indefinitely without risking detection on the surface is an invaluable attribute. The trend in conventional submarines is to try to duplicate these nuclear capabilities at an affordable price. Table 5 illustrates comparative capabilities of the major conventional submarines now operating world-wide.

Table 5
EXPORTED CONVENTIONAL SUBMARINE CAPABILITIES

	Kilo	Type-209	A-17	Agosta	S-90
Length	73m	67.3m	48.5	67.6m	64.4
Displacement	2800T	1230T	1143T	1740T	1662T
Manning	53	31	21	54	50
Max submerged speed	20kts	22kts	20kts	20kts	19kts
# of 533mm torpedoes	18	14	18	20	12
missiles	possible	no	no	no	yes

Source: Modern Sub Hunters, David Hunter
Jane's Warfighting Ships of the World, 1992-1993

Technological Developments

Propulsion

The most important conventional submarine advances have come in the area of propulsion. The diesel-electric submarine's Achilles' heel is its need to surface (or snorkel) periodically to recharge its batteries. During this period its diesel engine generates a relatively loud noise signature and the snorkel presents a radar target. Extensive research has been conducted in a number of countries to either greatly improve the indiscretion ratio or to do away with the surface requirement altogether with a totally different system.

There are currently three air independent propulsion systems being actively integrated into submarines--the Stirling engine, built in Sweden, a fuel cell system built in Germany and a closed-cycle diesel system developed in both Germany and Italy. The Stirling engine mixes liquid oxygen from a cryogenic storage system and diesel fuel together into a combustion chamber and ignites it. A heat transfer system converts the heat of combustion into electricity. The Stirling engine produces 65 kilowatts maximum continuous power while consuming 250 grams of diesel fuel and 950 grams of oxygen for every kilowatt hour generated.²³ The engine is 15 to 25 decibels quieter than a standard diesel-electric and its generators are in parallel with the batteries to simplify power control. The manufacturer, Kockrums, states that submerged endurance has increased to two weeks,²⁴ and is offering the engine on the open market as a retrofit into existing

submarines or to be integrated into new models. The Swedish Navy is currently operating their Natchen class submarines with this system.²⁵

The fuel cell system, developed by Howaldtswerke-Deutsche, Ferrostaal and Siemens, is a complete departure from the combustion system. In a fuel cell, two chemicals combine in the presence of a catalyst, to produce DC electric current. Efficiency is high--up to 70 to 80 % in some cases.²⁶ There are no severe heat dissipation problems, and in many cases the by-product of the reaction is pure water. Liquid oxygen is carried in an cryogenic container and the hydrogen is bound up in an iron/titanium alloy hydride.²⁷ Once fully charged, the batteries may be switched out of the power circuit and kept fully charged until required. The advantages of the fuel cell system are two-fold--only the auxiliary cooling system has any rotating parts. Since direct current is produced, there is no need for transformers or generators--the process itself takes place noiselessly. Its other advantage is submerged endurance. The fuel cell system to be used in Germany's Type-212 will allow two weeks of operations without the need for snorkeling.²⁸

The closed-cycle diesel engine is a standard engine modified to use liquid oxygen and diesel fuel. Fuel consumption on a closed-cycle is identical to a standard diesel engine system. Thyssen Nordseewerke is currently pursuing projects for the retrofit and modernization of existing conventional submarines with closed-cycle propulsion. A two-engine closed-cycle system would provide the energy storage of about 30 megawatt hours²⁹ and would allow a submarine to run completely

submerged at patrol speeds for two weeks without snorkeling. The RDM shipyard in the Netherlands has built a closed-cycle diesel, including a 600 kilowatts DC generator, a liquid oxygen storage and supply system with a 60 ton capacity, a system for argon gas storage, and a CO² scrubber. Calculations show that with the inclusion of an exhaust bypass system, a 1000 kilowatt diesel generator could run for three weeks at full power on closed-cycle.³⁰

Hull Designs

The placement of propulsion systems and storage tanks in submarines has basically remained as it was in the first models built. The hull is the barrier to the water pressures and the tanks and engines are contained within. An Italian defense company, Maritalia, has designed a submarine whose hull design may result in performance challenging that of a nuclear submarine. Called the GST (for Gaseous Storage in a Toroidal hull), this submarine's hull is constructed from a series of circular pipes, or toroids, with the prime energy source, gaseous oxygen stored within the toroids at a pressure of approximately 5,150 pounds per square inch.³¹ The oxygen is combined with diesel fuel for an ordinary diesel engine converted to closed-cycle running. Exhaust gasses are scrubbed and neutralized and stored back into vacated space within the toroids. Tests show that weight for weight the GST is five times stronger than submarines with normal steel plating. Another major advantage is that the GST has more than three times as much usable internal space as a diesel-electric--80%

against 25%. The company has produced a midget submarine 30 feet long, teardroped in shape that displaces 30 tons and has operated in over 2,500 hours of underwater testing. Work is currently underway to build a 70 to 90 foot submarine capable of carrying a crew plus 16 commandos, torpedoes, ground mines and a mine delivery vehicle. It is projected to have a top cruise speed of 16 knots and a burst speed of 25 knots with a range of 2000 miles submerged. Its estimated price tag is only \$38 million. A larger 2,800 ton GST submarine is being designed and its predicted performance includes a sustained speed of 30 knots for 3000 miles or five knots for 50,000 miles.³²

Weapons

Conventional submarines use 533mm diameter torpedo tubes to launch both torpedoes and mines. The Type-209 carries a type torpedo typical of current capabilities--the SUT/SST-4 wire guided torpedo. It has a swim-out capability instead of ejection by compressed air. Both this and its electronic propulsion contributes to very quiet operation.³³ Another torpedo, the Marconi Mk 24 Tigerfish, is a wire guided system that uses passive sonar to home in on the noise signature of the target and an active sonar mode if it loses passive contact. Range is 16 miles in the passive mode and eight miles in the active mode at 24 knots.³⁴ The Type-209 has automatic weapon gear that can reload a firing tube in only 50 seconds³⁵ and a modern fire control computer on the 1700 class submarine can handle five targets and three torpedoes simultaneously.³⁶ Naval experts predict international

development of torpedoes capable of 30 mile ranges at 60 knots with wake-homing capability in the next 10 years.³⁷

The technology advances by conventional submarines are widespread and are funded by an open international marketplace while ASW counter technology being developed in the U.S. is being constricted by budget constraints. The funding, \$40 million for 1993,³⁸ is failing to keep pace with improvements in diesel submarines. Seven years ago, some 200 senior scientists and naval officers of eleven NATO nations conducted a series of Long Term Scientific Studies, known collectively as MO/2005. The aim was to assess the implications of technological advances on maritime operations beyond 2005.³⁹ They predicted that diesel submarines would have Air Independent Propulsion, up to 20 days submerged endurance, be virtually undetected by passive radar, and have missile firing capability. Although research in such fields as laser detection, submerged wake detection, and low frequency active sonar was noted, no new "break-throughs" in submarine detection were foreseen. What was predicted seven years ago for submarines in 18 years is almost achievable now. The Type-212 and Type A-19 are Air Independent with predicted endurance of two weeks, the Germans and Italians are fast improving their torpedo technology and several submarines are U.S. Harpoon missile capable--the Russian Tango is suspected of being missile capable. So far the counsels predictions on submarine detection capabilities are on track--no "break-throughs" yet. In conclusion, conventional submarine potential threat

capabilities are increasing at a faster rate than our capability to maintain superiority in the littoral subsurface region.

CHAPTER IV

ROLES AND MISSIONS

Identifying future platform capabilities is only the first step in analyzing the threat potential. It is also necessary to identify future roles and missions likely to be assumed by a conventional submarine force. Examples and scenarios of future operational applications can be derived from those experiences successfully applied in the past in both war and during the cold-war.

Sabotage

The British attack on the German Battleship *Tirpitz* by an "X-craft" is an example of what can be accomplished at a local level by submarines when innovation, ingenuity and dedicated training is applied. The *Tirpitz* along with its sister ship, the *Bismark*, was the most formidable battleship in Europe; 56,000 tons, 828 feet long with eight 15" guns--the *Tirpitz* had the most devastating anti-aircraft battery afloat.⁴⁰ The battleship was harbored at Kaafjord, Norway, four degrees above the Arctic circle - behind 45 miles of narrow passage fjords, two anti-submarine nets, an elaborate ant-torpedo net, numerous shoreline gun installations, several destroyers, and two

separate mine fields. *Tirpitz's* strategic position in northern Norway forced the British Royal Navy to guard every Russian-bound convoy with a large force to prevent the *Tirpitz* from decimating the convoy. The *Tirpitz's* mere presence was sufficient to divert two precious battleships from the Home Fleet⁴¹ to ensure the convoys safety, thus easing the pressure off of German naval efforts closer to Britain.

In 1941 British Naval planners devised plans enabling a few dauntless men to pass undetected through the various German defense systems, place bombs under the *Tirpitz* in her own anchorage and escape undetected before the bombs blew. Called the "X-craft", these mini-subbs were 48 feet long, displaced 39 tons fully stored and loaded, had a maximum diameter of five and a half feet, carried a crew of four, and were powered by a four cylinder London bus diesel (for proven dependability).⁴² Its top speed submerged was two knots and six knots surfaced. Instead of torpedoes it carried two crescent-shaped two-ton explosives that were contoured to fit the shape of the external hull, and had a variable timing device.

After a year of training, six craft were towed *underwater for 1200 miles* by six full size submarines - a maritime first. Three X-craft made the entry into the fjords and two got through the elaborate defenses by slow, quiet penetration of all anti-submarine barriers. Once inside the *Tirpitz's* anchorage, they placed their charges underneath the ship's keel. When the explosives detonated, the keel of the *Tirpitz* was lifted seven feet out of the water. Damage was so extensive that it took 1,000 shipbuilders brought in from Hansberg,

Germany, five months to enable the ship to go underway on her own power.⁴³

Soviet Submarine Incursions into Swedish Littoral

The former Soviet Union exploited Sweden's littoral waters frequently from 1980 until 1990 with an average of between 17 and 36 known operations per year.⁴⁴ The Soviets were penetrating Sweden's coastal defense zones with the use of multiple 90 foot coastal submarines, four-man mini-sub, combat swimmers, and even crawling vehicles operating in coordinated operations.⁴⁵

During 1980-1981 the most notable of a series of detected violations of Sweden's territorial waters were those detected off Uto island (the southern Stockholm archipelago). One or more submarines were tracked west of the island for 36 days and one submarine was believed damaged by a Swedish destroyer.⁴⁶ The most noted incident, referred to in the press as "Whiskey on the Rocks" occurred 28 October 1981 when Soviet Whiskey U-137 ran aground on the shoals near the Karlskrona naval base during the cover of dark.

Numerous Soviet operations were conducted throughout the 1980s and large scale ASW operations attempting to force them to the surface failed. In February of 1984, over 600 detections were made and 22 depth charges were dropped to no avail at forcing the submarines to surface.⁴⁷ A major ASW operation conducted in response to incursions into the Stockholm harbor in May and June 1986 lasted several weeks with 30 depth charges and 60 homing explosive devises used to force the intruders up.⁴⁸

Sweden recognized its ASW inadequacies early on and established an investigative commission in October 1982. It found that Sweden's gross deficits in ASW capabilities were self inflicted. ASW surface and air capabilities had been drastically cut in the 1970s.⁴⁹ As a result of the investigation, new ASW helicopters and mine sweepers equipped with side scan radar were acquired.

The interesting question posed by this long-running cold war confrontation between the Soviets and an internationally recognized neutral country is why did the Soviets do it? The covert operations were obviously made to chart and test Sweden's coastal defenses, but why continue after they knew that they were being detected?

. The motive behind these operations may have been to ensure that "war" plans could indeed be carried out. That, if required, the Soviets were prepared to pre-empt Sweden's defensive and offensive capabilities immediately proceeding or concurrent with the main offensive in the European theater to "ensure" Sweden's neutrality and pre-empt any threat to the Soviet Baltic Fleet's northern flank as they broke out of the Baltic Sea.

The Rand report covering these events describes a Soviet published report that describes the scenario of the start of a fictional war in a coastal region. Its main point was that incursions like those in Sweden would take place against a third-party country before commencing hostilities with the primary foe. The Swedes have estimated that 70 passes of an attack aircraft would be required to destroy a unit of three coastal artillery guns. Placing a string of

destructive charges on each gun barrel by an attack diver would achieve the same result.⁵⁰

The lesson here is that our future adversary of the future will not necessarily use his assets for a direct confrontation with U.S. forces. We must ask this question - what neighboring countries might be attacked at the outset or preceding the outbreak of war to deny U.S. access to:

- Deep water port facilities required to support U.S. sealift requirements.

- Coastal defense systems that could assist U.S. battle space dominance efforts.

- Coastal Air Facilities that could be crucial to U.S. airlift requirements.

To an adversary with limited air and sea force capability, the crippling of logistic ports and airfields may be his best course of action preceding direct conflict with a superior U.S. force.

Commerce War

An Indian Naval Officer, Sanjay Singh, stated that a lesson that India learned from the Persian Gulf War was that "...[the] War clearly demonstrated that a coastal-defense navy built around missile-armed surface ships and aircraft is incapable of denying the use of the sea to a powerful blue-water navy."⁵¹ If not then a "direct confrontation" with a superior surface force what would be an alternative beyond those mentioned earlier? A *guerre de course* or commerce war could be

used against the trade necessary to sustain a nation's economy or, a more likely target for a nation with a small submarine force, the long logistical sealift required to sustain a U.S. military campaign far from its shores. The German U-boat campaign is a good example of this tenant because it placed strong logistical constraints on deliverable Allied combat power and tied up substantial portions of the Allied navies in escort duty. Germany's Grand Admiral, Karl Donetz, rationalized the continued submarine offensive as a way to tie up a disproportionate level of Allied resources in the "unproductive" anti-submarine warfare force.⁵²

Cost analyses calculated that the Allies had to outspend the Germans more than 15:1 in ASW equipment versus U-boat constructions. The German strategy forced the world's two greatest sea powers, Britain and the United States, to divert extensive resources to their navies and to deploy most of their warships on defensive operations to maintain control of the sea lines of communication. It was largely due to this consideration that U.S. ground forces could not reach Europe in sufficient numbers for the major land offensive build-up until 1943-1944. LCDR Michael Poirier in an article *Sea Control and Regional Warfare* put forward the idea of the *querre de course* aptly when he states:

The most compelling reason for most navies to choose this strategy is the absence of other maritime options. For a regional power that might face a large blue-water navy, only a submarine force gives adequate assurance that in seas nominally controlled by superior enemy forces, its navy can survive and effectively attack the ships that enable its enemy to project and sustain combat power ashore.⁵³

In conclusion, the head-on confrontation of a carrier battle group in full combat readiness by a conventional submarine may not be likely although the Argentines did just that. The targeting of supply shipping and personnel carriers as was the German U-boat objective in World War II, or covert raids against special targets such as with the X-craft against the *Tirpitz* or Soviet infiltration of Swedish defenses in the 1980s are all possible missions that are all well within the anticipated capability of near-future conventional submarine forces if not already.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

United States ASW forces are being reduced; even as we contract, conventional submarines are being purchased by an ever widening spectrum of nations in increasing numbers. The capabilities of these submarines are increasing as manufacturers compete to develop submarines with ever increasing endurance, fire power, automation and versatility.

Present day ASW forces were designed for blue-water battle. Conventional submarine capabilities are increasing at a rate which may overtake our ability to maintain superiority in the littoral battle space and they indeed may have done so with the latest technological improvements. The U.S. Navy has chosen to keep its high-value multi-purpose surface ships in the near future while retiring all frigates.

The Aegis equipped cruisers and destroyers will become centerpieces of an offensive capability able to protect itself and the rest of the battle group from air, surface and subsurface threats while projecting offensive fire power in the form of cruise missiles ashore as well as provide Theater Ballistic Missile Defense. One question posed by this paper is whether with all of these important missions, can these platforms be taken out of the battle group to also cover the important sea lanes? Can they afford not too? If, like in early months of World War II, we have insufficient numbers to cover both shipping and our combatants we may well be forced into making the same decision made at the beginning of the battle for the Atlantic--sacrifice the merchants and keep the fleet protected until reenforcements can be built.

History is replete with examples of the large ratio of ASW forces to submarines required to deal with the threat. Having been away from littoral ASW for so long, we have advanced down a technological path that served us well in deep water but leaves us dangerously exposed in the future. Our doctrine has given us a new mission--to fight in the littoral regions and to dominate those areas and to project that dominance "From the Sea" ashore. Doctrine is a valuable guide in directing our thoughts and energies into preparing to fight a certain way and to build the tools needed to match the task.

Certainly we can not afford the massive procurement programs of the 1980s but some modifications of platforms or new platform procurements could be performed in place of more expensive platforms already slated. Some recommended areas for further study would be:

1. Delay the retirement of the Perry class frigate until relatively inexpensive light replacements such as fast hover-craft or other alternatives could be funded. Most of the frigates in the Perry class are only ten years old--young enough for another 20 years service. If this option proves too expensive, consideration should be given to transferring them to the Reserves to keep them viable for potential use.

2. Consideration should be given to expanding the numbers of SH-60Bs and retrofitting helicopter support facilities on selected merchant vessels to assist in convoy protection. A large number would not be required, perhaps one to two squadrons to provide three to four helicopters per convoy.

3. Building an ASW carrier in place of a planned Nimitz-class replacement carrier. The ASW carrier would be smaller thus cheaper and carry both fixed-wing and rotor-wing, ASW aircraft. It would be an invaluable asset in the littoral battle. By positioning itself out from the close confines of the battlespace the ASW carrier could send in assets to cover the ASW requirements of the battle group as well as assets in the other direction to help cover the sea lanes. It may be argued that regular carrier numbers can not be decreased however, the increased offensive power offered by cruise missile capabilities of present and future surface combatants may allow some decrease in airpower in compensation for the security of the battle force and its logistical bridge from subsurface threats.

4. Build conventional submarines. Even long-range predictions see nothing to challenge our nuclear submarine supremacy in the deep waters that lay along 95% of the route from one continent to the next, but in that other five percent--in the littoral--our superiority diminishes greatly. By building a small fleet of advanced diesel-electrics or fuel cell submarines in place of, or along side a reduced order of the attack submarines to follow the *Sea Wolf*, we could get a platform that is highly effective at a greatly reduced cost. It could compliment the nuclear attack submarines by both terminal points of the sea lanes. It would help keep the important submarine industrial base alive and would provide an excellent export product to our allies who cannot afford nuclear submarines but whose subsurface assistance could prove invaluable in combined littoral operations. These submarines would also provide valuable conventional submarine training opportunities to other ASW platforms, and lastly, they would provide possibly the best ASW weapon against another submarine in the littoral battle space.

NOTES

¹Lessons of the Falklands, Department of the Navy Summary Report, Feb. 1983, pp. 8

²Intelligence and the Third World Submarine Threat, LT Matthew B. Ashley, Naval Post Graduate School, 1991, pp. 4

³Lessons of the Falklands, Department of the Navy Summary Report, Feb. 1983, pp. 9

⁴Ibid, 36

⁵Herbert A. Werner. *Iron Coffins*. Holt, Rinehart and Winston, N.Y., 1969, pp. xiv

⁶Jonathan Crane. *Submersible to Submarine*. The British Broadcasting Corporation, London, 1984, pp. 168.

⁷The Bicap Cross was so named because it consisted of two pieces of wood attached in the shape of a cross with antenna wire strung between the ends. Biscay Bay, off the coast of France, was where the radar detector was primarily used.

⁸Johann Fischer. "The Eagle and the Shark." *Naval Forces*, No. III, 1993, Vol XIV, pp. 47.

⁹Crane, 172

¹⁰Norman Friedman. "World Navies in Review - Germany". *U.S. Naval Institute Proceedings*, Mar 1994, pp. 104.

¹¹Julian Baum. "Prepare to surface." *Far Eastern Economic Review*, 4 Feb 1993, pp. 10-11.

¹²Friedman, 112.

¹³Sea Power 1994 Almanac. 1994, pp. 121-200. Of the 680 assets listed, 96 belong to the Reserve Force.

¹⁴*Ibid.*, 142"

¹⁵John J. Kieley III. "FFG-7: Smaller is Better" *U.S. Naval Proceedings*, Jan. 1992, pp. 44.

¹⁶Bruce R. Linder. "Nobody's Square Peg", *U.S. Naval Proceedings*, Jan. 1992, pp.41.

¹⁷Kieley, 44.

¹⁸John F. Morton. "Technology: Insertion is the Name of the Game", *U.S. Naval Institute Proceedings*, March 1993, 134-135.

¹⁹*Ibid.*, 134-135.

²⁰Norman Friedman. "Finding Submerged Submarines - with Lasers", *U.S. Naval Institute Proceedings*, March 1993, pp. 132.

²¹A look at a soundings chart would show why this is so. The eastern coastline of Japan has virtually no continental shelf. Deep diving submarines are required in Japan to protect against any submarine threat—shallow or deep.

²²Norman Friedman. "World Navies in Review - Germany", *U.S. Naval Institute Proceedings*, March 1994, pp. 114-116.

²³"Air Independent Submarine Propulsion", *Naval Forces*, Vol. 12, (1991).

²⁴*Ibid.*, 52.

²⁵David Miller. *Modern Submarines*, Prentice Hall, London, 1989, pp. 45.

²⁶*Ibid.*, 45.

²⁷"Air Independent Submarine Propulsion." *Naval Forces*, Vol. 12 (1991), pp. 53.

²⁸*Ibid.*, 53.

²⁹*Ibid.*, 53.

³⁰"Air Independent Submarine Propulsion". *Naval Forces*, Vol. 12 (1991), pp. 57

³¹Richard Compton-Hall. "The Incredible Shrinking Submarine", *New Scientist*, 1 April 1989, pp. 35.

³²*Ibid.*, 36.

³³John Moore, Editor. *Jane's Fighting Ships of the World 1992-1993*, Jane's Publishing Company Limited, London, 1993.

³⁴Miller, 55

³⁵*Ibid.*, 55

³⁶John Moore, Editor. *Jane's Fighting Ships of the World, 1990-1991*, Jane's Publishing Company Limited, London, 1982.

³⁷Michael Eames, "Foreseen Technology and its Impact on Naval Capabilities", *Canadian Defense Quarterly*, December 1991, pp. 14.

³⁸Morton, 134.

³⁹Eames, 13.

⁴⁰Thomas Gallagher. *The X-Craft Raid*. Harcourt Brace Jovanovich, Inc., New York, 1971, pp.2

⁴¹*Ibid.*, 12.

⁴²*Ibid.*, 41-43.

⁴³*Ibid.*, 163.

⁴⁴Gordon H. McCormick. *Stranger than Fiction*, A Project AIR FORCE report, RAND Corporation, 1991, pp.v.

⁴⁵Douglas Stanglin with David Bartal. "Cold-war hangover", *U.S. News & World Report*, Feb 19, 1990, pp.41.

⁴⁶"The Royal Swedish Navy" *U.S. Naval Institute Proceedings*, March 1982, pp. 130

⁴⁷McCormick, 16-17

⁴⁸*Ibid.*, 18

⁴⁹Milton Leitenberg. "Soviet Submarine Operations in Swedish Waters", *The Washington Papers*, Praeger, New York, 1989, pp. 55.

⁵⁰*Ibid.*, 148.

⁵¹Michael Poirier. "Sea Control and Regional Warfare", *U.S. Naval Institute Proceedings*, July, 1993, pp. 51.

⁵²Karl Donitz. *Memoirs: Ten Years and Twenty Days*, Naval Institute Press, Annapolis, MD, 1990, pp. 344.

⁵³Poirier, 65.

BIBLIOGRAPHY

- "Air Independent Submarine Propulsion." Naval Forces, Vol. 12 (1991), pp. 48-57.
- Ashley, Matthew B., Intelligence and the Third World Submarine Threat. Naval Post Graduate school, 1991.
- Baum, Julian, "Prepare to surface". Far Eastern Economic Review, 4 Feb 1993, pp. 10-11.
- Compton-Hall, Richard. "The Incredible Shrinking Submarine", New Scientist, 1 April 1989, pp.35-36.
- Crane, Jonathan. Submersible to Submarine. The British Broadcasting Corporation, London, 1984.
- Donitz, Karl. Memoirs: Ten Years and Twenty Days, Naval Institute Press, Annapolis, MD, 1990.
- Eames, Michael. "Foreseen Technology and its Impact on Naval Capabilities", Canadian Defense Quarterly, December 1991, pp.13-16.
- Fischer, Johann, "The Eagle and the Shark". Naval Forces, No. III, 1993, Vol. XIV, pp. 45-48.
- Friedman, Norman, "World Navies in Review - Germany". U.S. Naval Institute Proceedings, Mar 1994, PP 99-105.
- Friedman, Norman, "Finding Submerged Submarines - with Lasers", U.S. Naval Institute Proceedings, March 1993, pp.134-135.
- Gallagher, Thomas. The X-Craft Raid , Harcourt Brace Joanovich, Inc. New York, 1971.
- Kieley, John J. III, "FFG-7: Smaller is Better" U.S. Naval Proceedings, Jan 1992, pp.44-45.
- Leitenberg, Milton. "Soviet Submarine Operations in Swedish Water". The Washington Papers, Praeger, New York, 1989, pp49-58.
- Lessons of the Falklands, Department of the Navy Summary Report, Feb 1983.
- Linder, Bruce R. "Nobody's Square Peg", U.S. Naval Institute Proceedings, Jan 1992, pp.41.
- McCormick, Gordon H. Stranger than Fiction, A Project AIR FORCE report, RAND Corporation, 1991.

Miller, David. Modern Submarines, Prentice Hall, London, 1989.

Moore, John ed. Jane's Fighting Ships of the World 1992-1993, Jane's Publishing Company Limited, London, 1993.

Moore, John ed. Jane's Fighting Ships of the World 1990-1991, Jane's Publishing Company Limited, London, 1992.

Morton, John F. "Technology: Insertion is the Name of the Game", U.S. Naval Institute Proceedings, March 1993, pp. 134-135.

Poirier, Michael. "Sea Control and Regional Warfare", U.S. Naval Institute Proceedings, July, 1993, pp. 51.

"The Royal Swedish Navy". U.S. Naval Institute Proceedings, March 1982, pp.130

Sea Power 1994 Almanac. Navy League of the United States, Volume 37, Jan, 1994.

Stanglin, Douglas with Bartal, David. "Cold-war hangover", U.S. News and World Report, Feb 19, 1990, pp. 41.

Werner, Herbert A. Iron Coffins. Holt, Rinehart and Winston, N.Y., 1969.