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The AIP-Equipped SSK: A Revolution in Naval Warfare

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24 April 2006

ABSTRACT

There is another revolution coming in naval warfare. The modern diesel-electric attack submarine, “SSK”, has, in its basic concept, been in use since before world war one, but today has been so perfected that some characterize it as a growing menace and very challenging threat. The modern, air-independent propelled (AIP) SSK is a revolution in naval warfare.

AIP capability makes the SSK more independent of the surface and stealthy. This stealth provides a marked advantage for the SSK. It is able to hunt for a position from which attack its target, while the target, currently, has no truly effective means to detect the AIP SSK. This fact is admitted by the U.S. Navy and NATO. SSK subs are populating more than a third of world navies, as well as hard-line ideological nation-states. Western navies are developing new anti-submarine warfare concepts, doctrine, and procurements in response. Some of these concepts include autonomous underwater sensors.

Until these are fully developed, the revolutionary AIP SSK has a clear advantage in the submarine versus anti-submarine technology battle.

INTRODUCTION

Naval warfare has experienced a number of technological revolutions in its long, storied history. Naval historians have proclaimed the aircraft carrier as a revolution in naval warfare because it transformed battleship-centric naval gunnery combat into long range carrier-based air strikes against enemy fleets and ground targets.[1] Some historians also propose that the nuclear powered submarine and the nuclear powered ballistic submarine are revolutionary naval warfare concepts due to their previously unprecedented methods of power projection, their endurance, and technological advancements.[2]

There is another revolution coming in naval warfare, and, in fact, it may already be here. The modern diesel-electric attack submarine, "SSK" as it is known in navy parlance,[3] has, in its basic concept, been in use since before world war one,[4] but today has been so perfected that some characterize it as "…the growing menace…"[5] or more to the point: "Today's modern diesel [submarine] is a very, very challenging threat."[6] The modern, air-independent propelled (AIP)

[1] Andrew Krepinevich, "Transforming to Victory: The U.S. Navy, Carrier Aviation, and Preparing for War in the Pacific", The Olin Institute, 2000; available from http://www.csbaonline.org/4Publications/Archive/A.20000000.Transforming_to_Vi/A.20000000.Transforming_to_Vi.htm; Internet; accessed 25 February 2006.

[2] Norman Polmar, "The Polaris, A Revolutionary Missile System and Concept", *Colloquium on Contemporary History*, Department of the U.S. Navy, Naval Historical Center, 12 January 1994, No. 9; available from http://www.history.navy.mil/colloquia/cch9d.html; Internet; accessed 2 March 2006.

[3] John Hervey, *Submarines*, Brassey's (UK) limited, London, 1994, 1.

[4] Peter K.Kemp, *The Oxford Companion To Ships And The Sea*, (London: Oxford University Press: 1976), 840.

[5] Sandra I. Erwin, "Diesel Submarines Irritant to U.S. Navy", *National Defense Magazine*, August 2004, National Defense Industrial Org; available from http://www.nationaldefensemagazine.org/issues/2004/Aug/Diesel_Submarines.htm; Internet; accessed 14 March 2006.

[6] Tom Laux as quoted by Erwin, "Diesel Submarines…".

SSK has the quietest of all propulsion methods,[7] and, coupled with its other technological advancements; it is a revolution in naval warfare.

The modern SSK is a revolution, as Norman Polmar defines it: "By 'revolutionary', I mean a weapon system that 1) makes a significant technological advance in a given area or; 2) has a major impact in combat or on defense policy." [8] An additional characteristic of a revolution in warfare is described as: "Military revolutions witness the introduction of new capabilities, which, when combined with innovative operational concepts and force structure, produce a discontinuous leap in effectiveness, typically on the order of a magnitude or greater. "[9]

This paper will briefly describe the oceanic environment in which the modern SSK must survive, coupled with the littoral-warfare operational concept that allows the SSK to thrive and enjoy a significant operational advantage; followed by a short look at the history of SSK submarines and how they have a current technological edge; and finally, an analysis of how the modern SSK, as a major technological advancement and leap ahead in combat capability, has impacted the U.S. force projection capability, and, moreover, has caused changes to several national procurement strategies around the world.

THE OCEAN AND LITTORAL ENVIRONMENT

The SSK, like all naval warships, strives to survive and maintain a combat advantage in a complex oceanic environment. This environment is comprised of the seawater around the SSK and its potential underwater or surface targets and threats, the seafloor and its geology was well as its topography (or bathymetry), the surface conditions and weather, and any airspace targets or

[7] W.J. R. Gardner, *Anti-Submarine Warfare*, Brassey's (UK) Limited, London, 1996, 96

[8] Polmar, "The Polaris A Revolutionary…"

[9] Krepinevich, "Transforming to Victory...".

threats flying above the local area.[10] The properties of all these mediums (ocean floor, seawater, and maritime airspace) are constantly changing due to the SSK's or the target's changing position, moving ocean currents, and changing weather patterns. This complex and variable environment directly or indirectly impacts on the SSK and its target's ability to sense and engage one against the other. However, and unlike a surface target, because the ocean is opaque, a submerged SSK cannot easily be seen. An SSK must be sensed by other means if the target is to escape engagement, initiate countermeasures, or engage in warfare against the SSK. This visual stealth provides a marked advantage for the SSK, provided it is able to stay submerged and quiet, as it hunts for a position from which to successfully prosecute an attack on its target.[11]

One main sensing method, used by submarines, surface combatants, and naval anti-submarine aircraft, is called Sound Navigation and Ranging (SONAR).[12] SONAR uses passive and active types of sound echo ranging to hear either 1) a vessel's inherent radiated noise (passive SONAR) or 2) hear the echoes from sound waves that active SONAR sends out against a target.[13] A noisy target vessel produces passive sonar contacts that propagate to the SSK. These "passive" sound waves are sensed by the hunter's SONAR systems. By receiving passive sound from a noisy target, the hunter has the advantage of hearing it's target vessel without having to revert to making active sonar sound waves.[14] These active SONAR "pings" have the disadvantage of alerting the target vessel of the hunter's presence. Because sound sensing can

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[10] Gardner, *Anti-Submarine Warfare*, 39.

[11] Browning, B.J., PhD and Lakeman, L.B., PhD. *The Role of Fuel Cells In The Supply of Silent Power for Operations in Littoral Waters*, Report # RTO-MP-104 prepared for NATO Research and Technology Organization (RTO), (Hampshire: NATO, April 2004), 2.

[12] Louis Gerken, *ASW versus Submarine Technology Battle*, (Chula Vista, CA: American Scientific Corporation, 1986), 173.

[13] Hervey, *Submarines*, 92-97

[14] Hervey, *Submarines*, 92-97.

"see" through the ocean, the SSK can lose its stealth advantage if it is too noisy or operates in quieter, less turbulent, deep ocean waters. Therefore, SSKs tend to operate closer to shore where they can have distinct advantages in noisier, turbulent, and shallower littoral or coastal waters.[15] Combined with a national sea denial[16], littoral-warfare concept, the SSK can conduct short range littoral area patrols or long duration ambushes in approaches to harbors or amphibious capable beaches, thereby maximizing their stealth and surprise from SONAR.

Littoral waters "…are comprised of two segments of the battlespace: Seaward--covering the area from the open ocean to the shore—and Landward--covering the area inland from the shore that can be supported and defended directly from the sea..[17] They characteristically are much more turbulent, noisy, and cluttered with ship traffic, shipwrecks, and sound "contamination".[18] "Finding a submerged submarine is largely an acoustical business…"[19], thus this background sound clutter that coastal areas provide can overwhelm enemy ASW sensors and provide an ideal environment for an SSK to maintain its visual and sonic stealth advantage.[20]

A SHORT LOOK AT THE HISTORY OF THE SSK

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[15] Gardner, *Anti-Submarine Warfare,* 106, 107.

[16] Sea Denial is "…to throttle enemy activity to the point where it becomes insufficient to reinforce their amphibious landing, sustain their army of occupation, or to re-supply their island nation with food or other essential imports." Hervey, *Submarines*, 6.

[17] Lieutenant Commander Frank J. Murphy (USN), "Littoral Warfare: Adapting to Brown-Water Operations", (Quantico: Marine Corps University Command and Staff College Paper, 1993); available from http://www.globalsecurity.org/military/library/report/1993/MFJ.htm; Internet; accessed 12 April 2006.

[18] Gardner, *Anti-Submarine Warfare,* 55.

[19] J.R. Hill, *Anti-Submarine Warfare*, 2nd ed, (Annapolis: Naval Institute Press, 1989), 44.

[20] "The high ambient noise levels from local shipping traffic and marine life make passive sonar detection almost impossible in littoral waters." Brian Markle, "Sensor-Enhancing Software Helps Detect Diesel Submarines", *National Defense Magazine*, September 2004, available from http://www.nationalDefensemagazine.org/issues/2004/Sep/Sensor-Enhancing.htm; Internet; accessed 12 March 2006.

Submarines have been used in naval warfare since before 1800 when American inventor, Robert Fulton, built a submarine, named the "Nautilus", for the French to use against British warships standing in blockade of France.[21] Fulton piloted (and manually propelled) his "Nautilus" submarine on several failed attempts against the British warships and, subsequently, lost the French contract.[22] Fulton belatedly discovered that the British could see his shallow running submarine quite easily and, rather than let him ram them, merely moved out of his way.[23] Fulton proved a key principle of submarine operations, namely that submarines must preserve the element of stealth and surprise to accomplish their missions.[24]

It appeared that manually propelled systems were too limited to provide a submarine with true "attacking" capability. Manual propulsion quickly gave way to new coal fired engines, steam turbines, battery-electric, and gasoline internal combustion.[25] Eventually, around 1904, French inventors experimented with diesel fueled engines to replace the dangerously volatile gasoline-electric powered submarines.[26] The electric system, using batteries, could run the submarine's propulsion system quietly, with the vessel submerged, and with no exhaust smoke, but only for a very limited time. The noisy, smokey, diesel engine would then have to be used to regenerate electrical charge in the batteries, allowing the electrical propulsion process to continue. Once again, however, the submarine would lose its stealthy imperative by having to

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[21] Brayton Harris, *The Navy Times Book of Submarines*, (New York: Berkley Books, December 1997), 47.

[22] Harris, *The Navy Times Book*…, 48.

[23] Ibid, 48.

[24] J.E. Moore and R. Compton-Hall, *Submarine Warfare, Today and Tomorrow*, (London: Michael Joseph Limited,1986), 3, 30.

[25] Harris, *The Navy Times Book*..., iv.

[26] Bellis, "The Evolution…".

surface in order to run the diesel engine, allowing it to take in air and vent its deadly exhaust gases. Despite this dependence on surface air, diesel-electric submarines attacked and destroyed vast tonnages of surface combatant ships and merchant vessels throughout both World Wars.[27] However, with the advent of new search and detection methods like radio detection and ranging (RADAR) and Sound Navigation and Ranging (SONAR)[28], surfacing submarines were much more liable to be detected and destroyed or, at least, disrupted from accomplishing their mission.[29] The Germans devised a "schnorkel" (or snorkel) system, in 1944, that used a long, retractable, tube that extended above the water surface and allowed the submarine's diesel engine to intake surface air and exhaust its gases up to the surface, all while the submarine remained at periscope depth.[30] Even this snorkel tube became highly detectable by ever advancing submarine detection technologies like RADAR, however. While diesel-electric submarine designs through the 1940's and 1950's continued to largely copy the German submarines of World War II, designers in the 1960's and 1970's began to develop new hull shapes along with new compartment and propulsion designs.[31]

An easier way to organize one's thoughts and track the many iterations of SSK development is to divide each "generation" by their different key technological characteristics. For example, the Russian generations of SSK submarines could be organized with the Whiskey and Foxtrot as first generation SSKs.[32] These 1950's era subs were largely based on the German

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[27] Hervey, *Submarines*, 3-4.

[28] Moore and Compton-Hall, *Submarine Warfare…*, 45.

[29] Gardner, *Anti-Submarine Warfare*, 60-61, 73.

[30] Kemp, *The Oxford Companion…*, 841.

[31] Harris, *The Navy Times Book…*, 349-352.

[32] Yanko, Eugene, "SSK", Omsk VTTV Arms Exhibition and Military Parade JSC, 2006, Internet

Type XXI *U*-Boat submarines (as were most Allied powers submarines in this era).[33] The Type 641B *Tango* Class sub, commissioned in the late 70's and early 80's, is a second generation Russian SSK. It has some advancements in acoustic dampening, torpedo technology and propulsion, but is still, essentially, "industrial-age" as it primarily uses the captain and crews minds and voices to obtain firing solutions, synthesize and pass information around the crew.

The Type 877 Kilo Class submarine, commissioned in 1979 and still being constructed today, is considered a third generation SSK.[34] It is characterized by limited speed, fire control, and electricity production (limited ability to run a sophisticated Sonar, Radar, Ocean Environmental Sensor Suite, and Fire Control system due to low power capability), especially while in battery only mode.[35] Moreover, these older SSKs must come up close to the sea surface to run their diesel engines and charge their batteries at least every few days, called snorkeling.[36] These limitations of Fire Control, Environmental Sensing, Speed, and Loiter Time put enormous pressure on the crew of an older generation SSK to position their boat such that its limited capabilities can be offset by other actions. The commander can try to quicken his firing time by gaining target pre-approvals; enabling the command authority to attack a high payoff target without having to surface the sub to ask for permission. Also, the SSK can try to ensure it has enough battery charge to move silently to within torpedo range of the target, a closer proximity improving its Probability of Hit (P_H) and subsequent Probability of Kill (P_K), or have enough air to lie in wait, in quiet mode, for the target to approach within torpedo range. Compounding the

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available at http://www.warfare.ru/?lang=&catid=307&cattitle=SSK, accessed 14 March 06.

[33] Harris, *The Navy Times Book…*, 342.

[34] Eugene Yanko, "SSK", Omsk VTTV Arms Exhibition and Military Parade JSC, 2006, http://www.warfare.ru/?lang=&catid=307&cattitle=SSK; Internet; accessed 14 March 06.

[35] Hervey, *Submarines*, 54.

[36] Kemp, *The Oxford Companion…*, 841.

problem, however, the SSK must then still have enough battery power to safely and quietly exit the target area, without having to surface and risk counter-attack, and still be able circulate fresh air for the crew to breathe.[37] This complex set of problems for the pre-modern SSK submarines severely limited their combat power by keeping them so frequently dependent on surface air as to disrupt their own ability to fight. Some observers will view the SSK and note that it is not a revolution in naval warfare, but merely represents small, but continuing improvements on an old design. This argument does not take into account the leap-ahead capabilities represented by the newest SSKs.

THE MODERN, AIR INDEPENDENT PROPULSION SSK

One can see the need for even more improvements to provide the diesel-electric SSK submarine with more stealth and more "combat power"[38] to better accomplish its intended mission of attacking surface and subsurface targets. The U.S. Army's elements of combat power help in defining the "modern" or "new" SSK . "Combat power is the ability to fight…the total means of destructive or disruptive force, or both, that a military unit or formation can apply against the adversary at a given time."[39] As a military weapon system, the SSK can be analyzed using the five elements of combat power: Firepower, Maneuver, Leadership, Information, and Self-Protection.[40] "Firepower is the amount of fires that a position, unit, or weapon system can deliver."[41] For Firepower, the SSK has experienced leap-ahead technology in the form of 1)

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[37] Hervey, *Submarines*, 148-149.

[38] United States, Department of the Army, *FM 3-0 Operations*, (Alexandria: U. S. Army Publishing Agency, 2001), 4-3.

[39] Army, *FM 3-0*..., 4-3.

[40] Army, *FM 3-0*…, 4-3.

[41] Army, *FM 3-0*…, 4-6.

high speed torpedoes (like the 200 mph Russian *Shkval*)[42], and quiet long endurance torpedoes (like the Italian *Blackshark*,[43] the U.S. Mk 48 ADCAP, and German DM2A4); 2) torpedo guidance systems (like the wire guided, passive and active sonar guided Italian *Blackshark*, German DM2A4, and the U.S. Mk 48 ADCAP); and 3) Reduced signature firing systems that allow a virtually silent means of firing torpedo salvos (like water ram expulsion on the German Type 214 SSK), as well as 4) Anti-Surface missiles with effective ranges of over 200 miles (like the Russian SS-N-12, and the U.S. Tomahawk).[44] These Firepower systems enable an SSK to silently engage a target at long distance, from a quiet and submerged position, with a high probability of hit and kill on the target, while preserving the SSK's chance of a silent, submerged escape.[45]

The element of Maneuver, means the ability to gain a position of advantage through fire and movement.[46] SSK advances in Maneuver include gaining faster surface and subsurface speeds, more quietly attainable speeds, and longer patrol endurance independent of the surface. Also, new construction methods and surface coatings have enabled more stealthy submarine designs and deeper diving. One of the most transformational advances is the advent of modern Air-Independent Propulsion (AIP). AIP capability makes the SSK more independent of the surface, preserving its ability to stay submerged and, therefore, more stealthy. AIP as a concept

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[42] Joe Buff, "Enemy Weapon: Russian VA-111 Shkval", *Military.com*, 2006, http://www.military.com /soldiertech/0,14632,Soldiertech_060420_shkval,,00.html; Internet; accessed 14 April 2006.

[43] Wertheim, Eric. "Combat Fleets", *Proceedings*, Issue 5, Vol. 131, (Annapolis: Naval Institute Press, May 2005), available from http://www.usni.org/proceedings/Articles05/Pro05cfleets/htm; accessed 2 March 2006.

[44] Hervey, *Submarines*, 132-133.

[45] Hervey, *Submarines*, 151.

[46] Army, *FM 3-0* …, 4-4.

was devised as far back as 1865 (in the form of a peroxide mix)[47], was not seriously researched for use in SSK's until the Germans began designing AIP powered U-boats in 1940 (called the "Walter Turbine" used on U-791).[48] Modern AIP systems include three main types: *Module d'Energie Sous-Marine Autonome* (MESMA) Engine, Closed Cycle Diesel Engine, Stirling Engine, and Fuel Cells.[49] The MESMA engine is an "…AIP steam-turbine system, which basically burns ethanol and liquid oxygen to make the steam needed to drive a turbo-electric generator."[50] This AIP system has significant advantages over a standard diesel-electric: "MESMA offers a submerged endurance of three to five times greater than that delivered by a diesel-electric powerplant."[51] The Closed Cycle Diesel engine is a combustion engine that uses its own exhaust gases, that are purified through a filter system and mixed with oxygen from an auxiliary source, to continue its combustion cycle.[52] A Swedish design, the Stirling engine also use LOX, but mixes it with a low sulfur fuel. This combustion is then used "…to produce heat which is then used to expand a working gas…to drive a series of pistons."[53] Each of these last three types of AIP extend the underwater endurance of the SSK by a magnitude of three to five

[47] Wikipedia, "Submarine", Wikimedia Foundation, Inc., Apr 2006; http://en.wikipedia.org/wiki/Submarines#Submersion_and_navigation; Internet; accessed 12 April 2006.

[48] Wikipedia, "Submarine".

[49] "Since the dawn of the submarine age, boats that can be powered by internal combustion engines yet do not, for underwater travel, require an external air supply, have been the goal of the many designers." Eberhart Moller and Werner Brack, *The Encyclopedia of U-Boats*, ed. and trans. Andrea Battson and Roger Chesneau (London: Greenhill Books, 2004),172.

[50] Don Walsh, "The AIP Alternative. Air Independent Propulsion: An Idea Whose Time Has Come?", *Seapower*, Navy League of the U.S, December 1999, 36.

[51] Karen Winzoski, "Taking the Plunge: Should Canada Use Fuel Cell Technology to make the Victoria-class Submarines more Stealthy?", *Canadian American Strategic Review (CASR)*, (Simon Fraser University Paper, May 2003); available from http://www.sfu.ca/casr/ft-winz1.htm.; Internet; accessed 16 February 2006.

[52] Winzoski, "Taking the Plunge…"

[53] Ibid.

times.[54] Finally, the Fuel Cell powerplant appears to be the most promising for a truly stealthy AIP that produces no detectable by-products. Fuel cells are commonly represented by the hydrogen fuel cell Proton Exchange Membrane (PEM) technology that produces electricity by extracting hydrogen from methanol or a metal hydride. The hydrogen is then:

> …fed into the fuel cell where it breaks down into electrons and protons, with the help of a platinum-based catalyst. The electrons are used to generate the electrical power for the submarine, while the protons migrate across the proton exchange membrane. On the other side of the membrane, the electrons leave the electrical circuit and re-combine with the protons and with oxygen to form pure, potable water, which is the only by-product of this reaction.[55]

The impact of AIP on SSK operations is illustrated by a typical SSK's (the German Type 212 which uses a fuel cell) underwater endurance without AIP compared to a Type 212 with AIP. Without AIP, the 212 can stay submerged for about than two days, before needing to recharge its batteries (assuming a full charge at start and sitting on the bottom or patrolling at very low speeds) or circulate clean air for the crew.[56] With AIP, that endurance increases to more than 21 days.[57] In terms of combat capability increase, AIP gives the SSK freedom from its previously short battery timeline resulting in a much longer time window to maneuver onto a target and successfully attack. This new freedom allows the SSK orders of magnitude more effectiveness rivaling that of a nuclear powered submarine, an accepted revolution in naval technology that is largely independent of the surface.[58]

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[54] Winzoski, "Taking the Plunge…"

[55] Winzoski, "Taking the Plunge…"

[56] "U212/U214 Attack Submarines, Germany", *Naval Technology.com*, SPG Media ltd, 2006,http:// www.naval-technology.com/projects/type_212/; Internet; accessed 24 February 2006.

[57] Walsh, "The AIP Alternative…", 36.

[58] Stephen Saunders, "Executive Overview", in *Jane's Fighting Ships 2005-2006*, 108th ed., Fred T. Jane and ed. Stephen Saunders (London: Jane's Information Group, Ltd, May 2005), 28.

The element of Information refers to the receipt, analysis, dissemination, and communication of all data inputs into the SSK. Because the SSK must successfully fight and survive in a perennially complex environment pitted against a system of adversarial anti-submarine weapons, the SSK information systems and crew must be efficient at fusing a Relevant Maritime Picture and creating actionable, decision-quality intelligence for the SSK commander. 1950's through 1970's era SSK's depended primarily on SONAR information gained by a single set of listeners, periscope views that only the commander could see, combined with the commander's own estimate of the situation to gain situational awareness of its complex environment.[59] Beginning in the 1980's and continuing to evolve to the present day, however, SSK designers developed a more systems-based approach to integrate sensory input from two or more sonar arrays with environmental sensors (such as ocean salinity, temperature, depth, density, etc.) and fuse it with targeting data, navigational data, and intelligence from communications with other SSKs, friendly surface vessels, and higher headquarters. The newest SSKs now are now fielded with at least three types of sonar arrays spaced throughout the hull and trailed along behind, allowing multiple frequency monitoring and faster targeting.[60] Additionally, new SSKs have full command, control, computers, communication, intelligence, surveillance, and reconnaissance (C4ISR) suites: radar warning receivers, thermal imaging cameras, and satellite communications capable antennae, all as part of their periscope arrays.[61] These provide even more information producing sensors for the advanced SSK's computer to fuse into intelligence. This fusing of real-time sensory information together with intelligence

[59] Harris, *The Navy Time Book*..., 366.

[60] Joe Katzman, "India to Sign Multi-billion Dollar Scorpene Sub Contract (Updated)", *Defense Industry Daily*, http://www.defenseindustrydaily.com/2005/09/india-to-sign-multibillion-dollar-scorpene-sub-contract-updated/index.php.; Internet; accessed 9 March 2006.

[61] Hervey, *Submarines*, 67, 84-90.

from other friendly vessels and their sensors enables the modern (i.e. 1990's and later) SSK to experience the information advantage from distributed, network enabled, and collaborative operations that its adversary ASW surface vessels have enjoyed for many years.[62] This levels the information capability playing field, however the SSK still retains the stealth advantage by its ability to gain information on surface vessels while denying them information itself.

"Leaders…provide purpose, direction, and motivation in all operations."[63] Leadership in an SSK context speaks to the commander, officer staff, and non-commissioned officers within the submarine crew and the ability of this leadership element to command and control the SSK, accomplish the mission, and maintain the morale and fighting spirit of the crew. As mentioned above, modern SSKs have significant computer information systems that integrate sensors, combat staffs, fire control, and situation displays that can enable the commander to make faster, better informed decisions.[64] Also, because these new information systems allow the collaboration and co-location of information displays and combat staffs, new SSKs are eliminating some crew positions (*Lada* class has 32 crew compared with 52 in the older *Kilo*).[65] This smaller crew allows more room for improved crew amenities and crew quality of life, thus positively impacting the overall morale of a modern SSK on extended patrol.[66]

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[62] Hervey, *Submarines*,178.

[63] Department of the Army, *FM 3-0…*, 4-7.

[64] Department of the Army, *FM 3-0…,* 4-11.

[65] Eugene Yanko, "SSK", Omsk VTTV Arms Exhibition and Military Parade JSC, 2006, http://www.warfare.ru/?lang=&catid=307&cattitle=SSK; Internet; accessed 14 March 06.

[66] John Pike, "Type 212", *GlobalSecurity.org*, http://www.globalsecurity.org/military/world/Europe/type-212.htm; Internet; accessed 12 March 2006.

The element of "Protection is the preservation of the fighting potential of a force."[67] In a submarine context, Protection refers to the SSK's ability to ensure the safety of the crew and preserve its overall "combat power", primarily through the maintenance of its stealth advantage. If it fails to elude a counter-attack, its protection rests on its ability to deceive or thwart an enemy attack through countermeasures or survive an enemy strike through the properties of its rugged construction design and materials.[68] Modern SSK's are constructed with high-strength steel or titanium single or double hulls. These hulls are also coated with anechoic tiles that significantly reduce sound wave reflection and preserve silent stealth. Also, modern SSKs incorporate vibration dampening systems on each article of equipment in the hull that is found to produce noisy vibration harmonics that can be picked up by an enemy's passive sonar detection. Lastly, SSK's have been fitted with surface to air missiles (SAM) in order to defeat one of their most potent enemy assets; the sonar dipping helicopter.[69] Examples include the Russian SA-N-8 with a range of six kilometers.

The newest generation of SSKs have advancements in each of these elements of Combat Power, resulting in the most stealthy, deadly, long ranging, and maneuverable SSKs ever.[70] The leaps ahead in each of these principles, combined with employing the SSK for "sea denial" in a littoral environment, has also fueled the SSK's impact on national level strategies.[71]

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[67] FM 3-0 Operations, 4-8.

[68] Gardner, *Anti-Submarine Wafare*, 82

[69] Moore and Compton-Hall, *Submarine Warfare: Today and Tomorrow*, 82, 83

[70] "Modern diesel submarines have advanced propulsion systems and coatings that eliminate echoes, many of these submarines cannot be detected with the current sonar technologies…" Joe Katzman, "U.S. Navy Exploring New Concepts, Procurement Priorities for ASW", *Defense Industry Daily*, Watershed Publishing LLC, 2006, http://www.defenseindustrydaily.com/2005/03/us-navy-exploring-new-concepts-procurement-priorities-for-asw/index.php; Internet; accessed 9 March 2006

[71] United States Navy, Chief of Naval Operations, Submarine Warfare Division, "Future Submarine Force", http://www.chinfo.navy.mil/navpalib/cno/n87/future/sensors.html; Internet; accessed 5 March 2006.

For example, Russia's most recent SSK, the *Lada* Class (also called the *Amur* class) represents a fourth generation SSK submarine.[72] Like most fourth generation SSKs, it began construction in early 2000 or later.[73] Some have already been commissioned and are on combat patrol. This newest SSK can rest on the sea floor, and can operate almost noiselessly in battery-only mode like many of its older generation. It has low to zero noise signature when running in battery and AIP mode, and has multi-sensor "wake-homing", wire-guided, and "smart" torpedoes with a 50 to 100 kilometer range at 93 kilometers per hour and 56 kilometers per hour.[74] The significance of these torpedo speeds and ranges is that these types of torpedoes can actually catch a nuclear aircraft carrier that might previously have outrun the older generation SSK and its torpedoes. As do older generation SSKs, the new SSK has cruise missile and anti-ship missile capability with ranges beyond 250 kilometers.[75] However, rather than spreading each of these different weapons control stations around the SSK's hull in their own separate compartments, new SSKs co-locate them into one combat information center that can maintain a common operational picture (COP), to include information given from the SSKs friendly task groups and higher headquarters.

If it merely shares the same capabilities of older SSKs, the question can be ask then: why would new SSKs compose a revolutionary system? Two main facts of modern AIP SSKs are: 1) modern AIP SSKs have more submerged endurance at faster speeds and 2) they have quieter

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[72] Hans Karr, "The Saint-Petersburg-Class - Conventional Submarines of the 4th generation from Russia", *Marineforum,* trans. Commander Axel Herbst (German Navy), March 2006, 30-31.

[73] Jane, *Jane's Fighting Ships…*, 118-120, 348, 611-612, 922.

[74] Fred T. Jane, "Type 65/ DT/ DST 92", *Jane's Defense*, 21 August 200, available from http://www janes.com/defence/naval_forces/news/jnws/jnws000821_1_n.shtml; Internet; accessed 6 March 2006.

[75] Jane, *Jane's Fighting Ships…*, 611-612.

propulsion systems. These two facts combined with the common technologies it shares with non-AIP SSKs (i.e. safer and longer endurance batteries, advanced torpedoes, new hull materials, air defense, C4ISR, and net-centric technology) result in an SSK that is deadly at long ranges, but, more importantly, has the means to remain undetectably stealthy throughout the duration of its patrol.[76] Finally, combining these improved Firepower , Maneuver, Information, and Protection elements, mentioned above, with an already strong Leadership element, produces the AIP SSKs remarkable ability to maneuver, like the proverbial "invisible man", undetected and undetectable to a position of advantage.[77] The SSK can use entire weeks of its undetectable movement to ambush or gain an assailable flank of the target. It can gain intelligence from its own sensors or from its friendly vessels, fuse it on the COP, and quickly decide which weapons to use and how best to attack. These weapons are then silently triggered and its AIP still allows plenty of submerged endurance, allowing the SSK to escape, once again, undetected.

Bringing this section to a close, one should understand that the modern AIP-equipped SSK is a leap ahead technological advancement from its predecessors and has a distinct advantage over other naval combatants, especially when employed in a littoral-warfare concept in noisy coastal waters. The next section will show how the new SSK has significantly impacted the naval strategies and policies of several nations around the world.

SSK IMPACTS ON SELECTED NAVIES

The proliferation of diesel-electric (SSK) submarines is widely documented by military journals and western navies.[78]

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[76] Jane, *Jane's Fighting Ships…*, 118-120, 348, 611-612, 922.

[77] "Their advantage is stealth…they can lay in wait for a long time in stealth mode." RADM John Waickwicz, USN Fleet Anti-Submarine Warfare Command, as quoted by Erwin, "Diesel Submarines…"

[78] "'Ten nations lining the Western Pacific own 212 diesel submarines, including 132 that fall in the "SSK"

> Because they are much less costly to produce than nuclear submarines, easily available on the world arms market and hard to detect, diesel boats [subs] are now viewed as classic 'asymmetric' threats that could wreak havoc on a technically superior U.S. naval force.[79]

These SSK subs are populating more than a third of world navies, as well as hard-line ideological nation-states.[80] Moreover, the most prolific sub, the Soviet 877, is a highly capable hunter of submarines and surface ships and is being fielded and improved upon by over 40 countries (including possible near term hot-spots: Iran, Venezuela, and China).[81] In 1999, the proliferation of these types of subs caused the U.S. Navy ASW community to realize it was neither trained for nor capable of defeating then-current diesel electric submarines.[82] This proliferation problem is compounded now, in 2006, by even newer, more capable SSK types than the Russian 877 *Kilo*, that incorporate advanced command and control systems, weapons, and even quieter, more capable propulsion devices and hulls.[83] These new AIP-equipped SSK capabilities have produced a huge impact on US countermeasures designed for the "old" SSK platform. As one author states:

> ASW had not been a large concern [for the U.S. Navy] until recently, when AIP [SSK] submarines became more operationally effective and relatively easily to obtain.[84]

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or hunter killer,' category, according to 'The Military Balance 2005-2006,'…China alone owns 64." Audrey McAvoy, "Navy Emphasizes Anti-Submarine Training", *ABC News*, 26 January 2006, Associate Press, 2006; available from http://abcnews.go.com/Politics/wireStory?id=1545249&page=2; Internet; accessed 5 February 2006.

[79] Erwin, "Diesel Submarines…"

[80] Otto Kreisher, "As Underwater Threat Re-emerges, Navy Renews Emphasis on ASW", *SEAPOWER*, Navy League of the U.S., October 2004, available from http://www.navyleague.org/sea_power/oct_04_15.php; Internet; accessed 16 February 2006.

[81] Jane, *Jane's Fighting Ships*..., 118-120, 348, 611-612, 922.

[82] Lieutenant Jack Shriver (USN), *The Submarine Review*, April 1999, 90.

[83] Norman Polmar. "Swedish Boat Will Help Navy Fight Quiet Submarine", *U.S. Naval Institute Proceedings*, Vol. 131, Issue 6, (Annapolis: Naval Institure Press, June 2005), 88.

[84] Andrew Dualan, "Why is the U.S. Navy Leasing a Swedish Submarine? Air-Independent-

While navies have developed many submarine detection technologies since SONAR was first invented, including radar, thermal imaging, and magnetic anomaly detection; "There is no silver bullet in ASW…We can't build a single system that is going to find every submarine in every kind of environment."[85]

Adding pressure to the ASW mission, the current U.S. Administration mandates that the U.S. military have access to "…an area of operations within ten days."[86] It also states that the U.S. goal on defense issues is to "…build and maintain our defenses beyond challenge."[87] Moreover, "the U.S. Navy's Sea Power 21 vision requires …naval forces to have assured access to littoral waters…"[88] and stipulates that they also "…must have the ability to conduct maritime operations in the presence of diesel submarine threats…capable of launching wake homing torpedoes."[89] These requirements of meeting short time windows, procuring dominant forces and defeating advanced capable SSKs and their torpedoes have caused the U.S. Navy to change its older ASW policies that were based on the Soviet style submarines.

The US Navy developed some countermeasures to engage a non-AIP equipped, Soviet SSKs. In some cases, the most effective was to blanket the area with ASW assets and prevent

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Propulsion and the Resurgence in Anti-Submarine Warfare ", *Jewish Institute for International* Affairs, 4 March 2005; available from http://www.jinsa.org/articles/index.html/function/view/categoryid/164/Documented/2873/history/3,2360,656,164,2873; Internet; accessed 6 February 2006.

[85] Paul Rosbolt (USN, Director ASW Programs, Naval Sea Systems Command) as quoted by Erwin, "Diesel Submarines…".

[86] Sandra I. Erwin, "Shrewd Tactics Underpin Navy Strategy to Defeat Diesel Submarines", *National Defense Magazine*, National Defense Industrial Org, 2005, http://www.nationaldefensemagazine.org/issues/2005/Mar/UF-Shrewd_Tactics.htm; Internet; accessed 9 March 2006..

[87] United States, National Security Council, *U.S. National Security Strategy 2006*, (Washington: U.S. Government Printing Office, February 2006), 29.

[88] U.S. Navy Sea Power 21, as quoted by DARPA, "Acoustic Arrays for Torpedo Defense (AATD)", http://www.darpa.mil/ato/programs/AATD/index.htm.; Internet; accessed 22 February 2006.

[89] U.S. Navy Sea Power 21, as quoted by DARPA, "Acoustic Arrays...".

the SSK from coming to snorkel depth (knowing it must snorkel in relatively short order to charge its batteries).[90] The ASW Commander could then predict its limited possible snorting locations, and lay in wait with reconnaissance and target acquisition assets to defeat the SSK. Because non-AIP SSKs have no ability to re-charge batteries, short of coming to snorkeling depth, a localized, heavily resourced ASW fight could be feasibly prosecuted within a relatively short time.[91] Even with this doctrine, these ASW procurements, and ASW trained manpower, however, the U.S. Navy has experienced failures in preparing its fleets for the modern diesel-electric SSKs:

> Quiet submarines for the most part cannot be detected with the conventional sonar technologies now employed aboard the Navy's nuclear-powered submarines and surface ships.[92]

Another observer notes that "…both Norwegian and Dutch diesel-electric submarines have successfully penetrated U.S. Navy formations during exercises."[93] According to this observer, even more weaknesses:

> …U.S. antisubmarine units have encountered unexpected difficulties in operations against some South American submarines during recent UNITAS operations, and Israeli subs are said to always 'sink' the high-value ships in exercises against the U.S. Sixth Fleet.[94]

This propensity to avoid detection, to attack and thwart the "sanitization" by the U.S. Navy produces a large timeline delay on the Joint Force attempting to gain access to littoral areas. With guidance to "dominate the Joint Area of Operations (JOA) within 10 days of

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[90] Hervey, *Submarines*, 54.

[91] Gardner, *Anti-Submarine Warfare*, 130-132.

[92] Erwin, "Shrewd Tactics …"

[93] Vincent Truba, "Building Diesel-Electric Subs", *Proceedings*, Vol. 131, Issue 6 (Annapolis: U.S. Naval Institute Press, June 2005), 62.

[94] Norman Polmar, "Realistic ASW Training", *Proceedings*, U.S. Naval Institute Press,…

notification for operations"[95], a U.S. naval task force faced with an anti-access (sea-denial) force of SSK submarines, experience long delays in "preparation" and "sanitization" of the littoral area past their ten day mandate. When the modern SSK fights in a Sea Denial or sovereignty protecting role and produces such large delays, it defeats this enumerated U.S. power projection strategy. Looking at the problem in context of a U.S. projection strategy for a possible Taiwan Straits crisis John Tkacik, Jr. states that:

> China has been investing heavily in submarines which it sees as the poisoned arrow to the Achilles heel of American might…China has identified America's strategic center [in a future Taiwan conflict] as its maritime predominance, and its [China's] sub fleet is clearly designed to overcome U.S. supremacy at sea.[96]

Moreover, retired RADM Eric A. McVadon states that:

> …China, quite simply, can put to sea more submarines than the U.S. Navy can locate and counter…the delay in sanitizing the area before the entry of Carrier Strike Groups is what the Chinese are counting on…to present the world with the…*fait accompli* with respect to Taiwan.[97]

China's *Song* SSKs comprise its most modern submarines, while their diesel electric fleet, overall, is China's largest type of submarine fleet.[98] China appears so convinced of the SSK's ability to counter an opposing force projection strategy that, not only is China making *Song* class SSKs, it is still procuring large numbers of advanced Russian SSKs as well.[99]

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[95] Erwin, "Diesel Submarines…".

[96] John Tkacik as quoted by Ronald O'Rourke, *China Naval Modernization: Implications for U.S. Naval Capabilities-Background and Issues for Congress*, Report No. RL33153. Washington: U.S. Library of Congress Congressional Research Service, 18 November 2005; 8.

[97] RADM (retired) Eric McVadon as quoted by Ronald O'Rourke, *China Naval Modernization: Implications for U.S. Naval Capabilities-Background and Issues for Congress,* Report No. RL33153. Washington: U.S. Library of Congress Congressional Research Service, 18 November 2005; 8.

[98] Jane, *Jane's Fighting Ships…,*118-120.

[99] Chinese Defense Today, "Project 636 Kilo Class Diesel-Electric Submarine", http://www.sinodefence.com/navy/sub/Kilo.asp; Internet; accessed 6 February 2006.

Russian, India, and Iran are also procuring new AIP-equipped SSKs as expeditiously as possible.[100] Also, Sweden has changed its procurement program to only acquire AIP SSKs.[101] The list of operational modern SSKs grows each year. "The worldwide fleet of diesel subs, always at their best in their own littoral waters, will some year soon break a thousand."[102]

These new diesel SSKs, have made such an impact on U.S. Navy operations that the U.S. Navy is now leasing a Swedish AIP SSK in order to train as many U.S. Navy ASW units as possible from June 2005 to June 2006.[103] The problem for current U.S. antisubmarine units to find SSKs has caused some experts to mock U.S. ASW operations as "Awfully Slow Warfare" because it was taking them weeks to "sanitize" an area of operations.[104] This has led to a new ASW doctrine for the U.S. Navy. The Chief of Naval Operations (CNO) approved a new ASW concept of operations that creates new ASW command structures, new tactics and new technology procurements.

> Clark's [the CNO's] goal is to 'fundamentally change' ASW operations away from individual platforms - ship, submarine or aircraft - to a system with the attributes of 'pervasive awareness, persistence and speed, all enabled by technological agility.'[105]

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[100] Jane, *Jane's Fighting Ships*..., 118-120, 348, 611-612, 922.

[101] "Plans call for all [Sweden's] submarines to be refitted with AIP systems." Nuclear Threat Initiative, "Sweden: Current Capabilities", (Monterey: Institute for International Studies, 2005), http://www.nti.org/db/submarines/sweden/index.html; Internet; accessed 12 March 2006.

[102] Joe Buff, as quoted by Noah Shachtman, "Navy Wants Underwater Spycam Net", *DefenseTech.org*, Military Adavantage, 2006; http://www.defensetech.org/archives/001541.html; Internet; accessed 30 March 2006.

[103] Polmar, "Swedish Boat…", 88.

[104] Admiral John Natham (U.S. Navy Vice Chief of Naval Operations), as quoted by Erwin, "Shrewd Tactics…".

[105] Mark W. Kenny, RADM (USN), as quoted by Kreisher, **"**As Underwater Threat…".

The U.S., and even NATO, are changing ASW doctrine, command structure, and procurement policies to a more network enabled system of systems architecture.[106] In order to cope with the quiet, long endurance AIP SSKs, these navies are developing fleets of miniature, autonomous underwater sensors, linked through wireless communications, that would be able to search wide areas of waterspace to find and report even a quiet, stealthy submarine.[107, 108]

The head admiral of U.S. Navy ASW reasons that ASW has returned to prominence because the Chief of Naval Operations:

> …looked at what the president requires of the Navy. That is access to project power…" into an area of conflict, and derived "…that the biggest threats to access are submarines and mines of our potential adversaries.[109]

This quote speaks to the littoral environment and the U.S. Navy's strategy to project combat operations from the sea to shore. New SSK weapons systems have serious implications for these carrier and amphibious based operations as one surprised observer found: "I noticed that the logo

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[106] Joe Katzman, "U.S. Navy Exploring New Concepts, Procurement Priorities for ASW", *Defense Industry Daily*, Watershed Publishing LLC, 2006, http://www.defenseindustrydaily.com/2005/03/us-navy-exploring-new-concepts-procurement-priorities-for-asw/index.php; Internet; accessed 9 March 2006.

[107] Posey, Carl. "Robot Submarines Go To War. Part 2: The Navy's AUVs", *Popular Science*, March 2003, available from http//www.popsci.com/popsci/science/6327359b9fa84010vgnvcm1000004eecbccdrcrd.html.; Internet; accessed 12 February 2006.

[108] This report lists several areas where current ASW forces have "…weaknesses…These are: Inability to thoroughly search the full water column, Inability of searching ships to detect submarines beyond the torpedo danger zone. Inability to sustain effective barriers under poor environmental conditions. Inability to conduct coordinated moving sweep or barrier operations with both low frequency active sonar ships and submarines utilizing multi-static principles. Inability to classify active sonar contacts with sufficient speed, resulting in airborne resources for contact investigation not being able to cope with the demand, especially in shallow water environments." Ziegenbein, Jochen and Pye, Ken. *CDE Project Summary: Multiplatform & Cooperative Multistatic Low Frequency Active Sonar Systems (MS LFAS)*, Report prepared by SACLANT Undersea Research Centre, La Spezia: Italy, 15 January 2002, available from www.act.nato.int/organization/transformation/ cde/Projects/LFAS%20Project%20Summary.doc; Internet; accessed 16 February 2006.

[109] Mark W. Kenny, RADM (USN), as quoted by Kreisher, **"**As Underwater Threat…"

for the cutting–edge…"Black Shark" torpedo was a shark with a U.S. aircraft carrier in its mouth."[110] These emerging SSKs are causing carrier leadership to take notice:

> The U.S. Navy has a heavy investment in carriers of the battle groups. They [therefore] must have the best in ASW protection to fend off enemy submarines.[111]

Finally, the impact of AIP SSKs has forced large changes in ASW procurement strategies:

> U.S. forces engaged in ASW operations need both waterborne and airborne sensors to collect information around the clock…This goal cannot be achieved…until the U.S. Navy and the other services develop an overarching command-and-control network…'There is a large gap in our ability to tie everything together.'[112]

The deduction remains that the U.S. ASW infrastructure currently cannot defeat the modern AIP SSK submarine. It will only be able to do so in the future when new U.S. ASW procurements enable a new ASW doctrine to be effective.

CONCLUSION

Revisiting the accepted criteria for a revolutionary technology; "1) makes a significant technological advance in a given area or; 2) has a major impact in combat or on defence policy."[113]; and 3) is a new capability that, combined with doctrine and force structure, produces a magnitude greater increase in effectiveness.[114] The "information-age" SSK represents

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[110] Walt Elliot (USN, Retired). "Collaboration is Key to Saving Whales, Supporting Our Sailors", *Seapower*, April 2004, Navy League of the United States, available from http://www.navyleague.org/sea_power/apr_04_06.php; Internet; accessed 12 March 2006.

[111] Gerkin, *ASW versus Submarine…*, 424.

[112] Captain David Yoshihara (USN, Director of the USN ASW Task Force), as quoted by Erwin, "Shrewd Tactics …"

[113] Norman Polmar, "The Polaris…."

[114] Andrew Krepinevich, "Transforming to Victory…"

technological advances in quiet propulsion, sonar and radar "stealthy" coatings, advanced fire control, maneuver control, and damage control computing technology, environmental sensing and air defense technology, and even advance guided missile and guided nuclear missile technology.[115] This allows one or two modern SSK's to operate in a sea denial concept and have a strategic effect of deterring U.S. amphibious and littoral operations past their strategic timeline and mandate.

New AIP SSKs will continue to be procured in growing numbers due to their revolutionary stealth advantage and ability to directly attack an opposing nation's power projection strategy. As some nuclear powered submarines found out, modern SSKs are formidable opponents:

> …in 2002, during the biennial RIMPAC…an Australian *Collins*-class diesel-electric submarine was able to score multiple kills against two U.S. *Los Angeles*-class nuclear powered attack submarines.[116]

This paper has shown that the modern AIP-equipped SSK has induced Sweden[117] to build only AIP SSKs, and caused China[118] and Russian[119] to procure more AIP SSKs, in a time where they could have, instead, chosen to build more nuclear powered attack submarines. Moreover, the AIP SSK has caused India to stop procuring older SSKs and, instead acquire AIP SSKs, and even to retro-fit its existing SSKs to have AIP propulsion. Finally, experts have testified before the U.S. Congress and in major publications that the current U.S. ASW policy needs significant

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[115] Joe Katzman, "India to Sign Multi-billion Dollar Scorpene Sub Contract (Updated)", *Defense Industry Daily*, http://www.defenseindustrydaily.com/2005/09/india-to-sign-multibillion-dollar-scorpene-sub-contract-updated/index.php; Internet; accessed 9 March 2006.

[116] Dualan, "Why is the U.S. Navy…".

[117] Nuclear Threat Initiative, "Sweden: Current Capabilities", (Monterey: Institute for International Studies, 2005), http://www.nti.org/db/submarines/sweden/index.html; Internet; accessed 12 March 2006.

[118] Chinese Defense Today, "Project 636…"

[119] Yanko, "SSK".

changing[120], its systems cannot detect AIP SSKs and that these SSKs directly contravene the U.S. power projection strategy.[121] These AIP-equipped SSK submarines have met or exceeded the imperatives of a revolution in warfare, and therefore, constitute a revolution themselves.

[120] "The newest…is Fleet ASW Command…in San Diego...The other organizations are: Task Force ASW… in Washington, D.C.…[and] The Program Executive Office for Integrated Warfare Systems at Naval Sea Systems Command (NavSea)", Kreisher, "As Underwater Threat…"

[121] Morgan, John. (CAPT, USN). "Anti-Submarine Warfare: A Phoenix For The Future", *Federation of American Scientists*, http://www.fas.org/man/dod-101/sys/ship/docs/anti-sub.htm; Internet; accessed 4 March 2006.

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