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THE UNRAVELING AND REVITALIZATION OF U.S. NAVY ANTISUBMARINE WARFARE

John R. Benedict

That “those who cannot remember the past are condemned to repeat it” is a truism.¹ As Captain John Morgan warned more than five years ago concerning U.S. Navy antisubmarine warfare (ASW), “Acknowledging and understanding ASW’s recurring cycles of ‘boom-and-bust’ can accelerate the awakening that is now underway in the Navy. We need to avoid any further unraveling.”² The present Chief of Naval Operations (CNO), Admiral Vernon Clark, has recently

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The views expressed in this article are the author’s alone and do not represent the official position of JHU/APL, the Department of the Navy, the Department of Defense, or the U.S. government.

[This detailed Johns Hopkins University Applied Physics Laboratory presentation summarizes the research that forms the basis for this article.](#)

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taken a number of related steps, most notably the establishment of a new Fleet ASW Command in San Diego, California.³ A central premise of this article is that we can learn from previous successes and failures in reinvigorating antisubmarine warfare. That reinvigoration is critical; antisubmarine warfare needs to be “maintained as a Naval core competency.”⁴ ASW is a key component of Sea Shield (projecting defensive power from the sea), which in turn enables both Sea Strike (projecting offensive power from the sea) and Sea Basing (supporting a widely distributed and netted fleet). These three operational concepts are the essence of the CNO’s Sea Power 21 vision.⁵ Without effective antisubmarine warfare it cannot be ensured that losses to submarine threats can be kept to acceptable levels among carrier strike groups, expeditionary strike groups, surface action groups, combat logistics forces, maritime prepositioning forces, afloat forward staging

bases, merchants (strategic sealift and commercial), or other maritime forces in joint operating areas.

This article draws upon open sources to document capabilities and trends of the past and to identify the factors that most closely correlate to health in anti-submarine warfare. Those sources support a number of major arguments—above all, that the U.S. Navy is not doing well in antisubmarine warfare. The real threat is the transfer of submarine-related technology to possible future adversaries. Further, and although the submarine threat to U.S. military access in key regions is being addressed to some extent, new undersea threats related to homeland defense and force protection are largely being ignored. Third, focusing on ASW technologies and systems without concomitant disciplined data collection and analysis represents a false economy. Fourth, the open literature shows that basic oceanographic research and operational and technical intelligence related to antisubmarine warfare have been allowed to atrophy. In addition, the current acquisition environment is taking too long to field new systems; virtually no innovative ASW sensor and weapon concepts (without Cold War origins) have entered service since the dissolution of the Soviet Union.

Finally, open sources make clear that there is no panacea in antisubmarine warfare; the U.S. Navy will, as previously, need to pursue a variety of technical and operational approaches to countering adversary submarines in the future. Specifically, getting healthy in antisubmarine warfare will depend more on sensor hardware and software technology—particularly related to surveillance and cueing*—than on marginal adjustments to manned-platform force structures, which are declining in any case. Getting healthy also depends on training at all appropriate levels, with feedback mechanisms to ensure progress. In addition, without reliable, timely, and accurate surveillance cues and reliable weapons, ASW becomes a very hard, inefficient, and asset-intensive game—yet the next generation of distributed ASW surveillance systems (beyond the Advanced Deployable System) has yet to be established.

The U.S. Navy appears to be on the brink of a real commitment to revitalize antisubmarine warfare, but the pace of this revitalization will be significantly less than it needs to be if sustained support, effective organization, and ample resources are not forthcoming. Even a comprehensive and unified effort will take many years to turn antisubmarine warfare around.

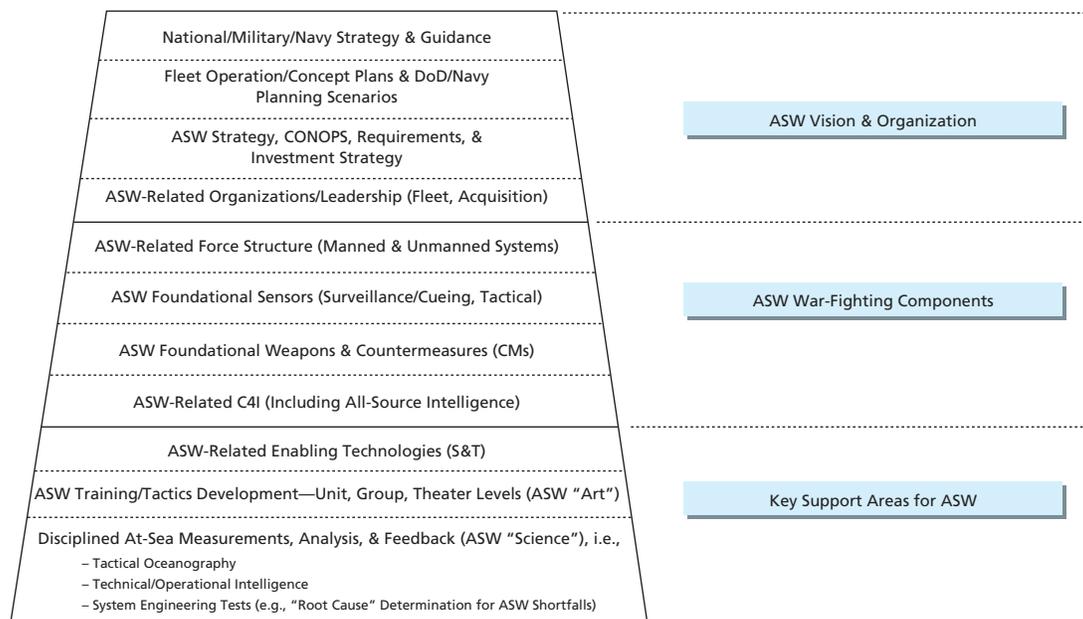
THE IMPORTANCE OF UNITY OF EFFORT IN ASW

The effort to revitalize antisubmarine warfare can be fragmented, with different naval communities taking independent paths, or it can be integrated and

*That is, alerts to the presence of possible targets quick and precise enough to allow the targets to be localized, identified, targeted, and ultimately engaged by tactical assets.

cohesive. If the latter, there is a chance for effective unity of effort from top to bottom of the pyramid shown in figure 1. The top portion of the pyramid relates to vision, acquisition strategy, and the organization and resources needed to implement them; without these, it is unlikely that the required capabilities will be fielded. In a crisis or contingency involving a submarine threat, the top of the pyramid determines whether the right equipment and capabilities have been fielded to deal with it. Until recently there has been no consensus on ASW war-fighting or investment strategies; the various communities (submarines, surface combatants, aircraft, undersea surveillance) have largely set their own priorities and fended for themselves. This is understandable, considering that for much of the post-Cold War era there has been no agreement on ASW requirements, concepts of operations, engineering approaches, fleet tactics, or doctrines.⁶ Some communities during the 1990s assigned very low priority and meager resources to antisubmarine warfare compared to other missions and roles.⁷ They did this although ASW, as was evident both in the Second World War and in the Cold War, requires a diverse collection of assets.

FIGURE 1
ASW PYRAMID OF SUCCESS OR FAILURE



The middle of the pyramid represents the key elements of antisubmarine warfare (force structure, sensors, weapons, countermeasures, and C4I*) that would be brought to bear in a conflict involving adversary submarines. The

*Command, control, communications, computers, and intelligence.

bottom of the pyramid represents key support areas; they largely determine whether the ASW forces and systems in the middle of the pyramid achieve their full potential or disappoint the fleet. These support areas represent the dull and dirty work that is often overlooked and under-resourced; indeed, since the end of the Cold War the ASW support infrastructure has been significantly reduced. For instance, neglect in at-sea environmental measurement, intelligence on the threat, and system engineering has undermined the *science* of antisubmarine warfare, while neglect in training and tactical development at the unit, group, and theater levels has undermined the *art*.

Two historical examples illustrate the importance of unity of effort to success in antisubmarine warfare. The first is the Tenth Fleet, established by the U.S. Navy in May 1943 to control antisubmarine operations in the portions of the Atlantic assigned to the United States. It was organized into five divisions that performed, respectively, fusion and dissemination of operational intelligence, routing and rerouting of convoys based on surveillance and intelligence, allocation and coordination of ASW units (none were directly under the command of the Tenth Fleet per se), the development of doctrine and tactics, and the evaluation and fielding of materiel and equipment.⁸ Previously, U.S. Navy antisubmarine warfare had been largely unresponsive and ineffective. The unifying contribution of this command, and of its British counterpart, helped turn around the Battle of the Atlantic.

A second historical example is the Cold War, during which ASW emerged as a top priority, served by a clear, shared war-fighting vision and a concept of operations that emphasized far-forward offensive operations and layered defenses. Reliable undersea cues were available from the Sound Surveillance System (SOSUS). There was also an investment strategy, delineated in an ASW Master Plan, which was regularly updated. Adequate resources were applied, and strong organization was evident in the requirements and acquisition communities and in the fleet. Each component understood its roles and contributions to the overall antisubmarine mission.

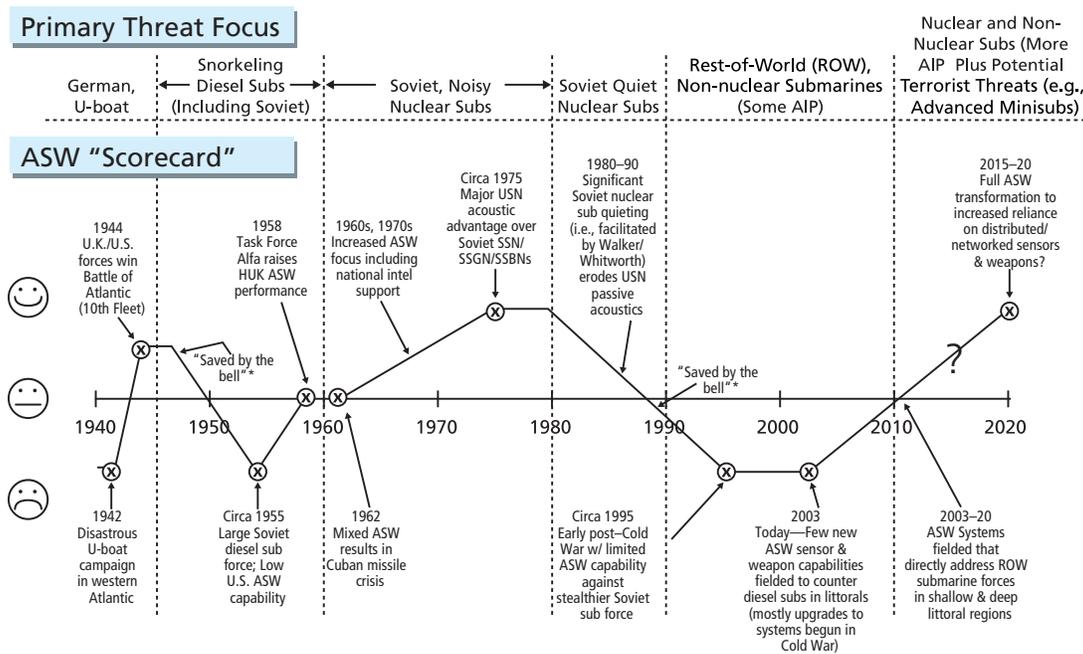
Even so, it took decades to achieve superiority against the evolving Soviet submarine threat, just as in World War II it took years to defeat the U-boat threat in the Atlantic. In the 1982 Falklands War, conversely, it took the British only a few weeks to realize that they had major problems in ASW: lack of knowledge of the threat and environment, inadequate surveillance and cueing, unreliable tactical sensors for the littoral conditions, and undisciplined tactics.⁹ In the next conflict involving adversary submarines, the U.S. Navy probably will not have decades to prepare or years to win; the contingency may prove to be as unexpected and brief as the Falklands. The Navy can accept the risk and decline to prepare, hoping that the adversary will be equally unprepared (like the

Argentineans, whose torpedoes failed to work properly against British warships).¹⁰ Or it can prepare for such an eventuality, developing and maintaining the required unity of effort in antisubmarine warfare throughout the ASW pyramid.

A LONG-TERM VIEW OF ASW HEALTH

The cyclic nature of health or wholeness in antisubmarine warfare for the U.S. Navy and its allies over the last sixty or more years is indicated in figure 2, which resembles a roller coaster. After a disastrous start, the Allies (primarily the United States, Britain, and Canada) were able to overcome the German U-boat antishipping campaign and win the Battle of the Atlantic.¹¹ But the Allies were

FIGURE 2
LONG-TERM VIEW OF USN ASW TRENDS



*Cote, *The Third Battle* (see note 14).

See Benedict, *Long-Term Perspective*, p. 22 (see note 32).

woefully unprepared to deal with the Type XXI U-boats, equipped with snorkels,* that were entering service in 1945.¹² For example, at-sea radar trials conducted after the war against a snorkel established a .06 probability of detection per opportunity with the best Allied radars available.¹³ The Allies had been "saved by the bell."¹⁴ This threat, as subsequently posed by Soviet diesel submarines, became the primary focus in U.S. Navy antisubmarine warfare. Nonetheless, by

*Extendable air intakes that allowed submarines just beneath the surface to operate their diesels, renew their air, and recharge batteries.

1958 the CNO, Admiral Arleigh Burke, wanted “to know why the Navy’s ASW effort, despite all the high tech, was so weak and ineffective.”¹⁵ He formed Task Force Alfa on 1 April of that year to experiment at sea with new ways to counter diesel Soviet submarines. The stated goal was to be able to detect submarines and then track them continually for up to four days, using “hold-down tactics” designed to force them eventually to snorkel. Combined ASW tactics were developed with destroyers, helicopters, and fixed-wing aircraft, the latter both carrier- and land-based. But after extensive work against surrogate U.S. diesel boats, Task Force Alfa was able to track these submarines only up to eight hours.¹⁶ It was unable to overcome physical and budgetary constraints through tactics and doctrine alone. Nonetheless, the improvements it made in ASW tactics and effectiveness yielded the partial success achieved during the Cuban missile crisis four years later.

The 1962 crisis provides the best operational example of the U.S. Navy combined-force antisubmarine capabilities that emerged from the 1950s. Four Soviet Northern Fleet long-range diesel attack submarines (Foxtrot-class boats equipped with conventional and nuclear torpedoes) were sent to Cuba as an advance reconnaissance force. They were most vulnerable to detection for about a month, 1 October–2 November. The U.S. Atlantic Fleet was essentially on a war-time footing, with about 85 percent of its assets at sea, including those involved in the quarantine around Cuba.¹⁷ Numerous hunter-killer groups of carrier aircraft and destroyers supported by land-based patrol aircraft (P-2Vs and P-3s) were alerted to the transit of the Soviet submarines and attempted to locate and track them. Despite some SOSUS contacts in and to the south of the Greenland-Iceland–United Kingdom gap, none of the Foxtrots had been firmly tracked as of 25 October, when they reached their stations off Cuba. They were now inside the quarantine line, where the various ASW-capable assets were generating many false contacts with their tactical sensors. Nonetheless, by 2 November all four boats had been detected. Three were initially found, either snorkeling or on the surface, by aircraft (land- and carrier-based); one was initially detected by destroyer radar while snorkeling and was subsequently reacquired by a World War II–vintage AN/SQS-4 shipborne active sonar. In three of the four cases, hold-down tactics forced the Foxtrots to surface to recharge batteries. The fourth Foxtrot was able to break contact before being obliged to snorkel.¹⁸

The emergence of Soviet nuclear submarines, including SSBNs equipped with nuclear land-attack ballistic missiles, increased the priority of antisubmarine warfare within the U.S. Navy during the 1960s and 1970s. This resulted in a heavy reliance on passive narrowband acoustic sensors to exploit discrete “tonals.” These sensors included improved SOSUS arrays, towed arrays on American nuclear-powered attack submarines (SSNs), improved sonobuoys for

P-3 and S-3 aircraft, and eventually towed arrays on surface combatants. This was a successful time for antisubmarine warfare, in which robust wide-area surveillance by SOSUS, effective large-area search by land-based patrol aircraft responding to open-ocean cues, and protracted track-and-trail capabilities of SSNs were all demonstrated.¹⁹ This level of performance, however, was made possible by the relatively noisy first- and second-generation Soviet nuclear submarines of that era. Also, results were often less impressive at the battle-group level without the benefit of undersea surveillance cueing.²⁰ Furthermore, the success enjoyed in the North Atlantic and Mediterranean was difficult to replicate in the vast expanses of the North Pacific.²¹

The extent of acoustic superiority enjoyed by the U.S. Navy during the 1960s and 1970s was exposed to the Soviets by the espionage of John Walker and Jerry Whitworth, which ended only in the mid-1980s. The Soviets translated this knowledge into significant quieting improvements for Victor III, Mike, Sierra, Akula, Oscar, Typhoon, and certain Delta-class submarines.²² As pointed out recently, “Since 1960, 35 decibels of quieting have reduced . . . [detection] ranges from 100s of miles to a few kilometers.”²³ The change did not happen overnight, but by the mid-1990s a significant portion of the (by then Russian) submarine order of battle was significantly quieter than it had been in the 1970s. Once again, the U.S. Navy had been saved by the bell—this time, the end of the Cold War. A 1989 report to the House Armed Services Committee had warned, “The advent of quiet Soviet nuclear submarines and the prospect of even quieter non-nuclear submarines with considerable submerged endurance means . . . the loss of effectiveness of passive sonar. . . . [This] will affect virtually every phase of our ASW capability . . . [and] raises profound national security problems.”²⁴

Since the end of the Cold War, U.S. Navy ASW concerns have gradually shifted away from former Soviet nuclear submarines to the diesel submarines of the rest of the world. The latter could pose a risk to American and allied naval and maritime forces in regional contingencies.²⁵ Where previously the Navy had focused on a known adversary whose military and submarine force could threaten the nation’s very survival, it now concentrated on uncertain potential adversaries with area-denial strategies designed to inflict unacceptable losses (as occurred in Lebanon in 1983 and Somalia in 1993). Modern conventional submarines employing antiship torpedoes, mines, and cruise missiles are difficult to counter in adverse littoral environments and are capable of inflicting significant damage to U.S./allied forces.

How would the U.S. Navy do in antisubmarine warfare today? Vice Admiral John Grossenbacher, as commander of Submarine Forces, Atlantic (ComSubLant) and ASW Forces, Atlantic (CTF 84), recently stated, “As I testified before Congress, our ASW capabilities can best be described as poor or

weak. . . [A]s a minimum our Navy must have the capability and capacity, if required, to neutralize the potential undersea threats posed by China, North Korea and Iran, today.”²⁶ Admiral Thomas Fargo, Commander in Chief, U.S. Pacific Fleet (CincPacFlt), has declared, “Today when Naval components prepare OPLANs [operations plans,] [the] most difficult problem to deal with is [the] submarine threat. . . [ASW] is not a mission we can outsource to . . . [the] joint community—it is distinctly naval. . . [W]e will need greater ASW capability than we have today. [This is] at the top of my tactical problems in the Pacific.”²⁷ In recent Senate testimony Admiral Fargo remarked, “250 submarines call the Pacific home—but only 30 percent of these submarines belong to allied nations. . . . [F]uture technologies are essential to counter the growing submarine threat.”²⁸

U.S. Navy exercises with diesel submarines since the mid-1990s have often proved humbling. South African *Daphné*-class, Chilean Type 209, Australian *Collins*-class, and other diesel submarines have penetrated battlegroup defenses and simulated attacks on surface ships, including aircraft carriers, often without ever being detected.²⁹ The 1982 Falklands War may be the best available indication of how a U.S. Navy ASW operation might go today. The Royal Navy has been at the forefront of antisubmarine warfare for nearly a century. It was responsible for more than two-thirds of the U-boats sunk during 1942–44.³⁰ Unlike the U.S. Navy, the British navy continued to focus on Soviet diesel submarine threats throughout the Cold War, especially those that could operate in the European littorals to attack NATO reinforcement shipping. Yet in 1982, as we have seen, and despite such steady emphasis on conventional submarines, British antisubmarine forces in the Falklands were not up to the task. An Argentine Type 209 diesel submarine stayed safely at sea for over a month while the British expended more than 150 depth charges and torpedoes against false contacts. British antisubmarine forces scored no hits on the submarine and failed to prevent two attacks on surface ships, which were saved only by defective Argentine torpedoes.³¹

The Falklands ASW campaign proved to be more of a crapshoot than an exercise in sea control. The U.S. Navy needs to do better. But how many American ASW sensor programs fielded today are not Cold War legacies? How many were developed entirely as responses to nonnuclear threats in the littorals? The answer is zero. All U.S. Navy submarine towed arrays, all surface-ship active sonars, all aircraft sonobuoys, all helicopter dipping sonars, and all undersea surveillance systems in the fleet in 2004 have their origins in the Cold War. Most of these sensors have been adapted for littoral and diesel applications by software and hardware upgrades or redesigns. But truly new capabilities directed at post-Cold War threats are still trying to get through the acquisition process fifteen years after the fall of the Berlin Wall. These include the Advanced Deployable

System for undersea surveillance in the littorals, an advanced periscope-detection radar capability, and ASW mission modules being developed for the Littoral Combat Ship (LCS). So what makes us think that any antisubmarine contingency fought today or in the near term would look significantly different from the Falklands? In truth it probably would not, particularly if we continue to neglect some of the crucial enablers in the pyramid of success or failure.

Any prediction as to whether the health of U.S. Navy antisubmarine warfare will be on the upswing during the next fifteen years, as shown in figure 2, then, requires significant qualification. That is the stated intent of Navy leadership, but it remains an open issue.

ASW THREAT DEVELOPMENTS

The submarine threat continues to evolve in terms of stealth, submerged endurance, combat system automation, weaponry, and operational proficiency (as facilitated by user-friendly equipment). The real threat is the post-Cold War global marketplace, which allows any nation or group with adequate fiscal resources to acquire advanced military technology.

It is illuminating to trace diesel submarine characteristics from circa 1935 and then project them to about 2010. The state of the art has evolved from the standard German U-boat of the early Second World War to the Mark XXI with snorkel at the end of the conflict, to the Soviet Romeo and Foxtrot designs of around 1960, the German Type 209 series introduced in the 1970s (and still in service today), and Russian Kilo and follow-on designs since the 1980s, to the German Type 212/214 with fuel-cell-based air-independent propulsion (AIP), of which deliveries have been made since 2003 and are scheduled through at least 2012. It is striking how little resemblance there is between the U-boats of World War II and today's diesel submarines. The modern boats are two to three times faster submerged, have four and a half to six times more submerged endurance even without AIP (and fifteen to twenty times more with it), can reach two and a half to four times greater maximum depths, are much quieter (at low speeds they compare favorably to the most modern nuclear submarines), and are equipped with much more advanced weaponry (torpedoes, mines, even cruise missiles).³²

With regard to air-independent propulsion, at this writing four or five large conventional submarines are in operation with hybrid diesel-AIP propulsion, and at least another fifteen submarines are in development or on order.³³ AIP comes in various forms, including the closed-cycle diesel (the Dutch and Italian focus), the closed Rankine-cycle steam turbine (a French design reflected in Pakistan's Agosta 90B acquisitions), Stirling engines (Swedish and Japanese), and fuel cells (German, Canadian, and Russian). All are available for export.

Air-independent propulsion is expected to become standard for new conventional submarines by 2015 or 2020. AIP can provide weeks of submerged endurance at low speeds without the need to snorkel, making a bad situation in antisubmarine warfare even worse.³⁴ As an American submariner, Rear Admiral Malcolm Fages, warns, “The marriage of air independent, nonnuclear submarines with over-the-horizon, fire and forget antiship cruise missiles and high endurance, wake homing torpedoes . . . [means that] traditional ASW approaches, employing radar flooding and speed, are not likely to be successful against this threat.”³⁵

Excluding the United States, today more than forty countries have, among them, between three and four hundred submarines, depending upon whether minisubs (under three hundred tons) and submarines in reserve status are included. But the issue is not quantity but quality; nearly three-fourths of these submarines are relatively modern designs, incorporating technology of the 1970s or later.³⁶ This proportion will only increase in the future as countries like China replace their Romeos (diesel) and Hans (nuclear) with Kilos (diesel), Songs (diesel), and Type 093s (nuclear) over the next decade. With the help of Russia and others, the Chinese are rapidly converting from an operational force of more than fifty older, noisier submarines to a comparably sized force dominated by modern, quiet submarines. The recent sale of eight additional Project 636 Kilos equipped with wake-homing antiship torpedoes and submerged-launch 3M54E Klub-S antiship cruise missiles is indicative of the transformation of this submarine force.³⁷ The Project 636 Kilo “is one of the quietest diesel submarines in the world”;³⁸ wake-homing torpedoes are countermeasure-resistant, “user-friendly” weapons effective at ten kilometers or more, even for less proficient submarine forces;³⁹ and the Klub-S missile has a 220-kilometer maximum range against ships and a terminal speed of up to Mach 3.⁴⁰ Such a capability represents a very formidable threat to American and allied surface units.

From a lethality viewpoint, heavyweight torpedoes carried by submarines are a particular concern. These weapons, with explosive charges typically weighing two or three hundred kilograms, are designed to detonate under the bottom of a surface ship, rupturing the keel and thus causing rapid sinking and high casualties. Historically, hits by four torpedoes or fewer have sunk even ships of 13,000–30,000 tons, causing hundreds of deaths (up to two-thirds of the crew).⁴¹ Large aircraft carriers are not invulnerable to these weapons. Carriers are more likely to be rendered immobile and suffer mission degradation than to be sunk by standard 53 cm–diameter torpedoes, but during the Cold War the Soviet Union developed 65 cm torpedoes specifically designed to sink them. The Type 093 nuclear submarines being built by China are believed to have torpedo tubes capable of firing 65 cm weapons.⁴² The loss of life in the sinking of a typical surface

combatant would be comparable to that suffered in the 1983 Beirut Marine barracks bombing or during the entire 1991 Gulf War. For an aircraft carrier, the loss could be comparable to that in the World Trade Center on 11 September 2001.

The threat goes beyond damage to maritime forces. Several countries outside NATO and the former Soviet Union are pursuing the idea of placing land-attack missiles with nuclear warheads on their submarines. These include China and India, which have in development, respectively, the Type 094 SSBN (to replace the existing *Xia*) and the ATV (Advanced Technology Vehicle) nuclear-powered missile-equipped submarine programs. There is also speculation that countries like Pakistan and Israel are exploring nuclear-tipped land-attack cruise missiles for their submarines.⁴³

On a final disturbing note, minisubs, manned submersibles, and autonomous underwater vehicles (AUVs) are becoming worrisome with respect to force protection (including in overseas ports) and homeland defense. Commercial and military development in these areas has been rapid; advanced technology related to automation, navigation, AIP, and other categories has made these unconventional threats even more viable than in the past.⁴⁴ Minisubs (SSMs) and swimmer delivery vehicles (SDVs) are now, according to one expert, a “proven weapon of war. . . . [M]odern bases are virtually defenseless against this form of attack.”⁴⁵ The countries known to have SDVs or SSMs today include Colombia, Iran, North Korea (the largest minisub force in the world), Pakistan, and South Korea.⁴⁶ Drug cartels have used submersibles and minisubs to smuggle cocaine from ports in Colombia to ships at sea.⁴⁷ North Korea has used submersibles, minisubs, and coastal submarines to insert agents into the South.⁴⁸ The Tamil “Sea Tigers,” a terrorist group, has attempted twice to build SDVs or minisubs (but has been aborted so far by authorities).⁴⁹ The Neiman Marcus 2000 Christmas catalog offered a twenty-million-dollar personal submarine that could be deployed from a megayacht or ship.⁵⁰ Osama Bin Laden attempted to purchase a small personal submarine through a relative in the United States (the deal was stopped by the FBI).⁵¹ Tourist submarines carry up to approximately two million people underwater annually, with no reported fatalities to date.⁵² Current tourist submarines have limited submerged endurance (some ten hours), but a craft of that type carrying up to five tons of explosives could be deployed from a mother ship on a one-way, possibly suicide, mission. Future tourist submarines are being advertised with submerged endurances allowing ranges of 40–350 nautical miles.⁵³

A number of other commercial developments may interest terrorists as well: general-purpose manned submersibles (typically with two crew members, submerged endurance of from four to twenty-eight hours, and 150–300 kilograms of payload), autonomous underwater vehicles, remotely operated vehicles

(ROVs), and semisubmersibles with large payloads. AUVs and ROVs are being used extensively for oil and gas surveys and pipeline inspections. They are also used in preventive maintenance of fiber-optic submarine cables, cable laying, and oceanographic, hydrographic, and seabed surveys, sometimes at great depths.⁵⁴ Large-diameter (1–1.5 meters) AUVs can offer a combination of long endurance (36–150 hours) and large payloads, the equivalent of at least one torpedo.⁵⁵

Any assessment of the threat posed by minisubs, manned submersibles, and autonomous underwater vehicles requires a caveat. Why should adversaries go to the trouble, if American and allied borders, ports, merchant shipping, airports, and air traffic are already porous and vulnerable? The United States is attempting to secure its borders and coastlines against threats by land, air, and the sea surface. If it does not do the same against subsurface threats, its adversaries will presumably try to exploit that weakness to deliver agents, contraband, explosives, even weapons of mass destruction.

The U.S. Navy and Coast Guard need to identify and begin developing appropriate counters to this potential threat. These would include undersea surveillance systems capable of finding and identifying small submersibles off the coasts or even inshore. At present, neither the Navy nor the Coast Guard seems to be addressing this contingency in a significant way. This is inconsistent with recent guidance from the secretary of defense, Donald Rumsfeld: “We must transform . . . [and] be proactive[;] . . . not wait for threats to emerge and be ‘validated’ but rather anticipate them before they appear and develop new capabilities to dissuade and deter them.”⁵⁶

ASW FORCE STRUCTURE TRENDS AND IMPACT

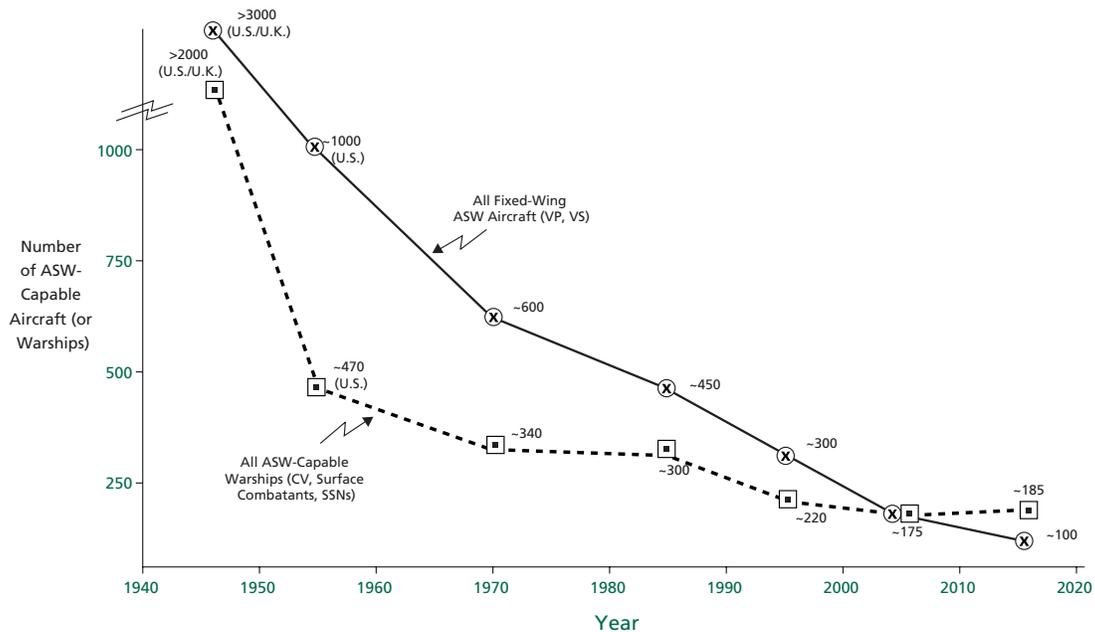
At the peak of the Second World War, more than five thousand Allied ships and aircraft were involved in operations against U-boats. Such numbers were crucial to winning the Battle of the Atlantic, a campaign of attrition that lasted several years, but they also demonstrate how demanding and costly antisubmarine warfare becomes without reliable, timely, and accurate surveillance cues and reliable weapons. For example, in those years, in daytime, 470–660 flight hours were required per visual contact gained; about the same (466–600) were needed per radar contact.⁵⁷ At night, visual detection was nearly impossible, but radar contact rates actually increased, since it was more likely that the U-boats would surface then. In addition, depth charge attacks had only 4–10 percent success rates (i.e., of sinking the U-boat) per barrage.⁵⁸ The result of these factors was a tough, grinding campaign in which over 2,500 merchant vessels (more than fourteen million tons) and more than five hundred American and British warships were sunk and over eight hundred U-boats were lost.⁵⁹ Eighty-five percent of the

U-boat sinkings were achieved by surface ships and aircraft, in roughly equal proportions.⁶⁰

Figure 3 shows the relentless downward trend since World War II in ASW-capable force structures, paralleling that across the entire military. By 1955 there had been about a 55 percent reduction in U.S. Navy ASW-capable assets compared to 1945. By 1970 there had been a 35 percent reduction from 1955 levels, and by 1985, 20 percent more. By 1995 ASW-capable assets had been reduced another 30 percent; by the end of 2005 there will be a further 30 percent drop (compared to 1995); and the trend is expected to continue. From 1945 to 2005, the antisubmarine force structure (warships and escorts, aircraft carriers, fixed-wing aircraft, and submarines) will have decreased by an order of magnitude, to about 350 units. Any successful concept for antisubmarine warfare must also account for the fact that today and in the future many of the remaining units do not and will not specialize in ASW. They will be multimission platforms, with antisubmarine warfare only one of several subspecialties.

The peak years of the Cold War (1975–80) provide an interesting counterexample to the World War II experience. The U.S. Navy was able with only moderate ASW force levels of eight or nine hundred units to dominate Soviet submarines. This dominance was due to integrated undersea surveillance

FIGURE 3
ASW-CAPABLE FORCE STRUCTURE TREND: 1940–2020



See Benedict, *Long-Term Perspective*, pp. 13–15. The component surface combatant, submarine, aircraft carrier, and fixed-wing aircraft force levels for 1945, 1955, 1970, 1985, 1995, 2005, and 2015 were derived from multiple sources, including *Jane's Fighting Ships* for the appropriate years (albeit for 1945 a variety of World War II source materials were used), as well as *Jane's All the World's Aircraft*.

system cueing and the success of sensor technologies (both surveillance and tactical) against the noisy Soviet nuclear submarines of that era. That is to say, all-source intelligence and acoustic superiority acted as “force multipliers.”

As both World War II and the Cold War illustrate, getting healthy in antisubmarine warfare depends more on sensor (and cueing) hardware and software than on numbers of ASW-capable platforms. Higher force levels, in a joint, multithreat environment, can enhance the likelihood that multimission units will be available for antisubmarine tasking, and they can better handle high false-contact rates. But large force levels cannot overcome poor sensor technology, surveillance, or cueing; weaknesses there are potentially fatal.

ASW SURVEILLANCE/CUEING AND SENSOR TECHNOLOGY ENABLERS

Table 1, if correct, points to a high correlation between ASW success and both surveillance (cueing) and sensor technology. Between 1940 and 1950 the primary ASW surveillance sensor was HF/DF (high-frequency/direction-finding) conducted ashore and on board specially equipped ships. The primary tactical “enablers” were radar and visual search by ships and aircraft, and early sonar (American) or asdic (British) acoustic sensors on surface ships. Each of these technologies was important, but none proved entirely satisfactory. Gaining radar or visual detection in the open ocean proved very time consuming. Sonar (or

**TABLE 1
SUMMARY OF ASW SCORECARD “DRIVERS”: 1940–2020+**

Time Frame	ASW Surveillance & Cueing “Scorecard”	ASW Force Structure “Scorecard”	ASW Sensor Technology “Scorecard”	Overall ASW “Scorecard”*
1940–1950	☹️	😊	☹️	☹️
1950–1960	☹️	☹️	☹️	☹️
1960–1980	😊	☹️	😊	😊
1980–1990	☹️	☹️	☹️	☹️
1990–2003	😞	😞	😞	😞
2003–2010	☹️	😞	☹️	☹️ [†]
2010–2020+	?	😞	?	?

*Emphasizes ASW “health” at end of designated time frames.
 †If key sensor capabilities are demonstrated, embraced by fleet (training/proficiency issues overcome) & fielded in adequate numbers.

See Benedict, *Long-Term Perspective*, pp. 9–11, 13–14, 16–17, 19, 48–49, 54–56, 60–61, 65–66, 70–72, 76–77, 82–83.

asdic) limited follow-on attacks against convoys, but it did not meet prewar expectations, and U-boats could counter it by attacking on the surface. HF/DF and ULTRA code breaking played important roles in the Second World War, but information was often withheld due to operational security or proved untimely or inaccurate. For example, HF/DF and ULTRA cues were withheld in 1940 from British hunter-killer operations, which then proved ineffective and were abandoned. In contrast, timely and reliable cues from these sources, shared with American hunter-killer groups in the eastern Atlantic from May 1943 to May 1945, contributed to fifty-two of the fifty-three U-boat sinkings—that is, only one sinking did not rely on this support.⁶¹ This figure represented about 30 percent of all U-boats sunk by the U.S. Navy in World War II.⁶² The British did not provide ULTRA-related cues to their tactical ASW forces, but they used this information to reroute convoys and to reinforce their surface and air escorts if they were likely to be threatened (based on estimated U-boat locations). Very-long-range aircraft in the Atlantic made one U-boat sighting approximately every thirty hours on patrol for “threatened” convoys, compared to one every 640 hours for “unthreatened” convoys—a dramatic demonstration of the force-multiplying effect of surveillance cueing.⁶³

From 1950 to 1960 the primary sensor-technology enablers were passive acoustics against snorkeling submarines, ship and aircraft radar, and shipborne active sonar in the five-to-fifteen-kilohertz (kHz) region. Once again, each of these sensor technologies was important, but none proved robust. Passive acoustic sensors in early SOSUS arrays, on U.S. submarines (nuclear or conventional), and on fixed-wing aircraft (shore- or carrier-based) provided good capability against snorkeling submarines. However, passive acoustics sensors were not as effective against submerged submarines on battery. Ship and aircraft radar was much less effective against snorkels than against surfaced submarines. Shipborne 5–15 kHz active-sonar detection ranges were eight to ten thousand yards at best. SOSUS was not complete in 1960, and its emphasis at that time was more on intelligence than the support of tactical antisubmarine warfare. These shortcomings were reflected in the mixed results seen in the Cuban missile crisis of 1962.

In the 1960–80 time frame the primary ASW sensor technology enablers were passive narrowband acoustics (in all antisubmarine communities), towed arrays for submarines and surface ships, and active acoustics for ships (3.5 kHz) and helicopters. Electronic intelligence from aircraft and spaceborne systems became a key component of all-source intelligence and cueing. As described earlier, the ASW and intelligence communities focused on tracking Soviet first- and second-generation nuclear submarines, and they had considerable success. Ship-towed arrays and shipborne medium-range helicopters came into the

fleet at the end of the era and (along with developments in carrier-based anti-submarine air) showed real promise.

Thus, the Navy emphasized a balance of offensive (integrated surveillance, land-based air, and SSNs) and defensive (surface ships and their helicopters, and carrier-based ASW aircraft) approaches. In the next decade (1980–90), as we have seen, the same ASW sensor technology was significantly less effective against much quieter Soviet nuclear submarines. By 1995 these stealthy submarines constituted the bulk of a reduced Russian submarine order of battle, but they were no longer the adversary.

Since 1990 the sensor technology focus has remained on passive narrowband acoustics and active monostatics, operated from ships and helicopters. But it has also included active multistatics, in the form of extended echo-ranging (EER), using individual impulse sources to ensonify multiple passive receivers. The “threat driver” is now the modern nonnuclear submarine, operating on battery, that may be encountered in regional contingencies. Passive acoustics against such stealthy boats are likely to produce primarily short-range detections. Active monostatics are better suited to the task but must overcome false-contact issues. Active multistatics via EER were originally intended to preserve the viability of large-area acoustic searches by land-based patrol aircraft; however, the first-generation EER sensor was not designed for shallow littorals, with their “clutter.” An improved system, IEER, is about to enter the fleet and may gain greater acceptance for use in littorals.

The undersea surveillance systems designed for the Cold War have limited applicability in contemporary locales of interest, including much of the Asian rim and the Arabian Gulf. SOSUS and the first-generation Fixed Distributed System (FDS) suffer from geographic mismatch—they are not in the right places. Other fixed surveillance system (FSS) concepts may be useful for known contingency regions, but they must be installed well in advance. Ocean surveillance ships such as SURTASS (Surveillance Towed Array Sensor System) units cannot employ their towed arrays or active sources in water as shallow as the Arabian Gulf. The SURTASS low-frequency active (LFA) sensor has only recently renewed testing after a more than five-year moratorium caused by environmental concerns related to its impact on marine mammals. The Advanced Deployable System (ADS), the one surveillance system designed expressly for use in shallow water and littorals, is still years away from the fleet. In the meantime, as Admiral Fargo has warned, current “IUSS*/acoustic cueing is much less than I would like.”⁶⁴ Ideally, by 2010 some combination of ADS, FSS, SURTASS, and LFA will be fielded and demonstrated to provide at least moderate effectiveness for cueing in key regions.

*Integrated undersea surveillance system.

Tactical ASW assets have traditionally relied upon timely and accurate surveillance cueing. Aircraft, which since World War II have been a rapid means of responding to distant contacts, have always benefited from cueing, whether they employ acoustic or nonacoustic tactical sensors. The same is true even for active shipborne sonars capable of detections, for example, at the first “convergence zone”; unalerted (uncued) convergence-zone contacts by ships have been rare.⁶⁵ Yet surface combatants have been primary players in antisubmarine warfare since World War I, particularly in protecting less ASW-capable surface units (aircraft carriers, logistics and amphibious ships, strategic sealift, merchant vessels). Finally, American nuclear-powered submarines have been major players in antisubmarine warfare since the early Cold War, particularly in contested waters where other assets would be at risk. These SSNs would also benefit from cueing, to improve the search rates of their passive sonars against modern diesel submarines.

But for all the importance of cueing, the next generation of ASW surveillance systems—for the years between 2010 and 2020, and beyond—has yet to be established. One promising way forward is the distributed sensor field.

THE NEED FOR DISTRIBUTED ASW SENSOR FIELDS

Distributed ASW sensor fields have been recommended for over a decade to compensate for the short detection ranges of individual sensors against stealthy submarines. A 1989 report to the House Armed Services Committee asserted that “one alternative to passive sonar as we have known it—a limited number of long-ranged passive sensors—is a large number of short-ranged passive sensors in a closely spaced network.”⁶⁶ A 1997 Naval Studies Board report predicted that “autonomous sources and/or receivers will permit the continued development of concepts using fields of distributed sources and receivers to very large scales.”⁶⁷ The same report projected that the Navy of the future would rapidly deploy networked sensors throughout theaters to establish safe maneuver areas without imposing mission limitations on manned platforms.⁶⁸ In 2003 Rear Admiral Harry Ulrich, as head of Sea Shield in the office of the CNO, stated, “Task Force ASW seeks to leverage a network of distributed sensors and weapons capable of sharing information quickly and striking with speed.”⁶⁹

The motivation for this sustained theme of networked, distributed ASW sensors is a preference for dispersing sensors instead of platforms for protracted anti-submarine tasks.⁷⁰ At a time when force structure is declining, it would take a large number of platforms equipped with short-range sensors to cover large expanses adequately and within the required time lines; tying up large numbers of platforms (particularly valuable warships) in surveillance is not a good use of these assets. Yet other than developmental ADS, no new persistent distributed

surveillance concepts designed to counter diesel submarines in littoral environments have entered the Navy acquisition process.

If distributed ASW sensor-field development is to be accelerated, both organizational and funding constraints and engineering challenges must be overcome. For most of the post–Cold War era, no flag officers have been assigned within either the Navy Staff or the office of the Secretary of the Navy to coordinate non-platform-specific antisubmarine development. As a result, such work on distributed and networked sensors as exists has been done within platform communities, where it competes for funding against other needs of those communities. It should be no surprise that low priority and limited funding have been applied to engineering issues that will determine the success of these non-platform-specific programs.

Two such areas particularly deserving attention are communications, sensor automation, and interrelationships between the two. Communications are one of the key enablers for distributed ASW sensors, and they need to meet both bandwidth constraints and covertness requirements. In-sensor automation can reduce bandwidth but must be done carefully to avoid unacceptable levels of false contacts or likelihoods that valid targets will be dismissed.

THE NEED FOR INNOVATIVE ASW APPROACHES

In 1998 the Chief of Naval Operations, Admiral Jay Johnson, predicted, “New technologies coupled with innovative operational concepts will yield a different approach to ASW.”⁷¹ The Naval Transformation Roadmap issued in 2003 stated, “Transformational efforts in ASW are focused on developing new operational concepts that leverage advanced technologies to improve wide-area surveillance, detection, localization, tracking, and attack capabilities against quiet adversary submarines operating in a noisy and cluttered shallow water environment.”⁷² A prerequisite to successful innovation, for antisubmarine warfare as much as any other discipline, is to encourage creativity within the government, academia, and private industry. This will necessitate changing Navy acquisition practices that resist radical new concepts and require fifteen or more years from concept formulation to service in the fleet. Ten areas are particularly ripe for innovation.

- Distributed ASW sensors: “Improved capabilities center upon achieving greatly enhanced situation awareness . . . [and] developing a next generation off-board distributed acoustic system with both active and passive capability.”⁷³
- Sensors for in-shore and coastal antisubmarine warfare: to counter future asymmetric undersea threats to homeland defense and for force protection.

- ASW weapons to neutralize very small targets: to counter minisubmarines, swimmer delivery vehicles, other manned submersibles, and unmanned platforms such as semisubmersibles and autonomous underwater vehicles.
- Active acoustic and nonacoustic sensor approaches: for better ASW sensor balance against stealthy targets—that is, not merely relying on passive acoustics.
- Offboard vehicles (unmanned or minimally manned): airborne, surface, and undersea vehicles for a variety of ASW applications in order to reduce risk to manned platforms and free them for other purposes, to act as force multipliers, extend the reach of warships, and provide greater cost-effectiveness.
- Miniaturized antisubmarine sensors: for use in distributed fields, offboard vehicles, and small aircraft.
- Reconfigurable payloads: to allow multiple applications for the manned or unmanned vehicles and platforms.⁷⁴
- Advanced self-protection measures: to shoot first at an attacking submarine and if that fails, to counter effectively a variety of antiship torpedoes, even large salvos of them. This increased emphasis on unit self-defense is reinforced by the need for dispersion of forces.
- Advanced weapon concepts: weapons that are interoperable with distributed, networked sensors without requiring the physical presence of a manned platform; new applications for torpedoes or ASW weapons concepts that go beyond torpedoes.
- Advanced networks and communications: to link sensors to shooters, to support data fusion, and to allow effective command and control of offboard vehicles.

It should be evident that a variety of sensor, weapon, countermeasure, networking, and communications approaches will be needed for future ASW operations. Antisubmarine warfare is a continuing counter-versus-countermeasure game. Technological breakthroughs help manage the threat—they cannot eliminate it. No single sensor works well in all environmental, target, and operational conditions, or is likely to in the foreseeable future. Passive acoustic sensors are susceptible to target quieting and often strongly depend on prior knowledge of target “signatures.” Active acoustic sensors are susceptible to environmental clutter, cannot always ensonify the entire depth regime, and, because they give away their presence, can sometimes be evaded or avoided. Nonacoustic sensors that can detect deep targets tend to have limited search rates; those with

potentially high search rates are generally ineffective against slow and deep targets or are vulnerable to environmental conditions, such as cloud cover. Thus, antisubmarine sensors are inherently “niche players” in terms of environments (water depths, acoustic conditions, atmospheric conditions), targets (physical sizes, acoustic signatures, operating depths and speeds), and operational factors (system covertness, host platforms or deployment mechanisms, persistence and endurance, fixed or mobile applications). As such they will require a variety of communication paths to be effective elements of an overall network. By the same token, ASW weapons and countermeasures will also need to be diverse, to handle the expected range of undersea targets.

ASW SUPPORTING INFRASTRUCTURE

If the foundation, the crucial bottom portion of the antisubmarine warfare pyramid, is not sound because key support areas have been neglected, antisubmarine systems entering the fleet can be expected to fail. Beyond the science and technology enablers already alluded to, four support areas are worth highlighting.

Environment Characterization

Knowledge of the environment is essential for antisubmarine warfare in any locale, but especially in littoral waters, where complex spatial and temporal (i.e., time and space) variations can wreak havoc on the performance of acoustic sensors. It is important to conduct prior surveys to establish such static parameters as bottom characteristics, which determine how sound at different frequencies propagates as it encounters the bottom and the extent to which bottom reverberation will limit active-sonar performance. Dynamic environmental parameters, such as sound velocity profiles, must be measured during actual operations. Similar static and dynamic parameters influence nonacoustic sensors. Notwithstanding, according to some experts, in the post–Cold War era the “Navy . . . [has] let its ocean surveillance community and its support for basic oceanographic research atrophy . . . [including] the ability to exploit this operationally.”⁷⁵ The experiences of the British in the Falklands testifies to the difficulties encountered without sufficient knowledge of the surrounding seas to make useful sonar range predictions.⁷⁶

Threat Characterization

Cueing begins with intelligence on potential adversaries. During the Cold War, extensive all-source analysis was performed continuously against Soviet submarines, as part of the “preparation of the battle space.” This process addressed such technical characteristics as submarine “signatures,” acoustic “fingerprints” to aid in search and classification; it also involved determining threat-submarine

operating patterns and tactics. The Navy's Ocean Surveillance Information System nodes that directed this effort closed when the Cold War ended, and no equivalents have been put in place. In comparison with the Cold War and World War II, ASW-related intelligence support today is unfocused and lacks continuous analysis and feedback.

ASW System Understanding

Disciplined data collection and analysis are needed for antisubmarine systems as well, to understand fully their hardware and software limitations (design and physics issues) and employment constraints. In recent years the Naval Studies Board strongly recommended that the Navy "establish and maintain a dedicated, long-term program centered on at-sea measurements and tests," which it had found lacking in the post-Cold War era.⁷⁷ Without such a program it is difficult to discern the root causes of deficiencies and decide what corrective actions are needed. Antisubmarine warfare has a fine tradition of regular at-sea exercises, but after most of them the Navy has been able to reconstruct only *what* happened, not *why*. That would require additional instrumentation and analysis, but it would reveal whether training, tactics, hardware, software, or some combination is the source of poor performance.

This state of affairs is not new to ASW. In 1942, for example, the National Defense Research Committee concluded that the operational capabilities of U.S. Navy antisubmarine equipment were poorly understood and that what was needed was "a formal and ongoing means of systematically gathering and analyzing all available operational data."⁷⁸ That task became one of the key functions of the Tenth Fleet, and similar steps were taken by the United Kingdom. Reinforcing the need for this type of effort today, Vice Admiral Grossenbacher recently commented, "We are not, however, sufficiently disciplined . . . yet to systematically collect data, analyze it, and then effectively feed that knowledge back into tactics, techniques, procedures and technological development."⁷⁹ The U.S. submarine force is now attempting to correct this shortfall for its ASW sensors through the Acoustic Rapid Commercial-Off-the-Shelf Insertion Engineering Measurement Program. Such sensor-level data collection and analysis need to be done across the entire ASW community, in a consistent way, and even applied to large fleet exercises. Without this diagnostic approach, it will be difficult to know what to prescribe to bring antisubmarine warfare back to health.

Training and Tactics Development

Training (in equipment maintenance and operation) and tactical and doctrinal development are elements of the art of antisubmarine warfare that have received too little emphasis in the post-Cold War era—which is disconcerting, in view of how perishable ASW skills can be. If this underemphasis is not corrected, the full

potential of systems, technology, and physics cannot be realized. Vice Admiral Edmund Giambastiani (as ComSubLant) has testified to the Senate Armed Services Committee that “while a traditional strength of the Navy during the Cold War, ASW capability and proficiency have waned. . . . ASW is now more difficult against new generations of nuclear and diesel submarines and will become increasingly critical.”⁸⁰ During the Second World War, as we have seen, the Tenth Fleet unified ASW training and related doctrine and tactics development during a critical two-year period. In the late 1950s Task Force Alfa was established to do the same. Later in the Cold War, integrated training was achieved in real-world operations by theater ASW task forces in the Atlantic, Pacific, and Mediterranean (TF 84, 12, and 66, respectively) against deployed Soviet submarines. Good unit training was also available, for example, in surface-ship acoustic analysis centers.

The post–Cold War era, in contrast, has been marked by episodic training opportunities with weak feedback mechanisms, but perhaps that will not be true much longer. The recently formed Fleet ASW Command is intended as a “center of excellence,” a “focal point” for antisubmarine operations and training.⁸¹ If this command provides the same sustained unity-of-effort contribution as occurred in World War II, during the post–World War II years, and for much of the Cold War, proficiency at the unit, battlegroup, and theater levels should dramatically improve.⁸²

ON THE BRINK OF COMMITMENT

After more than a decade of watching antisubmarine warfare unravel, the U.S. Navy appears to be at the point of revitalizing it. The surface ship community, which largely deemphasized antisubmarine warfare in the post–Cold War era, has exhibited a renewed interest in its ASW capability. It plans upgrades to the AN/SQQ-89 ASW combat system, aboard the *Arleigh Burke*-class destroyers and other surface combatants. The increased focus on surface ASW is most apparent in the Littoral Combat Ship program, which has allocated funds for ASW-mission-module development. LCS is expected to rely heavily for its ASW capabilities on offboard systems, including distributed sensors such as ADS, manned or unmanned aircraft, and other unmanned vehicles. Over two hundred MH-60R ASW-capable helicopters with advanced dipping sonars will be entering the fleet over the next ten years. Existing P-3s will soon be upgraded with IEER. The planned P-3 replacement, the Multi-Mission Aircraft (MMA), will have antisubmarine warfare as its primary mission, the surveillance and reconnaissance role having been largely transferred to unmanned airborne vehicles. About a hundred MMAs are to be procured in 2012 and afterward as the P-3 phases out. The SSN community too is focusing on littoral antisubmarine warfare, with developments like a neutrally buoyant TB-29 towed array for

shallow-water use. Also, procurement of the *Virginia* class is under way; the name-ship was commissioned on 23 October 2004. Further, as noted, the moratorium on SURTASS LFA testing has finally ended, at least for high-interest Pacific Fleet operating areas.⁸³ The ADS program will reach the fleet in a few years as the first distributed field system designed specifically for surveillance and cueing in the littorals. The Mark 54 lightweight torpedo will be entering the fleet and will correct some of the weaknesses of the Mark 46. Surface ship torpedo defense has been revitalized; the first hard-kill system, an antitorpedo torpedo, could be fielded by early in the next decade.

Notwithstanding all this ASW-related activity, however, total funding has not changed appreciably, which ultimately may limit the pace of reinvigoration. Key initiatives could be slowed: distributed and networked sensor developments beyond ADS; active multistatics beyond IEER, such as “coherent” instead of impulsive sources; nonacoustic sensor development (periscope-detection radars, electro-optic devices, advanced magnetic sensors); new weapon concepts beyond upgrades to legacy torpedoes; offboard vehicle development; advanced torpedo defense measures beyond the first-generation ATT; and potentially paradigm-breaking technology concepts for detecting, tracking, and destroying submarines, minisubs, and other submersibles. Thus the time line of figure 2 requires caveats, particularly with respect to the rate of new technology insertion. However, this tight budget environment cannot be allowed to produce continued neglect of such key ASW support areas as tactical oceanography, intelligence, at-sea data collection and analysis, training, and tactical and doctrinal development.

The new initiatives, Task Force ASW and the Fleet ASW Command, need to reverse the deterioration that has occurred in antisubmarine warfare during the past fifteen years. Admiral Walter F. Doran, speaking as Commander in Chief, U.S. Pacific Fleet, has pointed to the urgency: “ASW is my top warfighting concern in the Pacific theater. Our challenges are many as adversary submarines can threaten assured access for joint forces. Diesel submarines, in particular, are an asymmetric threat to joint forces in strategic littoral areas worldwide. They can threaten our sea-based naval power projection and supply lines for sustained joint operations.”⁸⁴

NOTES

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 For *Daphnés*, V. F. Holderness [Cdr., South African Navy (Ret.)], “Relaunch the Non-Nuclear Boats,” U.S. Naval Institute *Proceedings*, June 1995, pp. 45–46. Two U.S. Navy ships reportedly exercising against a South African *Daphné*-class submarine were unable to detect it even at short ranges; a U.S. observer on the submarine commented to its crewmembers, “There is a \$1B warship above you that doesn't have a clue where you are.”
 For the Type 209, Robert Holzer, “Dangerous Waters: Submarines, New Mines Imperil Ill-Prepared U.S. Navy Fleet,” *Defense News*, 4–10 May 1998, pp. 1, 14–15. In a 1996 bilateral exercise a Chilean Type 209 submarine reportedly penetrated an ASW screen of a U.S. Navy battle group and operated among the ships, generating firing solutions, without being detected.
 For *Collins*, David Lague, “Dub Sub Fleet Impresses U.S.,” *Sydney Morning Herald*, 27 July 2000. During RIMPAC 2000 an Australian *Collins* submarine reportedly penetrated a U.S. Navy screen “to be in position to sink a

- U.S. aircraft carrier"; Nathan Hodge, "Australian 'Hit' on U.S. Sub Gets Attention," *Defense Week Daily Update*, 1 October 2003, in which the U.S. Pacific Fleet confirmed that an Australian diesel submarine "sank" an American SSN during a recent training exercise.
30. Cohen and Gooch, *Military Misfortunes*, p. 93.
 31. Scheina, "Where Were Those Argentine Submarines?" pp. 115–20; Woodward, *One Hundred Days*, pp. 5–6, 17, 105–106; Harry D. Train II [Adm., USN (Ret.)], "An Analysis of the Falklands/Malvinas Islands Campaign," *Naval War College Review* 41 (Winter 1988), p. 40; and George Krause, "World Submarine Proliferation and U.S. Sea Control," *Submarine Review* (April 1993), p. 62.
 32. See John R. Benedict, *Taking a Long-Term Perspective on U.S. Navy ASW Objectives, Capabilities and Trends (Historical Survey and Projections, 1940–2020)*, 12 January 2004, p. 86.
[This detailed Johns Hopkins University Applied Physics Laboratory presentation \(itself drawing on David Miller, *Submarines of the World* \[London: Salamander Books, 2002\]\) summarizes the research that forms the basis for this article.](#)
 33. Three Swedish (*Gotland*-class) submarines and one Danish (*Nachen*-class) submarine have Stirling engines that provide AIP capability. Two of four planned Type 212A submarines, equipped with fuel-cell AIP, are going through sea trials. Italy has two Type 212A submarines under construction. Greece has ordered three Type 214 submarines (export version of Type 212A); South Korea also has ordered three. Portugal has plans for two AIP submarines from the German firm HDW. Pakistan has procured three Agosta 90Bs from France, to be equipped with the "Mesma" closed Rankine-cycle steam turbine AIP system. One Japanese submarine is being converted to Stirling AIP.
 34. U.S. Navy Dept., *Worldwide Maritime Challenges* (2004), p. 11, and *Worldwide Submarine Challenges* (1996), p. 18 (both Washington, D.C.: Office of Naval Intelligence).
 35. Malcolm I. Fages [Rear Adm., USN; Navy Staff, N87], remarks at Naval Submarine League Symposium, June 2000, as published in *Submarine Review* (October 2000), p. 34.
 36. See Benedict, *Long-Term Perspective*, p. 87, and "Future Undersea Warfare Perspectives," *Johns Hopkins APL Technical Digest* 21, no. 2 (2000), p. 271.
 37. Lyle Goldstein and Bill Murray [Lt. Cdr., USN], "China's Subs Lead the Way," U.S. Naval Institute *Proceedings*, March 2003, p. 58, available at www.military.com/NewContent/0,13190,NI_China_0303,00.html; Department of the Navy (Office of Naval Intelligence), *Worldwide Maritime Challenges*, 2004, pp. 12, 23.
 38. U.S. Navy Dept., *Worldwide Submarine Challenges* (February 1997), p. 20, and *Worldwide Maritime Challenges* (2004), p. 12 (both Washington, D.C.: Office of Naval Intelligence).
 39. See Benedict, "Future Undersea Warfare Perspectives," p. 271.
 40. Reflects SS-N-27 Novator Alpha characteristics as described in various trade publications (*Military Parade*, *Jane's Defense Weekly*), as well as in Kan, Bolkcom, and O'Rourke, *China's Foreign Conventional Arms Acquisitions*, and U.S. Navy Dept., *Worldwide Maritime Challenges* (2004), p. 23.
 41. See Benedict, *Long-Term Perspective*, p. 91.
 42. Goldstein and Murray, USN, "China's Subs Lead the Way," p. 59.
 43. *Proceedings*, *Jane's*, and other open sources have speculated that Pakistan could adapt Exocet or Harpoon, and Israel the Harpoon or Popeye Turbo, with nuclear-tipped warheads. See, for example, "Global Intelligence Update," Stratfor.com, 26 October 2000.
 44. *Jane's Fighting Ships*, *Jane's Underwater Systems*, and *Jane's Underwater Technology*. And see Benedict, *Long-Term Perspective*, p. 84.
 45. Paul Kemp, *Undersea Warriors* (Annapolis, Md.: Naval Institute Press, 1996), pp. 230–31.
 46. *Jane's Fighting Ships 2003–2004* (Coulsdon, Surrey, U.K.: Jane's Information Group, 2003).
 47. Rohan Gunaratna, "The Asymmetric Threat from Maritime Terrorism," *Jane's Navy International*, October 2001, pp. 25–26; Associated Press, "210 Miles from Pacific Ocean, Drug Smugglers Try to Build Sub," *New York Times*, 8 September 2000, p. 1. Colombian

- police stopped construction of a large mini-submarine by a drug cartel (then 30–40 percent complete, with the help of Russian engineers). Reportedly this minisub was capable of transporting up to ten metric tons of cocaine.
48. U.S. Navy Dept., *Worldwide Submarine Challenges* (1997), pp. 24–28; and Joseph S. Bermudez, Jr., “Midget Submarine Infiltration Upsets South Korea’s Troubled Waters,” *Jane’s International Defense Review*, August 1998, pp. 24–25.
 49. Gunaratna, “Asymmetric Threat from Maritime Terrorism,” pp. 26, 28.
 50. Madalyn Russell, “Rich Boys’ Toys: Personal Submarines,” *Underwater Magazine* (January/February 2001), available at www.diveweb.com/rovs/features/janfeb2001.02.htm.
 51. *Ibid.* See also Steve Connally and Craig Lewis, “Bin Laden’s Brother & Riddle of the Suicide Subs,” *Star*, 1 October 2001, available at www.bioniddolphin.com/tom/media/pics/articles/Star10-01-01.jpg, and “Bin Laden Family in America,” *National Enquirer*, 1 October 2001, available at www.bioniddolphin.com/tom/media/pics/articles/enquirer10-01.jpg. Notwithstanding the sensationalist sources, the general facts were confirmed by David Wise and Vernon Loeb, “Attack Carefully Planned, Experts Say,” *Washington Post*, 13 October 2000, p. 29.
 52. L. Bruce Jones, “The Tourist Submarine Industry: A Summary Article,” *U.S. Submarines*, www.ussubs.com/submarines/summary_article.php3; “Frequently Asked Questions, Luxury Submarines,” *U.S. Submarines*, www.ussubs.com/faq/luxury.php3.
 53. “Submarines,” *U.S. Submarines*, www.ussubs.com/submarines/index.php3; “Tourist Subs,” *Jane’s Underwater Technology*, juwt.janes.com/docs/juwt/browse_section.html.
 54. *Jane’s Underwater Technology*, juwt.janes.com/docs/juwt/browse_section.html; and Brian E. Morr, “Autonomous Submarines: Broadening Industry’s Horizons,” *Sea Technology*, September 2001, pp. 26–33.
 55. *Jane’s Underwater Technology 2002–2003* (Coulsdon, Surrey, U.K.: Jane’s Information Group, 2002); “Autonomous Underwater Vehicles,” *Jane’s Underwater Technology*, juwt.janes.com/docs/juwt/browse_section.html.
 56. Donald H. Rumsfeld, “Transforming the Military,” *Foreign Affairs* 81, no. 3 (May/June 2002), p. 29.
 57. Charles M. Sternhell and Alan M. Thorndike, *Antisubmarine Warfare in World War II*, OEG Report 51 (Washington, D.C.: Operations Evaluation Group, Office of the Chief of Naval Operations, 1946), p. 140.
 58. *Ibid.*, p. 125; C. H. Waddington, *O.R. in World War II: Operational Research against the U-boat* (London: Scientific Books, 1973), p. 177.
 59. U.S. Navy Dept., *Antisubmarine Warfare: Meeting the ASW Challenge* (Washington, D.C.: Navy Staff, OP-71, ASW Division, April 1990), p. 14; “The U-Boat War, 1939–1945,” uboat.net.
 60. U.S. Navy Dept., *Antisubmarine Warfare*, pp. 10–13; Frank A. Andrews, “Submarine against Submarine,” *Naval Review* (1965), p. 43.
 61. William T. Y’Blood, *Hunter-Killer: U.S. Escort Carriers in the Battle of the Atlantic* (Annapolis, Md.: Naval Institute Press, 1983), pp. 272, 282–83.
 62. *Ibid.*, p. 272.
 63. Waddington, *O.R. in World War II*, p. 223.
 64. Admiral Fargo remarks, 16 June 2000, p. 49.
 65. Discussion with Vice Adm. James Fitzgerald, USN (Ret.), 21 July 2003.
 66. Burkhalter et al., *Report of the Advisory Panel*.
 67. Naval Studies Board, *Technology for the U.S. Navy and Marine Corps: 2000–2035: Becoming a 21st-Century Force*, vol. 7, *Undersea Warfare* (Washington, D.C.: National Academies Press, 1997), chap. 1, p. 20, available at www.nap.edu/html/tech_21st/uw1.htm.
 68. *Ibid.*, pp. 22, 41.
 69. “U.S. Explores New Anti-Submarine Warfare Concepts,” *Jane’s Defense Weekly*, 2 July 2003 (interview with Rear Adm. Harry Ulrich, of the Navy Staff, N76, the Sea Shield lead).
 70. See Benedict, “Future Undersea Warfare Perspectives,” pp. 274–75.
 71. As quoted in Chief of Naval Operations, *1998 ASW Focus Statement*, 19 July 1998, www.hq.navy.mil/airwarfare/Programs/N880E/Air%20ASW%20Vision%20Statement.htm.

72. U.S. Navy Dept., *The Naval Transformation Roadmap*, available at www.chinfo.navy.mil/navpalib/transformation/trans-toc.html, p. 19.
73. *Ibid.*, pp. 19–20.
74. The Littoral Combat Ship (LCS) and Large Displacement Mission Reconfigurable Unmanned Undersea Vehicle (LD MRUUV) are manned and unmanned platform examples, respectively, of “reconfigurable ASW payloads.” Both platforms are payload limited but are intended for a variety of ASW applications, exploiting modular designs that allow for reconfiguration of payloads either at sea or in a depot.
75. Cote and Sapolsky, *Antisubmarine Warfare after the Cold War*, p. 18, available at web.mit.edu/ssp/Publications/confseries/ASW/ASW_Report.html.
76. *Ibid.* The inability to “adequately depict acoustic and environmental conditions found in the littorals” was also cited by the U.S. General Accounting Office; *Evaluation of Navy’s Anti-Submarine Warfare Assessment*, GAO/NSIAD-99-85 (Washington, D.C.: July 1999), p. 5, available at www.gao.gov/archive/1999/ns99085.pdf.
77. Naval Studies Board, *Technology for the U.S. Navy and Marine Corps*. The need in ASW for “a much more extensive and extended at-sea testing program” was reinforced by Rear Adm. Wesley Jordan in “Moving Forward in ASW,” *Sea Technology*, January 1997, pp. 53–56.
78. Tidman, *The OEG*, p. 31.
79. Vice Adm. John J. Grossenbacher, remarks at NDIA “Clambake” at Newport, Rhode Island, September 2001, as published in *Submarine Review* (January 2002), p. 16.
80. E. P. Giambastiani [Vice Adm., USN; ComSubLant], testimony before the Senate Armed Services Seapower Subcommittee on Submarine Warfare in the 21st Century, 13 April 1999, pp. 7–8, www.globalsecurity.org/military/library/congress/1999_hr/giambast.htm.
81. “Disproving Skeptics, Navy Unveils Anti-Submarine Warfare Command,” *Inside the Navy*, 10 November 2003, p. 1.
82. During the Cold War the following organizations exemplified focused ASW operations and training: the Fleet ASW Training Center, Destroyer Squadron 31, Submarine Development Group 2, and VX-1 (the Air Test and Evaluation Squadron).
83. Marc Kaufman, “Activists Plan Fight for Marine Mammals,” *Washington Post*, 16 November 2003, p. 11; Bill Gertz, “Rumsfeld Defends Use of Sonar to Okinawans,” *Washington Times*, 17 November 2003, p. 3; Marc Kaufman, “Navy Agrees to Injunction Limiting Sonar Use,” *Washington Post*, 14 October 2003, p. 3; and Marc Kaufman, “Whales’ Plight Revives Sonar Theory,” *Washington Post*, 11 July 2004, p. 1. The U.S. Navy is seeking to alleviate environmental concerns without undermining active sonar training and proficiency.
84. Doran, letter, 19 February 2004.