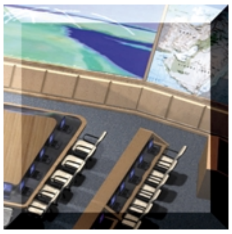

Future Undersea Warfare Perspectives

John R. Benedict, Jr.

Significant Undersea Warfare technology, including modern stealthy submarines and minisubmarines, air-independent propulsion, and advanced submarine combat systems with associated weaponry (torpedoes, mines, submerged-launch missiles), is being transferred among the nations of the world. Countering future undersea threats will become increasingly difficult, and conventional approaches to Anti-Submarine Warfare (ASW) and Mine Countermeasures (MCM) will not provide adequate situational awareness, tactical control, or force protection to achieve stated Joint warfighting objectives in future contingencies. Advanced technology solutions and new operational approaches are needed in four broad capability areas: (1) distributed, deployable/offboard ASW sensor networks, (2) organic MCM capabilities for the Fleet, (3) advanced offboard undersea vehicle concepts, and (4) advanced warship self-protection measures against undersea threats. Technology and operational initiatives in these areas form the cornerstones of a future undersea warfighting vision described in this article. (Keywords: Anti-Submarine Warfare, Mine Warfare, Undersea Warfare.)

INTRODUCTION

The proliferation of undersea technology and the future Undersea Warfare capabilities needed to counter this trend create a multifaceted challenge to the U.S. Navy and its allies. In this article, I describe a future undersea warfighting vision drawn from many sources, especially the studies and assessments presented in the boxed insert. However, the views expressed here are my own; they should not be construed as an official position of either APL or any part of the DoD. The article is divided into two parts: the first delineates the challenges posed by proliferating Undersea Warfare–related technology; the second describes the future Undersea Warfare capabilities that are needed (in four primary thrust areas) to counter these challenges.

POTENTIAL UNDERSEA CHALLENGES

Significant Undersea Warfare technology is being transferred among the nations of the world.[1] This transfer includes both military technology and commercial off-the-shelf technology having military applications. The technology areas discussed in the following sections are of particular concern if employed by future adversaries in regional contingencies and conflicts.

SELECTED UNDERSEA WARFARE STUDIES AND ASSESSMENTS, 1995–1999*

Anti-Submarine Warfare (ASW)

- 1997 ASW Assessment (Chief of Naval Operations (CNO)-N84)
- 1998 Network-Centric/ASW C^4I (Command, Control, Communications, Computers and Intelligence) Issue Characterization Study (CNO-N86)
- 1998–1999 Advanced Deployable System (ADS) Analysis of Alternatives (AOA) (CNO-N87; Space and Warfare Systems Command, PD-18)
- 1998–1999 ASW Surveillance CONOPS (Concept of Operations) Studies (Office of Naval Research)
- 1999 Large Deck Ship Torpedo Defense Study (CNO-N86/N84/N091)

Mine Countermeasures (MCM)

- 1995 Future Fleet Combatant Organic Mine Avoidance and Reconnaissance (FFCOMAR) Study (Program Executive Office-Undersea Warfare (PEO-USW))
- 1995–1996 Long-Term Mine Reconnaissance System (LMRS) Cost and Operational Effectiveness Analysis (COEA) (CNO-N87; PEO-USW/PMS403)
- 1997–1998 Airborne Mine Neutralization System (AMNS) AOA (OPNAV-N85; Program Executive Office-Mine Warfare (PEO-MIW)/PMS210)
- 1998–1999 MCM Force-21 Study (OPNAV-N85)
- 1999 LMRS Capabilities (Requirements) Study (CNO-N87; PEO-USW/PMS403)
- 1999 Organic Airborne and Surface Influence Sweep (OASIS) AOA (CNO-N85; PEO-MIW/PMS210)

Offboard Undersea Vehicles

- 1996 Unmanned Undersea Vehicles (UUV) Road-Map Study (Defense Advanced Research Projects Agency (DARPA))
- 1997–1998 Mini-Submarine/Small Submarine Survey (DARPA)

Foreign Undersea Warfare Technology Developments

- 1995 Foreign ASW Technology Developments Paper (at May 1995 Submarine Technology Symposium)
- 1999 Undersea Weapons—Technology Transfer with Anti-Ship Implications Briefing (at the March 1999 National Defense Industrial Association (NDIA) Undersea Warfare Division Spring Conference)

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*Studies led primarily by APL; sponsors listed in parentheses.

Modern Submarine Platforms and Stealth

Over 40 countries have submarines in their navies, including Russia, China, North Korea, India, Pakistan, Libya, Algeria, Iran, and Indonesia. Russia and Germany lead the world in export sales of large, modern conventional (nonnuclear) submarines. German suppliers have exported about 80 submarines (mostly of the Type 209 variety) during the last four decades. The Russians have exported more than 20 Kilo submarines to six clients in the last 10 to 15 years. Other nations that currently design, build, and export large conventional submarines are France, Sweden, the United Kingdom, the Netherlands, China, and Spain. Both German and Russian designs (Type 209 with follow-ons and Kilo with follow-ons, respectively) represent virtually the best diesel-electric submarines that Germany and Russia have to offer. These designs include advanced stealth technology, and the latest Kilo design (Project 636), for example, was exported to China. According to the U.S. Office of Naval Intelligence, the Project 636 upgraded Kilo is one of the quietest diesel-electric submarines in the world.[2] According to the Chief of Naval Operations (CNO)-N84, "Since 1960, 35 decibels of quieting have reduced [detection] ranges from hundreds of miles to a few kilometers."[3]

The legacy performance of passive acoustic surveillance sensors has been seriously degraded against modern stealthy submarines, particularly in adverse littoral environments (with high noise and poor propagation conditions). Figure 1 depicts the worldwide trend in the non-U.S. submarine order of battle (i.e., the total force level) toward modern or state-of-the-art technology (including stealthy designs).[4]

Modern Submarine Combat Systems

German and French firms are leading exporters of totally integrated state-of-the-art combat systems. These systems include the following:

- Advanced acoustic sensors (e.g., cylindrical bow arrays, flank arrays on hull side, towed arrays, passive ranging sonar, acoustic intercept sonar)

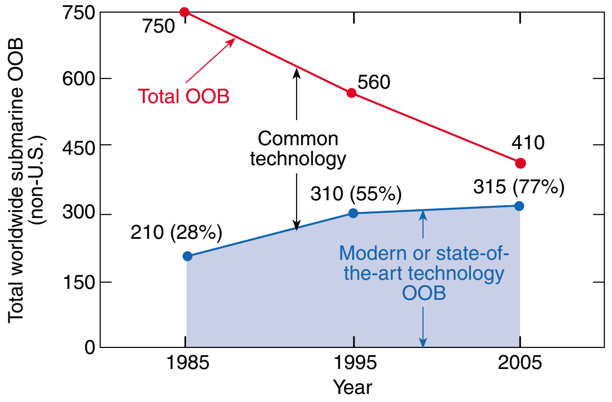

Figure 1. Worldwide (non-U.S.) submarine order of battle (OOB). Assessment includes all attack submarines, ballistic missile submarines, and large minisubmarines (adapted from Ref. 4).

- Advanced nonacoustic sensors (e.g., electronic support measures for signal intercept and direction finding; optical and laser rangefinders; thermal imaging sensors; and automatic rotation, recording, and display mast systems)
- Global Positioning System (GPS) navigation
- Modern communications
- Advanced signal processing and displays
- High-performance data buses for data fusion and information management (e.g., automated tracking and fire control solutions)

Modern, highly automated combat system designs generally incorporate "user-friendly" features that allow increased proficiency with reduced manning complements (for example, large, modern, conventional submarines requiring 20–40 total crew, compared with well over 50 crew needed with earlier, less automated designs). Russian and other designers worldwide are pacing Western European developments in this area, as evidenced by their most recent submarine designs, which feature increased automation and reduced manning.

Air-Independent Propulsion

Air-independent propulsion (AIP) systems include closed-cycle diesel engines, closed-cycle external combustion engines such as Stirling engines, fuel cells, and low-power nuclear reactors.[5] Each of these technologies is designed for hybrid configuration with the standard diesel engine to provide prolonged submerged endurance, i.e., to reduce the amount of time conventional submarines must spend snorkeling to recharge their batteries, because snorkeling is a tactical evolution that can increase the likelihood of detection by Anti-Submarine Warfare (ASW) forces (via either acoustic or nonacoustic means). Figure 2 shows the submerged endurance provided by various types of submarine propulsion.

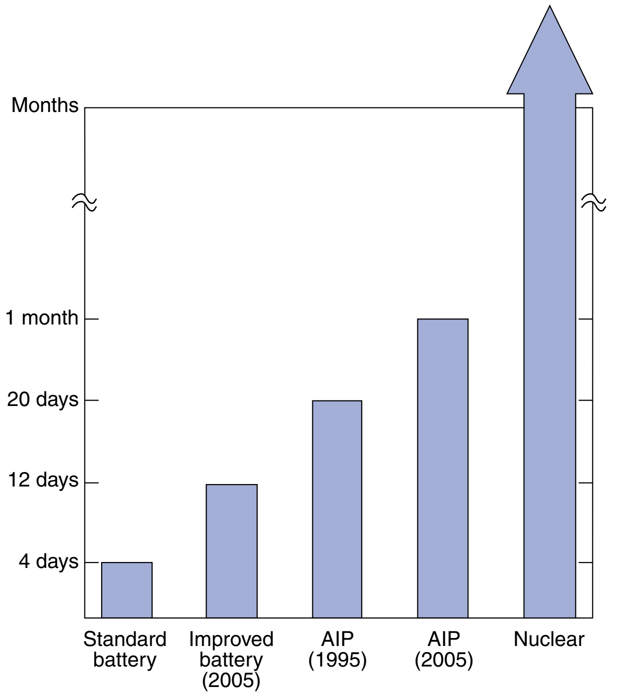

Figure 2. Maximum submerged endurance trends for submarines (slow "patrol" speed). (Endurance for nuclear submarines is independent of speed; AIP = air-independent propulsion.) (Figure adapted from Ref. 4.)

Sweden has fielded the first operational, conventional submarine with a modern AIP system (a Stirling-cycle engine). Germany is developing a fuel cell–based AIP system for its Type 212 submarine, which will extend submerged endurance by nearly an order of magnitude (30 days of submerged operations at 4 kt without a need to snorkel). France is providing Pakistan with a closed Rankine-cycle steam turbine AIP system (called "Mesma") in the Agosta 90B purchase, representing the first export sale of AIP to any country. Russia is offering AIP designs for both current Kilo and future Amur class submarine exports. Stated design goals for post-2010 Amur class models are 45 days of submerged endurance at economic speed.[6] AIP systems, supplied as 5- to 10-m "drop-in" sections for new construction or backfit of submarines, would increase overall submarine cost by 10 to 20%.

When the technical risk and affordability concerns are overcome, AIP should become standard in conventional submarine designs by the 2020–2025 timeframe. The operational implications are reduced vulnerability to various ASW sensors and fewer constraints on the use of submarines (less need to find a safe place to conduct noisy or exposed snorkel operations).

Modern Anti-Ship and ASW Torpedoes

The leading suppliers of heavyweight torpedoes are the United States, the United Kingdom, France, Germany, Italy, Sweden, and Russia. Russian 53-cm wake homing torpedoes are being aggressively marketed and are believed to be standard issue with export sales of Kilo submarines to Iran, Algeria, India, China, and others. These torpedoes offer at least a 10-km standoff capability for even less-proficient submarine forces, and they pose a significant threat to surface ships (from a statement of Rear Admiral E. D. Shaefer, Director of Naval Intelligence, before the House Armed Services Committee, 15 April 1993). Thus, "France, Germany and Italy have begun to offer wake homing as an option[al feature] in their export torpedoes . . . DM2A3, F17 MOD 3, A184."[7]

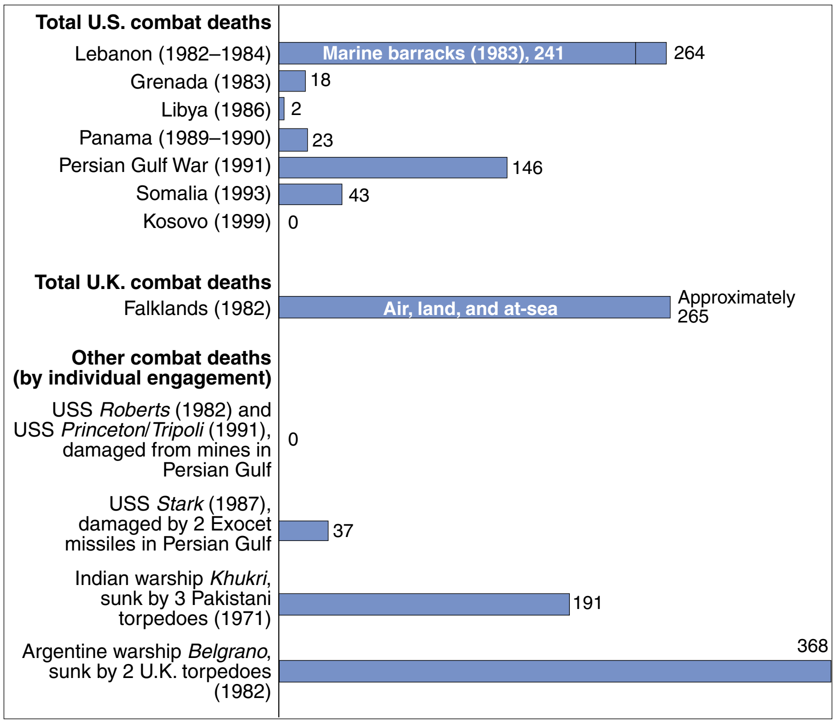

Figure 3. Comparison of combat deaths from anti-ship torpedoes with combat deaths due to other weaponry in regional conflicts.

Two of the most advanced torpedoes under development in the West are the German DM2A4 and the Swedish TP-62, which will feature very quiet operation through improved propeller/electric propulsion (the DM2A4) and advanced thermal propulsion with pump jet technology (the TP-62). Both weapons will also feature significant resistance to countermeasures through advanced active/passive acoustic homing and wire guidance. Modern anti-ship homing torpedoes are designed to achieve "under-bottom" hits that "break the back" of various combatants (frigates, destroyers, cruisers) and cause rapid sinking and associated high casualties. Sinking of large-deck warships such as aircraft carriers would be more difficult without either multiple hits or a larger-diameter, larger-payload weapon (e.g., the 65-cm wake homing torpedo that Russia developed for this very purpose). Russia is offering 65-cm torpedoes for export, but these would more likely be employed from surface ships, coastal sites, or fixed at-sea installations such as oil rigs, because nearly all conventional submarines will have only 53-cm torpedo tubes.

Most of the countries just mentioned are also actively exporting lightweight torpedoes that are designed for use against submarine targets. For example, the Italian A244 series has been provided to at least 15 countries. It offers advanced counter-countermeasure features, can be used in 45–60 m of water, and has advanced propulsion and warhead mechanisms for quiet and lethal operation.

Thus, modern heavy- and lightweight torpedo designs are potentially user-friendly, feature quiet operation (unless active acoustic homing is employed), are resistant to countermeasures, and are potentially highly destructive. See Fig. 3 for an indication of the lethality of anti-ship torpedoes and the potential for a "Marine Barracks Incident" at sea. (In 1983, an attack on the Marine barracks in Lebanon resulted in 241 deaths.)

Submarine-Launched Anti-Ship Cruise Missiles

The key developers of submarine-launched Anti-Ship Cruise Missiles (ASCMs) are the United States (Harpoon), France (Exocet), Russia (Novator Alfa, under development), and China (submerged-launch ASCM, under development).[4] The United States provided the submerged-launch Harpoon to Israel and Pakistan. France is providing Exocet capability as part of its Agosta 90B export deal with Pakistan. The potential export of the Russian Novator Alfa would substantially increase the level of available technology, because this is a torpedo-tube-fired, over-Mach 2 sea-skimmer having significant terminal maneuver capability. The Russians are reportedly marketing these missiles to Iran and others. The proliferation of ASCM sales to submarine forces allows greater standoff distances than with torpedoes and complicates ASW planning.

Modern Anti-Ship and ASW Mines

Russia, Italy, Sweden, and others are key suppliers of modern mine technology to the more than 50 countries that today possess at-sea mine capability. Mines are in demand because key contingency regions have significant minable waters, including the Persian Gulf, the Strait of Hormuz, the Red Sea, the Yellow Sea, the Korean Strait, and the coastal portions of the Sea of Japan. Mines have demonstrated cost-effectiveness. During the "Earnest Will" operations in the Persian Gulf in 1988, a $1500 mine nearly sank the USS *Samuel B. Roberts*, doing $96 million in damage. During Desert Storm, the threat of mines acted as a deterrent to a planned amphibious assault.

The Spanish MO-90 moored-influence mine can be anchored in waters as deep as 350 m with the mine case as deep as 40 m below the surface and still inflict unacceptable damage against certain surface ships. The Italian MRP bottom-influence mine can be laid in up to 58 m of water and be lethal against a variety of surface ships. At depths of 300 m it can be lethal against deep submarine targets. The Chinese EM-52 straight-rising mine can be used in water as deep as 100 m. The Russian MSHM mine (under development) will be capable of use very closely tethered to the bottom in up to 300 m of water. Upon detection of either a ship or a submarine target, this rocket-propelled mine (aimed or homing) will be able to engage those targets from large standoff distances (e.g., noisy ship targets over 500 m from the mine).

The Swedish Rockan and Italian Manta mines are relatively small, irregularly shaped bottom mines for use in shallow water; the Swedish Bunny is a large, anechoic-coated bottom mine. All three of these mines are inherently stealthy and compound the difficulty of minehunting. The U.K. Stonefish and Sea Urchin mines (like the Bunny and the MRP) feature a variety of influence mechanisms and programmable logic for target selection, thus seriously complicating minesweeping activities. In summary, modern mines can be used in a variety of water depths, are designed to abort the missions of (if not to sink) their targets, and are increasingly difficult to hunt or sweep.

Minisubmarines

Russian and Italian firms are offering modern, state-of-the-art minisubmarines for export that are typically 70 to 300 tons in submerged displacement. These minisubmarines take a crew of 4 to 6, plus 6 to 8 swimmers (for special warfare missions), and can carry a variety of payloads (e.g., 4–6 mines or 2 heavyweight torpedoes, either internally stored or externally mounted). They are capable of 6- to 12-kt submerged speed, 100- to 200-m maximum operating depth, and 60 to 190 nmi of submerged endurance. If upgraded with an AIP system, these same minisubmarines could have 250 to 1500 nmi of submerged endurance before needing to snorkel. Overall endurance would typically be 10 to 20 days, depending on food supplies and other factors.

The Italian firm Cosmos has been the most successful exporter of minisubmarines to date. Figure 4 shows the Russian Piranja class minisubmarine (nearly 300 tons submerged displacement), which is in their inventory and is also being offered for sale. North Korea has the world's largest minisubmarine force (more than 20 large 300-ton Sango and about 50 small Yugo units that are less than 100 tons each) and is still producing them locally. Minisubmarines can be carried or towed by "mother ships" (or submarines) large distances from their operating base. They are difficult to counter because of the shallow coastal regions in which they operate, and thus, innovative operational and technical approaches may be required to counter them.

The Technology Challenge

Mines are easy to obtain and use, yet difficult to counter. Modern submarines and minisubmarines are harder to use proficiently, but technology is making that less of an issue with automated combat systems and easy-to-target wake-homing torpedoes. Detecting submarines over the large areas in which they can operate is challenging, and technology is making detection even more difficult with advancements in stealth and AIP. Torpedoes are becoming increasingly stealthy, lethal, and resistant to standard countermeasure approaches. It is no wonder that, in Congressional testimony, CNO Jay Johnson identified the three top force protection concerns: weapons of mass destruction, submarines, and mines (from remarks made during a confirmation hearing before the Senate Armed Services Committee, 1996). The rest of this article describes a vision of the future Undersea Warfare capabilities needed to counter potential undersea threats to Joint force operations.

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State Foreign Economic Corporation
for Export and Import of Armament
and Military Equipment

Gogolevsky Bul. 21, Moscow G-19
Russian Federation, 119865
Tel.: (7-095) 2 01 49 49
Fax: (7-095) 2 30 23 91

Figure 4. Russian Piranja class minisubmarine advertisement (from Ref. 8).

FUTURE UNDERSEA WARFARE REQUIREMENTS

The CNO has proclaimed that "the purpose of the U.S. Navy is to influence, directly and decisively, events ashore from the sea—anytime, anywhere."[9] The stated Marine Corps tenets for maneuver warfare with naval expeditionary forces in the littorals are to win quickly and decisively, minimize casualties, and dominate the battle space by achieving overwhelming tempo of operations.[7] Will future Navy Undersea Warfare capabilities enable or impede these desired capabilities? Four broad areas of development in Undersea Warfare capability are envisioned as the means both to recover ground lost in recent years against undersea threats and to increase the freedom of maneuver and action for future maritime forces:

1. Distributed deployable/offboard ASW sensor networks
2. Organic Mine Countermeasures (MCM) capabilities for the Fleet
3. Advanced offboard vehicle concepts (both manned and minimally manned undersea systems)
4. Advanced warship self-protection measures against undersea threats (highlighted later by illustrative scenarios)

Each of these capability thrusts is addressed in turn.

Distributed, Deployable/Offboard ASW Sensor Networks

Declining numbers of U.S. warships (surface combatants and submarines) with increasingly diverse multimission tasking in the post–Cold War era make it impractical to use warships that cost $700 million or more apiece as sensor nodes in one warfare area for protracted periods. For lesser contingencies or in the early stages of short-warning conflicts, there is likely to be a dearth of warships on the scene. These warships could be widely dispersed in the theater of battle, doing various jobs related to Theater Air Defense, Theater Ballistic Missile Defense, strike/fire support, MCM, special operations, ISR (intelligence, surveillance, reconnaissance), and ASW. As one participant stated at a June 1998 seminar exercise held at APL on Network-Centric Warfare/ASW C^4I (command, control, communications, computers, and intelligence), "What is the benefit of networking a dozen [metal] washer-sized sensor areas in [a region the size of] an auditorium?" In other words, declining detection ranges for organic sensors on individual warships prohibit large-area surveillance (e.g., tens of thousands of square nautical miles in littoral regions of interest) with a few warships. Clearly, in future contingencies and conflicts, it is more desirable and practical to distribute large numbers of ASW sensors than to disburse a comparable number of multimission platforms over the same area, particularly in the early phase before the "cavalry" (warship reinforcements) arrives from the continental United States.

Note that surface ships (with their helicopters) and nuclear attack submarines (SSNs) will always have certain key ASW roles: own-platform self-protection, ASW screening operations during the transit of forces, ASW screening and barrier or area clearance operations in fixed areas, ASW operations in far-forward (contested) areas, and covert tracking operations during rising tensions. In addition, mobile ASW surveillance platforms may have key roles in C^4I and sensor field monitoring, or they may provide special or relocatable sensors. Nevertheless, more ASW tasks will likely have to migrate to maritime patrol aircraft and offboard surveillance systems so that large sensor fields can be distributed without engaging numerous warships for this single-mission focus.

Maritime patrol aircraft will be key to investigating surveillance cues, conducting large-area search operations, performing ASW screening operations during force transits, establishing barrier operations in certain fixed areas, and conducting overt or covert tracking operations. Yet, our current fleet of maritime patrol aircraft is aging (relying on service-life extension programs); basing also may prove to be problematic for some future contingencies. If basing is a problem, a larger ASW burden could fall to sea-based ASW-capable aircraft, despite the recent recapitalization decision to remove acoustic ASW from the S-3 Viking carrier-based fixed-wing aircraft. Sea-based ASW aircraft in the future would include the SH-60 helicopter and possibly the Common Support Aircraft, whose mission responsibilities could include ASW.

Finally, offboard surveillance systems represent a potentially cost-effective means of conducting both protracted surveillance operations over medium to large areas and protracted "tripwire"/barrier surveillance operations. It is disconcerting to realize, however, that *there are no deployable offboard surveillance systems in the Fleet today* to rapidly respond to contingencies in littoral regions. The only system in development that can meet this need is the Advanced Deployable System, which is a cable-based system (cables between sensor nodes on the ocean bottom, and cables back to a shore site for processing). In the near term, the fiber-optic cable allows high volumes of acoustic data to be reliably passed for processing. In the far term, it is desirable to eliminate the cable because of concerns about cable affordability and survivability and because some operational settings require very rapid deployments. Air-deployable concepts could meet short response timelines, but using manned aircraft to monitor RF communications for protracted surveillance missions (e.g., many weeks) is undesirable because of competing mission demands, both ASW and non-ASW. ASW aircraft can be made available for other missions if autonomous surveillance concepts can be developed that allow remote monitoring of surveillance fields from command centers (ashore and afloat). The following enabling technologies are key to the development of affordable autonomous sensors (and supporting systems):

- *In-sensor detection, classification, and localization processing* to achieve highly reliable, automated information processing that reduces data bandwidth requirements for RF transmissions to satellite communication networks
- *Advanced energy systems* to increase sensor endurance and reduce the need for reseeding surveillance fields
- *Advanced sensor technology* to achieve miniaturization and allow large-aperture arrays to be packaged and deployed in standard-sized sonobuoys
- *Advanced active acoustic source technology* to increase surveillance coverage and contact rates for certain operational situations by using affordable, safe, energy-dense power sources to "activate" sensor receive arrays
- *Advanced communications* to achieve reliable, jam-resistant RF links to satellites and, in some applications, acoustic links among sensors and control nodes

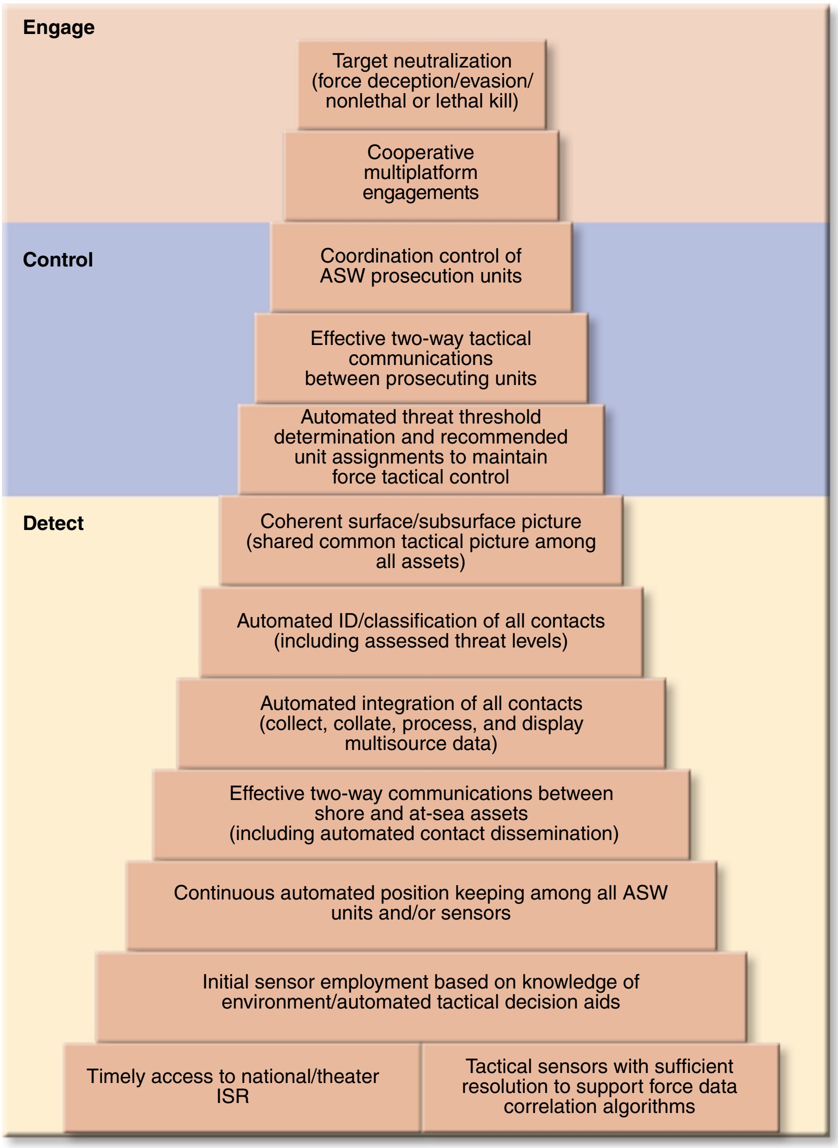

Figure 5. Network-centric–based ASW force coordination. Effective ASW begins with effective surveillance and tactical sensors. The "pyramid" must have a solid foundation (ISR = intelligence, surveillance, reconnaissance).

Advanced sensors and in-sensor processing are the crucial components for achieving affordable, deployable, autonomous, distributed surveillance systems. Without effective sensor concepts, network-centric–based ASW will (at best) fall short of its full potential or (at worst) fail miserably. Although we need to continue to ensure that our ASW weapons work, ASW begins with effective surveillance and tactical sensors, as Fig. 5 depicts. The bottom of the ASW pyramid needs to rest on this solid foundation.

Organic MCM Initiatives and Issues

The Navy is increasing its emphasis on "organic" (as opposed to dedicated) MCM capabilities, that is, integrating MCM capabilities into mainstream multimission Fleet assets (surface warships, submarines, helicopters).[10] Some degree of specialized MCM platforms and assets will likely be retained for the foreseeable future, but there is a clear intent to increase significantly the MCM capability on forward-deployed multipurpose Fleet units, as is the case for other warfare areas (e.g., anti-air, anti-submarine, and strike). Some of the potential benefits will include providing immediate options for mitigating the risk from mines to forward-deployed carrier battle group (CVBG) and amphibious ready group (ARG) assets. Increasing the emphasis on organic MCM also is likely to improve the options for conducting MCM reconnaissance operations in hostile environments (for example, with low-observable and clandestine unmanned systems) and generally to reduce overall MCM timelines. Eliminating significant portions of the dedicated MCM infrastructure might also produce some overall cost savings. Two things must happen to make this warfighting vision a reality. First, the organic MCM-related concepts must be demonstrated and the capabilities fielded in adequate numbers to take on a large share of the MCM tasking. Second, the combined organic and dedicated MCM capabilities must be optimized with a "systems view" of how to best exploit the emerging organic MCM technologies in conjunction with the legacy-dedicated MCM systems.

The emerging organic MCM technologies include unmanned offboard vehicles (both unmanned undersea vehicles and semisubmersibles) for mine reconnaissance and minehunting operations, as well as CH-60 variant helicopters equipped with both minehunting and minesweeping systems. The key organic MCM capability areas that could benefit from advanced technology developments are likely to be the following:

- Increased sensor area coverage rates
- Better clutter discrimination via computer-aided detection and classification
- Precision bottom-mapping capability
- Rapid transition from classification to identification of mines
- Lighter, compact systems for CH-60 helicopter tow, including effective influence sweeps
- Advanced offboard vehicle designs to enhance mission effectiveness (safe high-density energy sources, autonomous control, communications, navigation, sensors)
- Effective command and control over offboard vehicles
- Coherent tactical picture development (automated integration, fusion, and information management)
- Rapid, effective, standoff mine clearance
- Reduced signatures (acoustic, magnetic, or other) for warships and offboard vehicles

Even if significant progress can be made in these capability areas by leveraging technology, the full benefit of these advances will not be realized unless other developments occur in key support areas. First, manning and unit/force Countermine Warfare (CMW) training concepts must be developed that are compatible with the host platforms—surface combatants, submarines, and aircraft. (Note that the term CMW is synonymous with MCM, but is used to reflect a more complete *Joint* "systems perspective.") Second, the mine threat must be well understood, including future trends in stealth design, actuation mechanisms, and so on. Third, the littoral environment where mines are expected must be well understood, including the ability to exploit *in situ* measurements during actual contingencies to optimize CMW operations. Fourth, connectivity and communications planning for CMW must realistically reflect multiwarfare/multiservice competition for bandwidth. Fifth, the Commander-in-Chief needs to be made aware long before the contingency occurs of the crucial role that Joint forces can play in facilitating successful CMW operations. This includes timely access to national or theater ISR assets, offensive strikes against mine stockpiles and mine layers, and suppression or rollback of adversary sea-denial forces. The last two Joint contributions would depend largely on the rules of engagement. Sixth, adequate inventories of expendable and nonexpendable CMW systems are needed that reflect both intended utilization rates for various contingencies and potential losses to mine and nonmine threats based on realistic assessments of vulnerability to these threats.

Finally, an overarching concept of operations (CONOPS) for future CMW forces in the era of mainstreamed MCM capabilities must be established. This CONOPS must reflect basing and logistics limitations and potential mission conflicts on host platforms. For example, CH-60 employment on small combatants ("cross-decking" or "lily-pad" operations) is a potentially significant force multiplier but has operational and technical issues that must be resolved. Other CONOPS-related issues deserve attention as well:

- Potential paradigm shifts in the use of mine reconnaissance information to reduce timelines, including pattern recognition or "change detection" methods and associated tactical decision aids
- Benefits and limits of real-time mine detection and avoidance techniques by individual warships
- Maneuver guidelines and constraints for battle groups in minable waters prior to completion of CMW operations, whether or not mines have actually been identified
- Best route selection based on knowledge of the bottom, the environment, ship signature, water depths, general shipping patterns, etc.
- Best command and control structure for CMW operations in various operational settings to ensure adequate planning and execution of CMW operations

Figure 6 summarizes the key prerequisites for CMW operations to have a high payoff. Without these supporting areas in place, the full benefits of advanced system and sensor technologies will not be realized.

Offboard Vehicle Developments

Offboard vehicle initiatives were mentioned in the preceding section in terms of mine reconnaissance applications. These initiatives are just the beginning of future uses for minimally manned or unmanned undersea vehicles (UUVs) in support of naval and Joint missions. UUV developments are expected to parallel those for unmanned airborne vehicles (UAVs), with

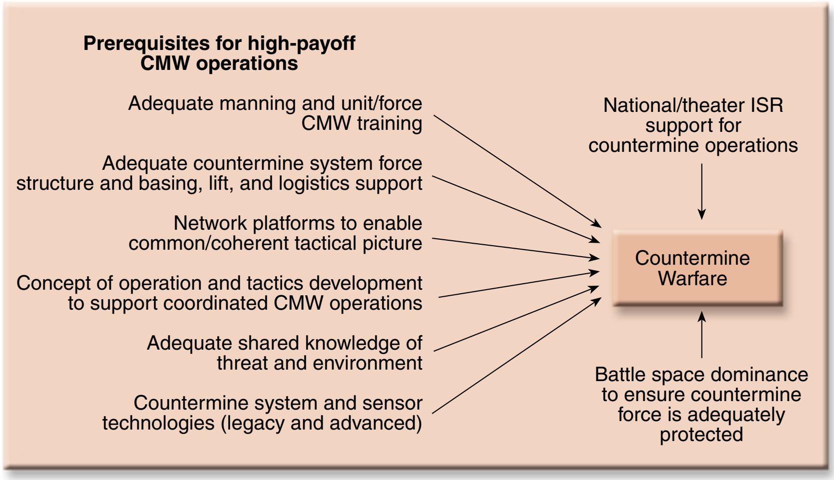

Figure 6. Prerequisites for CMW. The achievement of the full benefit of advanced system and sensor technologies will require the strengthening of training, logistics support, C^4I, and tactics development; improvement in understanding of the threat and the environment; and securing of ISR and battle space dominance support. (Note that the term CMW is synonymous with MCM, but is used to reflect a more complete *Joint* "systems perspective.")

significant emphasis on ISR mission applications for improved situational awareness and coherent tactical picture development. Minimally manned minisubmarines (for Navy use) could be assigned to similar ISR missions (with or without crew, depending on perceived danger). They would also be capable of more complex missions in which direct involvement of human operators was needed, for example, to increase the likelihood that correct decisions are made during highly dynamic or ambiguous operational situations.

As an example, one could envision a future Navy minisubmarine whose mission applications go well beyond those of the Advanced SEAL Delivery System (ASDS), which is currently being developed. This future minisubmarine could have the following physical characteristics:

- Submerged displacement of 65 to 250 tons or more
- Regular crew of no more than four
- Reconfigurable payload packages for specific missions
- Endurance of 2–4 weeks; submerged endurance (with AIP) of 500–2000 nmi
- Cruise speed of 3–8 kt; sprint speed of 20–25 kt
- Ability to operate in waters as shallow as 6–12 m or as deep as 200–500 m
- Very low observable signatures (acoustic and nonacoustic)
- Robust bottoming and hovering capability

The minisubmarine could be towed into theater by a host platform (an SSN or a surface ship). If it was within the 65- to 130-ton regime (within the C-5A payload restrictions, depending on flight distance and fuel load), it could even be airlifted into theater.

The minisubmarine could be optimized for use in different littoral environments as a complement to the SSN force, operating in very confined seas or in water depths that the SSN would prefer not to enter during certain types of crises, contingencies, or conflicts. Potential missions could include some combination of ISR; special operations force insertion, extraction, or support; special information warfare missions such as cutting undersea cables or RF/acoustic spoofing; covert offensive mine laying; port protection (countering undersea intruders); minefield reconnaissance and neutralization (e.g., employing UUVs); anti-surface operations against fast attack craft or other coastal craft; ASW detect-through-engage operations against submarines or minisubmarines in very shallow waters; and limited tactical fire support/shore bombardment with advanced UAVs and weaponry (for example, against highly mobile targets from firing positions very near shore).

Several key technologies would need to be relied upon to make this minimally manned minisubmarine concept feasible. First, a high degree of automation would be needed to reduce the crew size to minimal levels and yet still allow reliable accomplishment of complex missions. This would then allow the vehicle size to be dominated by the mission package rather than by the crew complement. Second, reconfigurable mission package concepts to accommodate miniaturized high-tech payloads would be required to allow a high degree of operational flexibility on a very small submarine. Third, AIP would provide the submerged endurance capability needed to reduce platform vulnerability when the minisubmarine is operating in near-shore or confined sea regions controlled by the adversary. Last, advanced hull concepts would be needed to achieve favorable hydrodynamic attributes and to provide a high degree of stealth.

Warship Self-Protection Measures

Both surface combatants and SSNs are likely to be aggressively employed in future regional contingencies to achieve various objectives of task force commanders. With declining numbers of warships of increasing individual military value, it is imperative to limit losses during a conflict to those deemed commensurate with the perceived payoff of achieving the Joint or coalition objectives. As was evident from a single firefight in

Somalia and a single terrorist attack on the Marine barracks in Lebanon, U.S. policy and involvement in a contingency can be dramatically altered if losses exceed the perceived value of the operation. In an all-out conflict such as a major theater war, perceived or actual undersea threats would not likely cause the United States or its allies to completely disengage. However, such threats could delay the buildup of maritime forces (CVBG, ARG, strategic sealift) in the theater, or they could restrict movements once the forces have arrived, effectively limiting naval contributions to the war until the undersea threats have been sufficiently neutralized.

Enhancing warship self-protection from undersea threats would enable the battle group or naval component commander to more aggressively employ warships for various missions even before the undersea threat was eliminated. The following hypothetical operational situations illustrate the need for warship self-protection measures against undersea threats:

- *A destroyer is assigned a Theater Ballistic Missile Defense mission* near a key allied port at the start of a short-warning scenario. The ship must quickly get on station to counter missile attacks against the port. (The attacking missiles carry either conventional payloads or weapons of mass destruction.) The water depths in the patrol area are shallow, and *offensive mining by the adversary* is a distinct possibility. This situation requires some combination of the following: offboard vehicle reconnaissance (if available and rapid enough), onboard ship sonar for real-time detection and avoidance of detected objects that could be mines, optimum route/speed selection, ship signature reduction and control, and, as a last resort, ability of the ship to absorb a mine hit and keep fighting. Against mines, neither the active measures (reconnaissance and avoidance) nor the passive measures (signature control and damage resistance) are robust in Fleet units today (as evidenced by the mine hits on the U.S. warships *Princeton*, *Roberts*, and *Tripoli*).
- *A large-deck warship (e.g., a combat logistics ship) is transiting*, either to a contingency region or within theater, and *it has no escort of ASW-capable ships*. Is it likely that this ship would be escorted before the submarine threat had been neutralized? The answer is problematical, because the number of surface warships is declining and because such a high level of multimission tasking is projected for the future. It should not be assumed that combat logistics ships operating in theater or even amphibious ships traveling to theater will have the direct support of ASW assets, particularly early in the contingency when few ASW-capable assets may be in theater. What combination of tactics, signature reduction, hardening, redundancy, damage control, and countermeasures (reactive versus nonreactive, soft kill versus hard kill) would provide acceptable protection for the large-deck ship against advanced, highly lethal anti-ship torpedoes? This is a challenging problem that defies simplistic solutions.
- *An SSN is transiting* to a forward area off an adversary's coast at the outset of hostilities. A significant portion of this submarine's transit is in minable waters and *adversarial defensive minefields* are a potential concern, although no direct evidence of mining has yet appeared. What combination of offboard vehicle reconnaissance (if available and rapid enough), onboard sonar for detection and avoidance of possible mine objects, optimal route/depth/speed selection, signature reduction and control, and ability of the ship to absorb mine hits is needed to achieve acceptable risk mitigation from mines for the SSN?

The vision of future warfighting I have described in this article places greater emphasis on warship self-protection from submarines, torpedoes, and mines than is apparent today. "Ship self-defense" is not synonymous with ASCM Defense; rather, it includes self-protection from any potential threats, including the undersea threats described here. In this vision, SSN self-protection is also upgraded to match the stressing conditions found in many littoral environments. The following goals related to warship self-protection seem to me to be the "minimum entry level" for operations in future contingencies.

Improvements in Anti-Submarine Warfare. There should be a high likelihood of getting off the first shot (based on developing a timely, effective firing solution) in the vast majority of encounters with adversary submarines. The enabling technology areas for this capability are advanced sensing mechanisms and signature reduction/control (that is, acoustic superiority), rapid localization techniques, quiet-launch and quiet-running standoff weaponry, and advanced weapon guidance and control for difficult targets and environments. Note that this goal would not apply to large-deck ships that are likely to have limited, if any, onboard ASW capabilities (except possibly for ASW-capable aircraft).

Improved Torpedo Defense. If the warship fails to prevent a submarine attack (including potential counterfire by the adversary), it should still have a high likelihood of denying any own-ship torpedo hits. The enabling technology areas for this capability are torpedo countermeasures (soft kill and/or hard kill) and signature reduction and control (in conjunction with countermeasures).

Improved Mine Defense. The likelihood that our ships will actuate a mine while conducting a transit or patrol in a potentially mined area should be low. The enabling technology areas for this capability are minefield reconnaissance with offboard systems (for example, unmanned vehicles and MCM-capable helicopters from own ship), onboard sonar for mine detection and avoidance, and signature reduction and control (in conjunction with tactics).

SUMMARY

This article has outlined a future undersea warfighting vision composed of four principal elements:

1. Distributed ASW sensor networks (rather than distributed multimission warships) to provide adequate surveillance cueing against submarines
2. New technologies (related to organic MCM) and innovative CONOPS to counter mines
3. Advanced offboard undersea vehicles (both unmanned and minimally manned) for a variety of mission applications
4. New system and technology developments that reflect increased emphasis on warship self-protection against undersea threats (including defense against torpedoes and mines)

This vision is consistent with the CNO's emphasis on leveraging

> . . . new technologies coupled with innovative operational concepts . . . that take advantage of the growing power of information technologies . . . networked search techniques . . . rapidly distribute[d] cueing sensors . . . long endurance sensors and unmanned . . . vehicles.[11]

Anti-Submarine Warfare and Mine Warfare are core naval competencies that need new directions if they are to keep pace with developments in other warfare areas and allow the Navy to have relatively unencumbered maneuver and action with acceptable risk. The engineering and technical challenge will be to develop affordable and cost-effective approaches that can readily make the transition into the Fleet. Otherwise, we risk having a familiar adage borne out in future regional contingencies and conflicts: "Failing to prepare is preparing to fail."

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THE AUTHOR

JOHN R. BENEDICT, JR., joined APL in 1985 and was appointed to the Principal Professional Staff in 1990. He received a B.S. in mathematics from the University of Maryland in 1969 and an M.S. in numerical science from The Johns Hopkins University in 1974. As a member of APL's Joint Warfare Analysis Department, he has extensive experience in naval operations analysis, primarily in the area of Undersea Warfare, with special emphasis on Anti-Submarine Warfare and Mine Countermeasures. Throughout his career he has been a study leader or principal investigator on a variety of tasks relating to Undersea Warfare, usually involving performance trade-offs among various options, such as platforms, sensors, and weapons. Mr. Benedict was also the Study Director for four Analysis of Alternatives efforts. In many of these studies, he has been responsible for the coordination of the combined efforts of technical teams composed of representatives from various Navy and university laboratories. His e-mail address is john.benedict@jhuapl.edu.