



Undersea Warfare Systems Engineering and Assessment: An Overview

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The end of the Cold War and the emergence of Third World submarine threats have required the rapid re-engineering of legacy undersea warfare (USW) systems and approaches. USW scenarios are now focused on less-familiar littoral environments and modern diesel-electric submarines. The National Security Technology Department (NSTD; formerly the Submarine Technology Department) has a long history of contributions to systems engineering and assessment in USW, beginning with the Submarine Security Program. The department has responded to these new challenges through programs to assist the Navy in adapting existing legacy systems to these new environments and threats. In addition, through simulation-based design and assessment, coupled with a physics-based understanding of the mission environment, NSTD has helped the Navy to identify opportunities to introduce new systems and technologies into the Fleet. The following series of articles provide a sampling of current work and future trends in USW systems engineering and assessment being performed by NSTD.

RAPID TECHNOLOGY INSERTION

Evolutionary improvement of legacy systems is one key to the affordable transformation of USW systems. In the past, system developments were often characterized by long periods of time between the introduction of new technology into the Fleet. When new technology was introduced, it typically came in large, undertested packages. NSTD has led the Navy in introducing a new development approach based on the build-test-build methodology. This approach is characterized by relatively short cycles for the introduction of modest-sized packages of new technology, with significant testing between these cycles. The department started using the approach in 1985 with the Low Frequency Active (LFA) system development program and the related Critical Sea Test (CST)¹ scientific and test program. The methodology was further expanded and formalized in the mid-1990s through the Advanced Processing Build (Acoustic) (APB(A)) and Acoustic Rapid COTS Insertion (ARCI) programs, which coupled software development and hardware insertion to update the technology of legacy submarine sonar systems. The APB program

concentrated on the rapid identification and verification of promising approaches to sonar signal processing. The ARCI program provided a COTS hardware baseline and system software set on selected submarine platforms that could be used as the launching pad for the rapid introduction and testing of new algorithms and approaches for submarine sonar. This approach, championed by NSTD, has led to a significant speed-up in the introduction of high-quality, tested improvements to submarine sonar. The article by Bates et al., "Operational Evaluation for Evolutionary Sonars," describes the APB process as it has been applied to passive sonar development. The authors also explore the adaptations required by the Navy operational test force, the Navy Program Manager, and the system engineer to make the process translate technical innovation into Fleet sonar improvement. The difficulties of verifying effectiveness when faced with constraints on test time or test data are identified and solutions proposed.

NSTD has long been involved in designing algorithms that remedy deficiencies identified during the systems engineering activity in legacy sonar systems. This activity has resulted in significant technical involvement with the design of algorithms for signal classification. In the 1980s, the LFA and CST active acoustics programs led the advancement of these technologies, since false alert rates were a driving limitation on the deployment and effective use of LFA systems. NSTD's leadership role in this area was evident in the Waveform/Processor Evaluation Experiment and in the design of the LFA Information Processor. More recently, the department has been active in the development of alerting algorithms for the passive signatures of the newer and some older threat submarines. With the advent of the APB(A) program, one of NSTD's passive acoustic algorithm improvements has already been inserted into submarine sonar systems and is well regarded in the Fleet.

An extension of the APB(A) process into the area of information management in submarine combat systems is the focus of the article by Jacobus et al., "Information Management: The Advanced Processor Build (Tactical)." The APB(Tactical), or APB(T), is the submarine combat system application of the APB(A) approach. Using a four-step process, potential combat system algorithm improvements are identified, evaluated, matured through integration and laboratory testing, and ultimately tested at sea. The article describes the use of tactical decision aids, expert systems, and intelligent agents to manage information used by the submarine tactical decision maker. Specifically discussed is the Integrated Vulnerability Management System, which provides situational awareness of the submarine's vulnerability to detection by a variety of acoustic and nonacoustic systems. Also described are current efforts for automatic detection and classification of periscope

images as well as automated constraint-based reasoning methods to aid tactical decision making.

MISSION CRITIQUE

Maintaining a cadre of well-trained, capable USW personnel is a critical challenge to the Navy. The value of evolutionary improvements to USW systems cannot be fully realized without corresponding improvements in training. Actual USW missions produce rich data sets for critical critique to improve the effectiveness of training. With the advent of the system-level recorder within the surface ship AN/SQQ-89 USW combat system, much of the acoustic data from the ship's sensors was recorded and made available, together with sufficient nonacoustic data, to make mission reconstruction and critique possible. With critique critical to effective training, the Navy established the Surface Ship Acoustic Analysis Center (SSAAC). The article by Ravitz, "SPEARS: A Surface Ship Sonar Data Analysis and Reconstruction System," describes a system developed in NSTD to enable improved mission reconstruction and critique at the SSAAC. This system allows regeneration of acoustic displays with the potential to critique operator decisions and with an eye toward continuous improvement in operator performance. The success of this system enables NSTD entry into the USW training arena.

AUTONOMOUS OPERATIONS

The use of autonomous and semi-autonomous systems in military operations is becoming more prevalent as the technology matures. First introduced on a notable scale in the Persian Gulf War, unmanned air vehicles (UAVs), which were used extensively in Bosnia, are finding even broader applications in the current war on terrorism in Afghanistan. The use of unmanned underwater vehicles (UUVs) is a very promising technological approach to assist the transformation of USW. However, because the communications paths available to UUVs are much more constrained than those available to their air counterparts, UUVs will rely to a greater degree on autonomy. Therefore, the development of software systems for autonomous control is critical. Since UUV development is mostly in the hands of others in the USW community, NSTD has concentrated on the development of software approaches and architectures to enable autonomous operations.

In "Intelligent Agent-Based Control," Scheidt describes the application of intelligent control agents in an Open Autonomy Kernel (OAK) for controlling complex distributed systems. Control agents are software agents that effectively automate a physical system so that it requires no operator supervision or monitoring. They employ a process of *estimation* to evaluate the state of the system, *planning* to achieve the

desired goals or satisfy the constraints of the system, and *execution* that ultimately translates into actuator commands to system components. Intelligent control agents operate on systems whose state space cannot be completely described through traditional means because of the size or complexity of the system. Model-based reasoning, drawing on partially observable Markov decision processes, is used in inference engines in intelligent control agents to identify likely system transition states without exhaustively generating all of the possibilities. Using a unique combination of control agents and model-based reasoning, the OAK architecture has been successfully tested on Navy auxiliary systems on the Arleigh Burke-class Aegis destroyers. Effective automation of these systems offers the potential for significantly reduced manning in future applications. Further extensions of the technology have applications in UUV autonomous operations and autonomous surveillance sensor grids in USW as well as other mission areas.

SIMULATION-BASED ASSESSMENT

Higgins et al., in “Simulation-Based Undersea Warfare Assessment,” describe simulation as a tool for developing tactics and evaluating system performance for the submarine force. The Object-oriented Rule-Based Interactive System (ORBIS) has been central to these

efforts. The article describes the evolution of ORBIS from its beginnings as a rather sophisticated tool using then-nascent object-oriented programming techniques to its current incarnation as a flexible open architecture system that takes advantage of today’s Java-enabled technologies. ORBIS can be applied to submarine tactics development, system performance evaluations, cost and operational effectiveness assessments, operator-in-the-loop distributed interactive simulation demonstrations, and submarine engagement studies. Higgins et al. also detail acoustic detection performance modeling for both active and passive sonars to illustrate the level of fidelity in sensor, signature, acoustic, environment, and propagation modeling that is captured in the simulation for processes critical to most USW assessments.

CONCLUSION

Building on the foundation of the Submarine Security Program, NSTD has expanded its systems engineering and assessment work to keep pace with the Navy’s need to address new missions and new threats through the introduction of new technologies.

REFERENCE

¹*Critical Sea Test, Final Report 1996*, SPAWAR Report, B. E. Raff (ed.) (1996).

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