ITEA Journal 2009; 30: 258–264

Enabling Test and Evaluation and Training for Undersea Range Programs

Robert Reid
Naval Undersea Warfare Center, Newport, Rhode Island

This article discusses leveraging test and evaluation (T&E) and training programs in the development, production, and installation of instrumented undersea ranges for the U.S. Navy and other customers. Enabling and leveraging of this capability also touches other non-Department of Defense arenas, such as the underwater tracking of marine mammals, with the same infrastructure that the U.S. Fleets use for undersea warfare test and training. This infrastructure includes an underwater sensor grid that is cabled to shore or telemetered to a mobile platform that includes analog and digital signal processing and undersea acoustic tracking and display hardware and software. Additionally, common digital signal processors and universal tracking software will be integrated into programs to avoid nonrecurring engineering and duplications of efforts. This article documents actual programs leveraging and attempts to quantify the value of these opportunities. The future plans for this sharing of undersea range technology are also discussed.

Key words: Infrastructure; instrumentation; real-time position data; technology sharing; tracking software; training; undersea test range; U.S. Navy.

Undersea warfare (USW) tracking ranges have been used for more than half a century to support the conduct of fleet training exercises as well as the test & evaluation (T&E) of USW systems. These ranges consist of both fixed ranges permanently located at a particular location and portable ranges that can be installed (typically for short periods of time) at a variety of locations to suit a particular exercise/T&E event requirement. Undersea tracking ranges (UTRs) provide the unique systems necessary for the command and control of, and the data collection/measurement capability for, training and T&E events. The primary capability of UTRs is to provide the "ground truth" time and space position information (TSPI) of underwater platforms with a secondary capability to provide voice/data communications between the UTR and the underwater platforms.

The UTRs exist for several primary reasons:

1. Provide postprocessed reconstructed data with sufficient fidelity to analyze the results of an at-sea exercise to enable the evaluation of USW systems to support acquisition decisions or to quantify the performance of system operators in terms of meeting the mission goals. The UTR data must be sufficient to enable the development and assessment of tactics and enable the identification of the root causes when the exercise reveals negative results.
2. Provide near real-time feedback on individual or group performance in a training exercise.
3. Provide real-time position data with sufficient fidelity to maintain a safe operating area.
4. Provide real-time position data with sufficient fidelity to enable efficient exercise conduct.
5. Provide real-time positioning with sufficient accuracy to recover spent weapons and targets.

These top level requirements can be grouped into two main categories: (a) exercise analysis and feedback (debrief), as defined in reasons 1 and 2, is required in near real-time for test and training and (2) exercise command and control, covering reasons 3 through 5, is a real-time requirement.

UTRs Configuration Item (CI) descriptions

Traditionally, UTR development/acquisition programs are thought of and discussed in terms of the site where they are located, such as the Pacific Missile Range Facility (PMRF), the Atlantic Undersea Test

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2009**	2. REPORT TYPE	3. DATES COVERED **00-00-2009 to 00-00-2009**

4. TITLE AND SUBTITLE **Enabling Test and Evaluation and Training for Undersea Range Programs**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Undersea Warfare Center,1176 Howell Street,Newport,RI,02841-1708**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

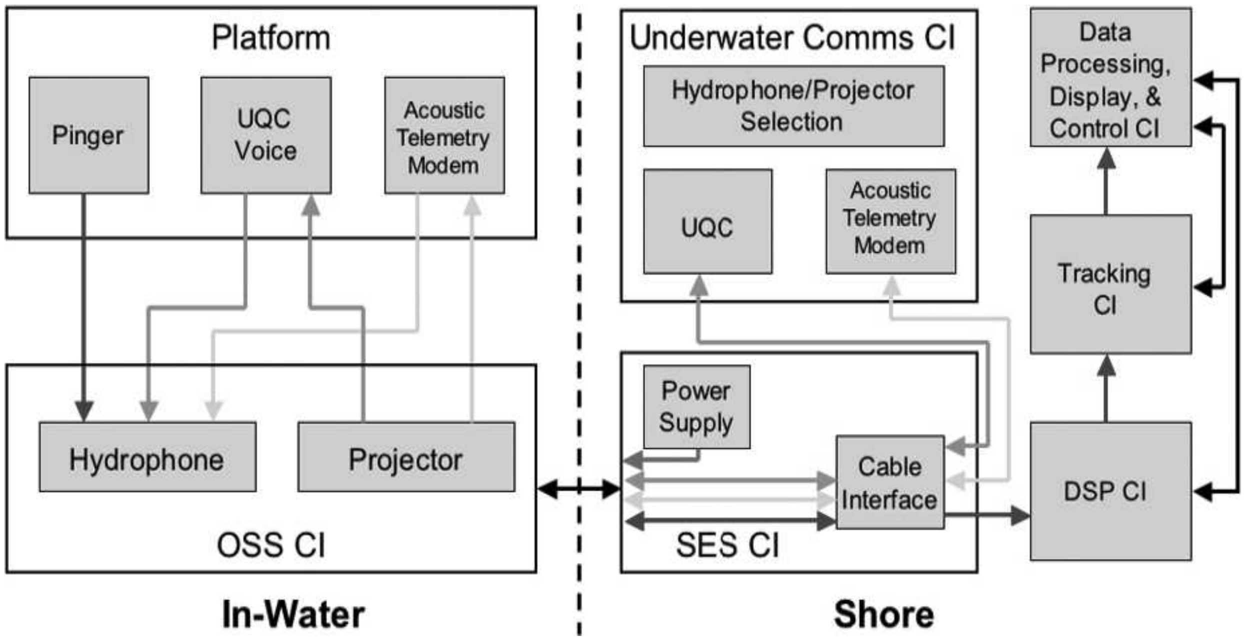

Figure 1. Undersea tracking range architecture.

and Evaluation Center (AUTEC), and the Southern California Anti-submarine Warfare Range (SOAR). This is partially because programs have been planned and funded for a particular range location. However, the new paradigm for a cost efficiency strategy for range sustainment is to deal in terms of UTR CIs. This approach is to maximize commonality for a set of CIs across all the ranges (fixed and portable, training and T&E) and to sustain (upgrade, refresh, etc.) the common CIs across all the UTRs. This is most practical for the shore-based systems; however, there are examples of this approach being successful for the in-water systems.

The system architecture of a UTR, whether it is fixed or portable or used for T&E or training, consists of the same set of functional subsystem blocks. These are shown in *Figure 1*. The primary capability of a UTR is to provide "ground truth" TSPI of underwater platforms in real-time to support exercise command and control as well as in near real-time for exercise analysis and feedback. Additionally, the UTR provides the capability for voice and data communications between the underwater platforms and the range operators to provide situational awareness. Current UTRs under discussion use a cooperative tracking architecture that utilizes acoustic pingers that are mounted on the underwater platforms being tracked. Ping signals are received by the ocean sensor subsystem (OSS), which consists of an array of receivers spread across the area that comprises the UTR. The OSS channels ping signals back to the shore (or sometimes a shipboard "dry side" in the case of some portable systems) via a shore electronics subsystem (SES) that interfaces with a digital signal processor (DSP). The DSP detects and time tags the ping signals, which then go to the underwater tracking subsystem (UTS) where the position of the underwater platform is calculated through triangulation. The data processing, display, and control subsystem (DPDCS) displays the TSPI in real-time as required for exercise command and control. TSPI is also archived for post-exercise processing and playback. The underwater communications subsystem provides the shore side capability for voice (UQC) and data communications (via the acoustic telemetry modem) with the platform. *Figure 2* provides a basic diagram of a UTR.

Pingers

Pingers are installed onto each platform/vehicle that is being tracked on the UTR. The pinger emits a short burst (10s of milliseconds) of acoustic energy at one of the standard tracking frequencies at a regular interval (0.25 seconds to 10 seconds typically). There are a handful of different ping signal formats that are in use today, each having unique properties to support its particular application. All of the UTRs currently use the two standard pinger units: one is a self-contained battery powered unit designated as the Sonar Transmitter Mk-84 that is used in weapons and mobile targets; the other is a shipboard unit used primarily on submarines and is called the Advanced Shipboard Tracking Electronics, Portable. Both units are capable

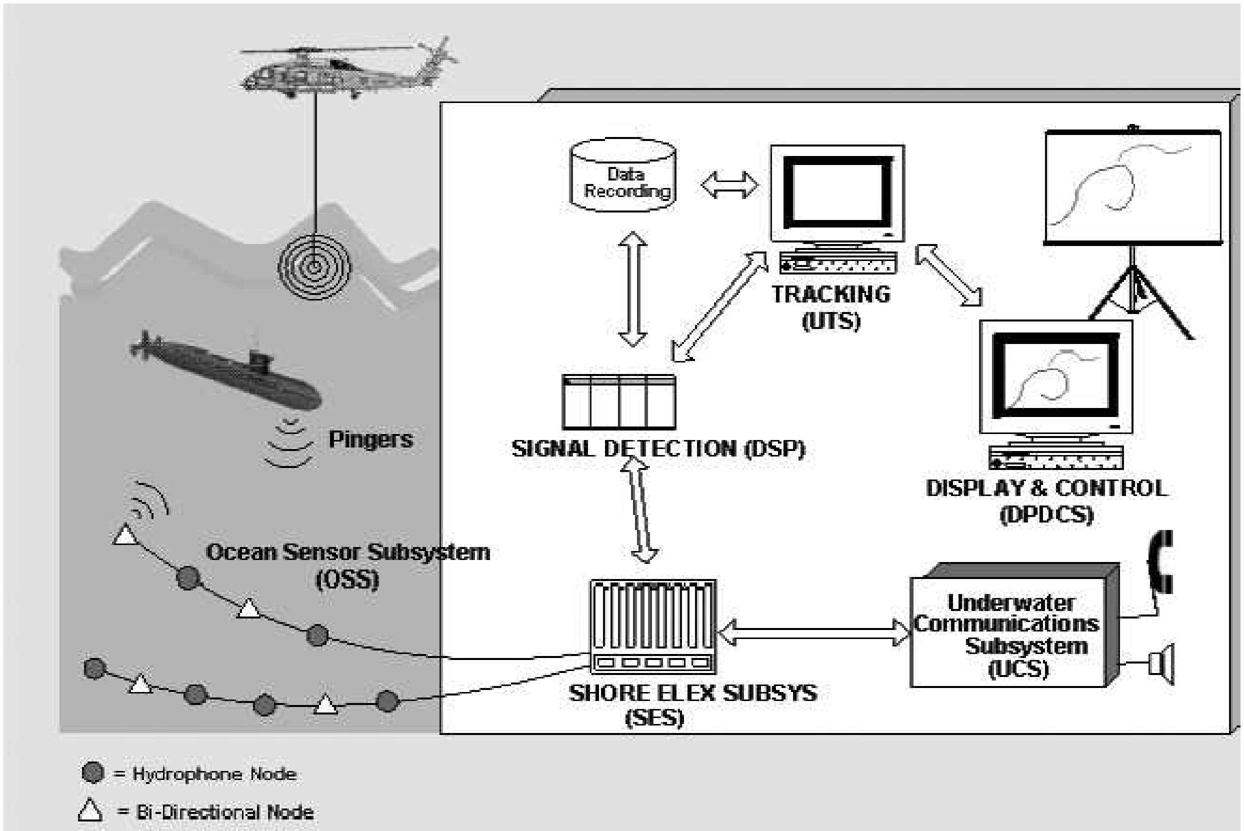

Figure 2. Diagram of a undersea warfare tracking range.

of generating the same set of signals. The pinger subsystem is a great example of a common CI approach that is used across all UTRs: all procedures (installation, repair, etc.), developments and upgrades, and logistics are managed and coordinated within a single program sponsored by Naval Sea Systems Command (NAVSEA).

OSS CI

The ping signals travel through the water, where they are received on the OSS. For a fixed range, the OSS consists of hydrophones and associated electronics located throughout the tracking range area. These sensors are mounted on the ocean bottom and integrated with a cable system to bring the signals back to a shore site. On fixed ranges, another component of the OSS is the projector that transmits UQC voice (underwater telephone) or acoustic telemetry data signals into the water for reception on the underwater platforms (typically a submarine). UQC and acoustic telemetry signals transmitted from the submarine are received on the same hydrophones as the ping signals. UQC capability is also referred to as WQC high band, which operates in the 8–11 kHz band. There is also a WQC low band, 1.5–3 kHz, which requires a much larger projector to transmit the signal. There are two projector cable systems in use on UTRs today: projectors at the end of individual coaxial cables and projectors multiplexed on mostly fiber optic cables, which is the approach being used in all new systems since 1995. In the fiber optic OSSs, projectors and hydrophones share the same cable, with all the nodes containing a hydrophone and a subset having both a hydrophone and a projector with its associated power amplifier. The dual nodes with both receive and transmit capability are called bidirectional nodes. As portable ranges have several in-water variations, only the "dry" CIs will be considered here.

SES CI

For fixed ranges, the SES serves as the shore termination component for the OSS, providing power to the OSS and interfacing electrically (coaxial cable OSSs) or optically (fiber optic cable OSSs) to receive signals from the hydrophones and transmit signals to the projectors. The SES also provides interfaces to the DSP CI. The SES to OSS interface is highly system-dependent for multiplexed systems. Therefore the SES and OSS are procured together in one contract. In the case of individually cabled projectors and hydrophones, the SES is composed of two separate components: the hydrophone support electronics that provides power to the hydrophone and amplifies the received signals and a power amplifier to drive the projector at the end of the cable. For modern multiplex ranges the SES receives optical data and demultiplexes that data into channels for the DSP to process. This is either done by analog or digitally depending on the site configuration. This SES also has the capability to transmit commands or control commands out of the OSS. For portable ranges, the SES is dependent on the OSS configuration.

DSP CI

The function of the DSP is to detect and time-tag the acoustic pings that are received by the OSS/SES. The current DSP configuration in use at most of the fixed ranges is Versa Model Europa (VME)–based DSP boards that contain eight DSP chips (either Texas Instruments TMS320C40 or Analog Devices SHARC). As this hardware is no longer supported by the vendor and therefore obsolete, the next generation of DSP systems is being developed. This hardware is based on a scalable Linux cluster architecture that is built on commodity personal computers (PCs) that are available from multiple vendors. This results in highly cost-efficient, maintainable, upgradeable hardware and software.

The DSP for portable ranges is somewhat more unique to the particular configuration. For cabled systems, the DSP is nearly identical to that of the fixed ranges (i.e., the VME DSP boards). For transponder systems, the DSP is coupled with the transponder system and therefore is usually procured in conjunction with the transponder system. For buoy-based systems, there are two variants. For the case where the signal from the hydrophone is transmitted back to the Portable Range Ops Center, the DSP is again similar to that of the fixed range systems (VME DSP boards). In the variant where the processing is performed in the buoy, the DSP is highly dependent on the vendor of the buoy, and current variants use a single chip DSP that is programmed to detect the signal of interest.

UTS CI

The UTS CI consists of software that receives the time-tagged ping information from the DSP CI and calculates the location (TSPI) of the pinger (and therefore the platform to which the pinger is attached). The tracking algorithm uses the time of arrival at multiple hydrophones in conjunction with the sound velocity profile of the ocean environment to triangulate the position. Presently, the UTS CI at each of the ranges is a unique piece of software with its own algorithms that have been customized for that range environment. With the new approach, the UTS is under development, and the initial version has already been deployed at three of the ranges (AUTEC, SOAR, and PMRF) and is being evaluated. The UTS design was intentionally abstracted to a high level to maximize flexibility to accommodate the incorporation of new features or different implementations of current features. Said another way, the UTS can be used as a shared tracking CI with different modules or features in use for each application.

DPDCS CI

The DPDCS CI provides the human interface to the range system. It enables the user to configure the display of TSPI data (both graphically and alphanumerically). The user is able to process data functions such as archiving, acquisition from other sensor systems (in addition to in-water tracking), product generation, and control functions such as those related to the tracking, DSP, and underwater communications CIs. Typically, the processing, display, and control software is hosted on a system that is composed of a number of computer workstations networked together. The various workstations serve different range operator functions such as Test Conductor, Range Safety Officer, In-water Tracking Operator, etc. Each range has a different requirement for the quantity of workstations required to meet its mission. Currently the DPDCS CI at each of the ranges is a unique software suite running on different hardware platforms. This is because the ranges have had data processing display and control CI upgrades at different points in time and because each range has conducted independent software modifications with the associated configuration control. Additionally, many of the ranges use hardware workstations that are no longer maintained by the vendor and software that is unique to the hardware. The most recent Data Processing Display & Control CI development (AUTEC Range-Ware Improvement program, Initial Operational Capability [IOC] fiscal year [FY]08) uses modern Intel platforms (PCs) as well as software subsystems that are not dependent on any specific operating system. A flexible range architecture approach was implemented to enable smoother integration of new instrumentation and processing systems. The hope is that other UTRs (PMRF and SOAR) will be interested in a shared software suite for display and control.

Underwater communications CI

The underwater communications CI provides the shore side functions associated with both data (acoustic telemetry) and UQC voice beyond the components used that are part of the OSS (projectors and hydrophones) and SES (power amplifiers and hydrophone switching). This includes any hardware and software that is used to select the transmit projector and receive hydrophone to be used. The newer variant of the underwater control system uses custom analog hardware integral to the SES and DSP hardware coupled with a computer system (independent from the DSP CI that detects ping signals) that is used as a modem for the acoustic telemetry (a similar modem is used shipboard as well). The acoustic telemetry modems are referred to as the Underwater Range Data Communications (URDC). Equipment on the submarine is also required to communicate situational awareness and/or voice with the UTR.

UTR program roadmap

A UTR Range Roadmap proposes an outline for future UTR development programs that are being executed to meet and sustain the UTR requirements. This discussion includes programs that are currently planned/budgeted for as well as those that are recommended/proposed to be added to the budget process.

Once the shore systems have been transitioned to shared product line CIs, software upgrades would occur on a yearly basis and hardware refreshes would occur approximately every 5 years. The plan would be to align funding coincident with all ranges implementing hardware refreshes. In the future, there is a potential for all five of the shore system CIs to be one integrated software suite running on a common hardware platform.

DPDCS CI: This CI is the one with the least amount of commonality across the UTRs. Under the currently planned programs for the Future Years Defense Plan, this situation will remain an issue. This CI has high potential for commonality across other ranges, not just UTRs. There is a currently funded program in AUTEC called RangeWare Improvement that is replacing the legacy DPDCS CI with an IOC of FY09. The CI is built around a flexible architecture such that it could be used at any of the UTRs with many common software modules. There will be some software modules unique at each range to deal with site-specific external system interfaces, etc. The software runs on commercial off-the-shelf PCs. The current plan may be to include the RangeWare to SOAR as part of the West Coast Shallow Water Training Range program (proposed for FY09 to implement a common DPDCS CI at SOAR). Implementation at other ranges is not planned at this time.

DSP CI: Within the currently planned programs in the Future Years Defense Plan, all of the fixed UTRs (with the exception of the Pacific Northwest Ranges) will be transitioned to a common CI that utilizes commercial-off-the-shelf (COTS) PC Clusters as the hardware platform by FY10 for DSP. This is being accomplished under the AUTEC Signal Process Replacement, the Barking Sands Undersea Range Expansion (BSURE) Refurbishment, and the SOAR Refurbishment programs. This will result in all fixed tactical training UTRs and AUTEC using DSP PC clusters as the DSP CI by the end of FY10.

UTS CI: Currently planned programs that will provide UTS are the RangeWare Improvement for AUTEC (IOC FY08), PMRF UTS Upgrade (FY08) SOAR (FY09), and the Portable Undersea Training Range. This will result in all tactical training UTRs and AUTEC using UTS as the tracking CI by the end of FY09.

Underwater communications subsystem CI: There is a URDC capability currently at both AUTEC and PMRF. This is a standalone capability in that the system on the shore side is not integrated as part of either the DSP or the DPDCS system. Additionally, there is no program funded to implement the capability at SOAR. The proposed approach to implementing an integrated URDC at SOAR and PMRF will be in response to STRs in FY09–10 and at AUTEC with a small project in FY09. This will result in all fixed Tactical Training UTRs and AUTEC using the Integrated URDC as the underwater communications CI by the end of FY10, if these STRs are funded.

OSS and SES CIs: The OSS and SES CIs for fixed UTRs are migrating to a hybrid common baseline within the BSURE Refurbishment program at PMRF and the SOAR Refurbishment. It is more difficult to manage the OSS/SES CI because of the cost of these systems and the life expectancy of 20–25 years. Future UTR refurbishments will take advantage of the common baseline and possibly contribute new technology/capability to the baseline. The factors that keep the OSS and SES from being a truly single CI are that there are unique characteristics for each range site (most notably water depth) and not all the ranges have been upgraded at the same time, resulting in different technology/design implementations in each.

System Support Activity (SSA): The Ocean Systems (OS)-SSA organization is the technical authority, configuration management, and life-cycle support manager with the mission to implement smart tactical and strategic investments in USW tracking range technologies and products to ensure the ranges have the right capability at the right time, at the right cost to support fleet readiness and T&E. The OS-SSA organization that includes the range developers, range operators, range users, and program and resource sponsors was stood up in FY06 and has been the

Table 1. Cost avoidance of configuration items (CI).

Configuration item	Cost avoidance (estimated $K)	Programs supported
DSP	3,350	AUTEC, SOAR, PMRF
UTS	1,350	AUTEC, SOAR, PMRF
Common display	5,000	AUTEC, SOAR, PMRF
Underwater communications	1,000	AUTEC, SOAR, PMRF

DSP, digital signal processor; UTS, underwater tracking subsystem; AUTEC, Atlantic Undersea Test and Evaluation Center; SOAR, Southern California Anti-submarine Warfare Range; PMRF, Pacific Missile Range Facility.

driving force behind commonality as directed by Operational Navy (OPNAV) and Naval Air Systems Command (NAVAIR).

The SSA is also responsible for developing standards and controls processes across program management (PM), systems engineering (SE), configuration management (CM), quality assurance (QA), and integrated logistics support (ILS) disciplines. These standards and processes are provided to development projects. The OS-SSA is utilizing common tools across the UTR community both for development and life-cycle support. These tools include:

- ISO 9001:2000 Certified Organization,
- Doors Requirement Tracking Software,
- Common PM, SE, CM, ILS, and QA Process Life Cycle,
- Common Problem Reporting System (Web-based STR Management), and
- Common Archive for Documentation (Local Network Drive and Web-based Repository).

Advantages of commonality

There are three advantages to leveraged programs and technology in support of U.S. Navy undersea ranges. These advantages are cost, schedule, and technical risk. The estimated cost avoidance for various CIs is listed in *Table 1*.

Another important consideration in the development of programs is the right mix of government and contractor personnel on the program. Government labs often use a stabilized labor rate and this is a factor. A stabilized labor rate is where the sponsor is billed the same no matter what skill is procured e.g., a senior engineer bills the same as an administrative assistant. Additionally the government labs generally do not have the production capabilities that contractors do. The Naval Undersea Warfare Center (NUWC), however, does hold the experience and technical capability for undersea range development. So, the right level of make or buy decisions goes into every program decision.

Reuse of existing designs or slight modifications of existing architecture speeds the development program as well. Naturally in the case of hardware and software, obsolescence is always a factor, but the OS-SSA has been funded to remain on top of current technology with the larger development programs implementing the newer technology that is made available to the other UTRs without the nonrecurring engineering involved. The paradigm is that one UTR takes the lead and the other UTRs reap the benefits.

A Risk Management Plan (RMP) describes how risk is handled within the OS-SSA development programs. Risk management is concerned with the identification and mitigation of problems that have yet to occur, whereas problem solving is concerned with the management and resolution of current issues. There are two distinct elements of the overall OS-SSA RMP. The first is the identification and quantification of risk areas perceived by the program's managers, development engineers, and stakeholders. This process is initiated at the program's outset with revision throughout the project and follows the Virtual Syscom Joint Instruction on Risk Management issued by the Office of the Secretary of Defense (OSD) and documented by this process. The second element is the use of objective risk checklists at the major design reviews to quantify the maturity of a program's planning and execution in program management, logistics, and engineering disciplines. This process is defined in the OS-SSA Systems Engineering Management Plan.

As articulated in this RMP, the Technical Project Manager shall ensure that the following activities are executed for the program:

- define and assemble the risk management team,
- conduct quarterly risk assessments,
- develop and execute risk mitigation plans for issues identified as high or medium risks,
- report on risk management status at program design reviews, and
- maintain program records on the RMP.

Attention to risk on a regular basis has produced programs that are more cost effective, and completed in a timely fashion with a manageable level of risk. It also provides a means for future programs to take advantage of lessons learned.

Summary: the future

NUWC has established this leveraging philosophy between its two main sponsors, tactical training ranges and T&E. This process of leveraging has proven successful in reducing the risk of technology insertion and development, the cost of programs, and the time it takes it takes to execute programs. This process, with constant continuous improvement via the ISO 9001:2000 implementation (NUWC Code 70 Range System Development has been certified ISO 9001:2000) and other common tools, will provide the best range systems to the Navy. Other foreign and non-Navy customers are taking advantage of this approach and an enterprise (the OS-SSA) is in place to support products in the long term. ❑

BOB REID currently serves as the customer advocate for the Undersea Range Development Programs for the Naval Undersea Warfare Center (NUWC) in Newport, Rhode Island. He is responsible for coordinating all aspects of the program, including the planning, technical development, integration, and test. Bob has received a bachelor of science degree in electrical engineering from the University of Massachusetts in 1981. He has written several technical memorandums, presented several papers, and holds several patents. E-mail: robert.reid@navy.mill