SYNTHETIC ENVIRONMENT TACTICAL INTEGRATION
VIRTUAL TORPEDO PROJECT

Authors:
Kenneth L. Dotson
G. Edward Roberts

U.S. Naval Undersea Warfare Center Division
Newport, Rhode Island

Abstract - Fiscal realities and a reprioritization of United States (US) military spending have demanded that all systems and capabilities be fully exploited through an effective and efficient development, testing, training and operations continuum. To the US submarine community, this has meant that the traditional isolationist culture had to change, new and novel data communications technologies were required and all available resources and technologies had to be fully exploited for development, testing, training, and operation. Until recently, however, submarine communications systems and architectures were ill equipped to handle data and communications links required to support most resource sharing. With the recent advances in submarine communications systems, the time is at hand to implement this critical element of the new US military paradigm. The Naval Undersea Warfare Center's Synthetic Environment Tactical Integration (SETI) Virtual Torpedo Project (VTP) utilizes new and innovative communications capabilities to provide a resource sharing capability to the submarine offering a high fiscal and capability payoff.

VTP provides operational submarines with real-time access to high fidelity torpedo simulations of the US Navy's underwater Weapons Analysis Facility (WAF). The WAF is a Hardware-In-The-Loop (HITL) facility offering extremely high fidelity torpedo engagement capability with full interactivity with the firing platform. Novel submarine communications capabilities are incorporated into VTP to allow for bi-directional data flow with up to two submarines at depth and speed. Additionally, hardware independent software (Java language) and a related downloadable client architecture are being developed to provide interoperability and reuse across the US Department of Defense (DoD) test and training infrastructure.

Recent tests and demonstrations such as Synthetic Theater of War - Europe (STOW-E) have implemented the capability to intermingle real and virtual worlds. However, the utility of these synthetic environments and the ability to provide such a capability economically for day-to-day use, in an underwater domain, has yet to be demonstrated. Through the use of state of the art underwater communications systems, innovative information compression methods and a Java based infrastructure, VTP addresses all of these issues and will provide a day-to-day virtual torpedo capability at a twenty-to-one (20:1) cost reduction over recoverable exercise torpedoes.

I. INTRODUCTION

This paper documents the Synthetic Environment Tactical Integration (SETI) Virtual Torpedo Project (VTP) technical and programmatic plan and represents the refined VTP concept. The plan is the guiding document for the implementation of the submarine Virtual Torpedo (VIRTORP) test and training capability.

A. History

SETI-VTP was initiated by the Naval Undersea Warfare Center Division, Newport (NUWCDIVNPT), to establish the systems, capabilities, and processes to provide Fleet access to and utilization of Naval Undersea Warfare Center's (NUWC's) modeling and simulation technology to advance Fleet in-stride training. This initiative introduces technology to facilitate training, reduce the cost of training, and/or increase the value of training through synthetic torpedoes, synthetic targets, and integration of onboard trainers with external environments.

This phase of SETI VTP links submarines operating on range with hardware-in-the-loop torpedoes in the Weapons Analysis Facility (WAF).

B. Fleet Endorsement

The Fleet Consolidated Technology Issues (CTI) dated 27 November 1995 ranks simulation/stimulation in exercises as a high priority; stating "...training can be more cost-effective if augmented with realistic simulation/stimulation...advances in technologies like virtual reality are needed to make
stimulation more realistic...improvements in embedded training, especially those tied to stimulation are required.” The COMSUBLANT/COMSUBPAC high priority Tactical Training CTI of 24 June 1996 documents the desire for integration of modeling and simulation capabilities into training as well as integration into onboard trainers (OBTs) and the Battleforce Tactical Training (BFIT). And the 1996 FLTASWIP (Commander-in-Chief, U.S. Pacific Fleet [CINCPACFLT]) 130508Z January 96) ranks expansion of future concepts for networked, OBT and simulator-based ASW training among the top 10 of 100 ASW priorities. The FLTASWIP goes on to state that they desire to integrate OBTs and networked simulators and “...network OBTs and other community's simulators and platforms.” Additionally, in response to NUWC informational briefings to CINCLANTFLT, they have documented the desire for a virtual torpedo capability to augment declining exercise firing rates. As depicted in Figure 1, submarine exercise firing rates have declined by 75% since Fiscal Year (FY) 1990 and are predicted to stabilize at approximately 60% below pre-FY90 levels.

![Fig. 1 US Navy Submarine Torpedo Firing Rates from fiscal year 1990 projected to fiscal year 2002. Rates are normalized to the current and projected decline in total numbers of US Navy submarines. The data only includes Fleet torpedo firings and does not include torpedo firings that were specifically for research, development, test and evaluation purposes.](image)

C. Project Statement

VTP enables the real-time interaction of Submarines operating on range with high fidelity hardware-in-the-loop torpedo simulations. The benefits of providing this capability include unlimited availability of VIRTORPs to augment exercise torpedo firings, the availability of high confidence torpedo hit-or-miss assessments, realistic evasion maneuvers of the target platform and the use of weapons in ASW training exercises without peacetime safety restrictions and their associated artificialities.

D. Scope

VTP addresses the simulation of torpedoes fired by submarines operating at the Atlantic Undersea Test and Evaluation Center (AUTEC) utilizing torpedo from the WAF. The design of the system allows for extension of this capability to other instrumented ranges and simulators. Additionally, this capability could be extended to open ocean exercises with additional development.

II. TECHNICAL APPROACH

A. Concept

1) Existing Capabilities

As depicted in Figure 2, VTP integrates four high value, yet individual capabilities into a single, seamless capability.

(a) Weapons Analysis Facility

The Weapons Analysis Facility (WAF) utilizes the actual torpedo guidance and control hardware and embedded software in the simulator; the weapon is real, only the underwater environment is simulated. The WAF provides high fidelity underwater acoustic stimulation to the torpedo and interprets and responds to the weapon's guidance commands. This facility provides highly accurate predictions of weapon performance against any target in any modeled underwater environment. Current weapons simulations include Mk 48, Mk 48 Advanced Capability (ADCAP), Mk 46, Mk 50 as well as foreign ordnance. The WAF is capable of simulating a
number of submarine platforms including the Los Angeles class as well as U.S. and foreign countermeasures. In addition, WAF simulation capabilities are currently undergoing a number of enhancements including the addition of Russian Kilo and the German Type 209 submarine simulations as well as a range-dependent ocean modeling capability.

(b) Exercise Communications Center

The Exercise Communications Center (ECC) represents a significant capability for NUWCDIVNPT to remain in the forefront of modeling and simulation development. ECC and the associated internal and external secure network links, augmented by the Division’s core laboratory facilities, provides synthetic environments and simulations to enhance the development, test and evaluation of Undersea Warfare (USW) systems. NUWCNet provides the connectivity between these facilities for internal development testing, such as NUWC’s USW Modeling and simulation/horizontal integration, and also provides the gateway to the NUWCDIVNPT’s nodes on the Defense Simulation Internet (DSI) and Defense Research and Engineering Network (DREN).

(c) Atlantic Undersea Test and Evaluation Center

The Atlantic Undersea Test & Evaluation Facility (AUTEC) consists of deep-water ranges and RDT&E support facilities located at Andros Island in the Bahamas. The AUTEC Ranges support weapons, weapon systems, and sensor systems RDT&E programs as well as Fleet training operations. AUTEC also provides facilities for basic acoustic, environmental, and oceanographic research and test programs. AUTEC provides highly accurate underwater and in-air tracking and bi-directional voice communications. With the addition of the latest advancements in underwater acoustic telemetry and the associated underwater modems, AUTEC is capable of real-time bi-directional digital data communications with SSNs.

(d) Underwater Acoustic Telemetry

The underwater acoustic telemetry communications technology is nearing operational maturity. Acoustic telemetry systems under test at NUWCDIVNPT have demonstrated reliable long range bi-directional data rates of over 1 Kbits/Sec. Although this data rate does not classify as a wide bandwidth connection by today’s standards, it is anticipated to be more than adequate to meet VTP connectivity needs. Future data rate enhancements are anticipated through advancements in communications methods and systems technology.

Integration of an acoustic telemetry system into SSN ship and range control systems is relatively straightforward. In fact, a recent test at AUTEC demonstrated underwater data communications
between an SSN, operating at depth and speed, and the AUTEC control center.

2) Future Enhancements

Through leveraging of improvement and modernization programs for the WAF, AUTEC, ECC, and Fleet tactical and training systems, VTP will continue to advance state-of-the-art training capabilities.

B. System Architecture

The VTP system maintains the modularity of its key components (WAF, AUTEC, SSN). As depicted in Figure 2, these modules are integrated using local and wide area networks. The Distributed Interactive Simulation (DIS) protocol is currently being utilized as the primary communications protocol between simulations. However, as the High Level Architecture (HLA) development nears completion, HLA will be implemented and DSI will be phased out. In addition, a dynamically loadable JAVA client architecture is being pursued under HLA. By developing VTP under an open JAVA based applications framework, JAVA applets can be dynamically downloaded. Thus, true distributed computing and distributed simulation can be realized. For the first implementation, JAVA applets will be developed by the WAF to augment the core set of two and three-dimensional displays. This applet will provide underwater acoustic highlights, which are calculated by the WAF torpedo. By dynamically loading this applet into the viewers during a VTP execution, the two complementing systems will be merged through a common framework and JAVA applets to provide additional display capabilities.

Acoustic telemetry modem communications require a special protocol due to the unique nature of the communications method.

C. Interoperability Standards

1) Test and Training Enabling Architecture

VTP is developing the HLA objects and overall architecture in accordance with the Central Test and Evaluation Improvement Program (CTEIP) Test and Training Enabling Architecture (TENA). Similarly, VTP is coordinating with the CTEIP Virtual Test and Training Range (VTTR) project in order to allow for future integration into this system.

2) Tactical Training Standards

Integration into joint tactical training systems such as the BFTT and the Joint Tactical Combat Training System (JTCTS) will require Fleet-wide implementation of the VTP capability. This implies procurement, certification, and integration of the VTP system onto the entire SSN Fleet. Since this is beyond the scope of this project, expansion into the joint tactical training programs will be addressed at a future date.

III. DEVELOPMENT PROCESS

VTP development was executed using the development process depicted in Figure 3. At key points in the development, isolated unit tests were conducted in order to assure that critical capabilities are operational prior to continuing to the next phase of the project. Furthermore, partial installations of the synthetic undersea battlespace capability were implemented and tested (identified as Phases I and II) in order to validate interface and data requirements as well as to subdivide systems development and test in order to reduce technical and schedule risks.

Fig. 3 The three layered project technical approach provides full hardware implementation at milestone I. This allows for a fully functional demonstration early in the program with refinement and enhancement through the remainder of the project.
A. Testing

Unit test plans were developed for each sub-element or unit of VTP. The accomplishment of each unit test provided and demonstrated key capabilities necessary for the overall accomplishment of the project. The major functional units are shown in the functional block diagram (Figure 4). During the engineering design study, critical unit test milestones were identified to assure each of these functional areas was operational prior to system integration.

![Functional Block Diagram](image)

**Fig. 4 VTP Functional Block Diagram showing the three primary elements of VTP. Communications between the simulations and range control is via satellite link. Communications with the submarine is via acoustic telemetry.**

IV. CRITICAL/KEY ISSUES

The following is a brief assessment of the critical/key issues associated with VTP.

A. WAF to VIRTORP latencies

There is known data communications latency, primarily driven by the speed of sound in water, estimated to be 5 to 7 seconds. In addition, there are system latencies of 3 to 5 seconds. The current system design accounts for this latency by including a rudimentary torpedo simulation on board the SSN to provide data back-fill when real-time feedback is required and unavailable due to latency. At this time, it is believed that the relatively slow speeds of the platforms involved as well as the human interaction delay factors will negate most of the tactical side effects of this problem. Additional investigations and validation are being conducted to validate this theory.

B. Flow Noise Related Degradation

The operation of the acoustic telemetry system is dependent upon using a submarine transducer as the receiver. As the submarine increases speed, such as it would do in an evasive maneuver, the flow noise will increase thus reducing the Signal-to-Noise Ratio (SNR). This may affect the reliability of the telemetry link. However, since the submarine’s tactical systems will themselves be virtually blind during high speed maneuvers, there should be minimal impact if simulation data is not available during that time. Further testing will be conducted during operational testing to determine the severity of this condition and its impact on training.

V. CONCEPT OF OPERATIONS

A. Management

It is the goal of VTP to "institutionalize" VIRTORPs at AUTEC. In this way, the scheduling, operation and maintenance, and financial and administrative functions will be handled as routine, day-to-day business. As such, AUTEC will be designated the program manager of the capability. NUWCDIVNPT will support setup, checkout, operation, and removal of VIRTORP capabilities and provide Fleet interface. AUTEC will coordinate the collection of charges and Fleet billing, and distribute funding to other parties in accordance with agreed rates.

B. Scheduling

Many of the facilities used in the VIRTORP project are Research, Development, Test and Evaluation (RDT&E) facilities developed for other than training purposes. It is recognized, however, that they can provide an outstanding training resource. Thus, an effective scheduling process will be developed to ensure that both RDT&E and Fleet needs are met with the highest possible degree of customer responsiveness consistent with good business practice. To accomplish this goal, AUTEC will be the central VIRTORP scheduling agent in coordination with the appropriate NUWCDIVNPT personnel.

NUWCDIVNPT personnel attend the quarterly Fleet scheduling conference. Here, planned Fleet training schedules will be coordinated with projected VIRTORP facility availability and specific VIRTORP sessions will be scheduled. VIRTORP sessions will be scheduled in six to twelve hour blocks. During a session, up to two submarines or one submarine and one target may operate.

C. Customer Charges

AUTEC, as a Major Range and Test Facility Base (MRTFB) activity, and NUWCDIVNPT, as a Defense Business Operating Fund (DBOF) activity, must be reimbursed for all direct costs incurred by a customer. The following costs may be included in the calculations:

- Temporarily installation of the acoustic telemetry link and the Mk 75 Digital Missile Simulator (DMS), make all necessary connections, and perform routine system tests. It is anticipated that the installation will take place dockside concurrently with pinger checkout.
- Personnel at AUTEC and in the Exercise Communications Center (ECC) will establish secure communications and will remain on station to ensure continuity of communications.
- WAF personnel ensure that the appropriate WAF hardware is configured for VIRTORP operations, perform all systems checks, and input appropriate environmental parameters.

The VIRTORP costs do not include services required even if VIRTORPs are not being utilized such as, but not limited to:

- Normal AUTEC charges for data acquisition.
- Mobile ASW target preparation, launch, recovery, and turnaround, if utilized.

VI. LOGISTICS AND LIFE CYCLE SUPPORT

A. Logistics Support

During the development of VTP, limited effort was expended on technical documentation, maintainability data, or training material, beyond critical systems specifications, configuration data and basic operations training. However, following accomplishment of the core capability, additional documentation and training material is being developed to support this capability. System training will be fully documented and training will be provided to all customers including range operators and range users. In addition, internal operations training will be documented and routinely provided in order to maintain our ability to provide quality service to the Fleet.

B. Life Cycle Support

Each simulator/simulation owner is responsible for the configuration control and maintenance for their systems and equipment. System changes, beyond basic maintenance, (i.e., data/material management, software and hardware upgrades) will be addressed under separate programs and funding. It is envisioned that, as Fleet usage and reliance on VTP increases, direct funding will be available/obtainable to support system modernization and capability enhancements. In addition, part of the Fleet usage charges may include some improvement and modernization funding allowances, which could be applied for system modernization.