Warfighter Readiness: Virtual Training on Demand

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ABSTRACT

Synthetic training has become a key element of the Fleet Response Training Plan. Advancements in Live, Virtual and Constructive (LVC) capabilities have accelerated this trend. Despite progress, synthetic training remains a challenging proposition, where warfighters must schedule their participation well in advance and are reliant on the limited resources of training centers to coordinate events, conduct testing, and carefully structure scenarios. Imagine a world more like the one our kids inhabit; a place where military units could connect to game servers that allowed geographically dispersed units to select training scenarios and participate with other units in tactically relevant vignettes, on-demand with a minimum of overhead. This "anytime, anywhere" concept would allow sailors to facilitate timely mission rehearsal, complete training, receive credit, and glean performance evaluations from after-action review technology designed to enable warfighters to "Get Real, Get Better."

The Office of Naval Research (ONR) is sponsoring an effort to develop an on-demand wargaming capability to facilitate mission rehearsal and fleet training while underway. Enabling ship training system configuration and readiness, the solution provides automated tests and validation relating to onboard systems and sensors. When complete, this prototype will provide access to an online library of scenarios for dynamic on-demand training, readiness, and re-certification. Research and development on this effort has been conducted by utilizing virtual and bare-metal labs for testing and evaluation. Initial tests are being planned in the summer of 2023 with live assets on a pierside ship to evaluate prototype capabilities and, as yet untested, Link 16 integration.

This paper will explore how research has been done to advance the training capability for our future warfighters. It will describe research efforts towards training system readiness and configuration in a virtual lab, architectures and components used while engineering a potential solution, and will illustrate test outcomes, future growth, and sustainment.

ABOUT THE AUTHORS

Jennifer Quinton is a Senior Software Engineer at Arorae Corporation with over ten years supporting government research efforts. Her background includes diagnostics and analysis of the 48G radar, model development of the Harpoon and Tomahawk missiles, and design and development of the augmented reality navigation trainer Advanced Navigation Team Shipboard Simulation (ANTS2). She is currently the lead engineer on the Navy Continuous Training Environment On-Demand Online (NCTEnDO) wargaming capability development effort.

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INTRODUCTION

Live, Virtual and Constructive (LVC) training technology is changing the way the US Navy, joint forces and our partner nations train and exercise (Molenda, 2023). Training centers with large server rooms and game floors full of system integrators and simulation operators are becoming commonplace across the Department of Defense. These sites are able to replicate complex threats across multiple warfighting domains simultaneously, but accessing these incredible resources requires long planning, setup, and test periods prior to training, and cannot support training and rehearsal on short notice at the point of need. As a training and simulation community, we must provide our warfighters an opportunity to not only train to a standard, but also rehearse, experiment, and innovate to meet emerging tactical challenges, thereby realizing Admiral Gilday's call to action to "Get Real, Get Better" (U.S. Navy Press Office, 2022). Our vision brings virtual training to the sailors wherever and whenever, and it is called The Navy Continuous Training Environment on Demand Online (NCTEnDO).

NCTEnDO, a capability in development, allows military units to connect with other users on a secure server via the Secret Internet Protocol Router Network (SIPRNET) and execute tactical scenarios on demand. Imagine a Joint Strike Fighter (JSF) crew in Lemoore, an Unmanned Aerial Vehicle (UAV) in Virginia, a Littoral Combat Ship (LCS) in Singapore, and an E/A-18G Growler electronic attack aircraft in Whidbey Island, all logging in and practicing a coordinated strike on any adversary in a location of their choosing without a large training center coordinating the exercise. This is not a novel concept; people connect to gaming systems via Wi-Fi and play complex scenario-based games with others around the world in every coffee shop, basement, or dorm room. That ease of access does not exist for high fidelity, distributed, combat simulation. NCTEnDO seeks to bring that capability to every ship, squadron, Warfare Development Center (WDC), and Training Command in the fleet. NCTEnDO automates system configuration processes and scenario delivery using simulation components, protocols, and tools provided in the Navy Continuous Training Environment's (NCTE) approved Navy Training Baseline (NTB). It will provide a collaborative space where units join to rehearse upcoming missions, innovate new tactics, or simply refresh tactical skills anywhere in the world at any time. This paper will detail how this project came to be, describe our approach for delivering training on demand, and present findings from prototype testing.

BACKGROUND

The US Navy's Fleet Synthetic Training (FST) program began by attempting to allow ships to share a common virtual training scenario across several platforms. Capabilities such as Force Training Video (FTV) gave individual ships a capability to perform internal crew training and sustainment in a common scenario using onboard capabilities and met watch standers need for a resident training capability to maintain proficiency post formal training. From these humble beginnings, the Navy has developed a robust, distributed, training capability to train in any combination of live, virtual, and constructive domains (Cain, 2022). Programs like Battle Force Tactical Trainer (BFTT) and Advanced Training Domain (ATD) connect tactical systems to training systems over the Navy Enterprise Tactical Training Network (NETTN) in a single training federation. The Navy's current FST program and LVC exercises demonstrate just how far training technology has come since FTV (Eckstein, 2021). However, while our ability to provide training to ships has grown as the underlying technology has advanced, the ability for units to train themselves to maintain proficiency, rehearse missions, or collaborate with other units outside of the formal training pipeline has not kept pace. The problem lies herein, the same resources available to units in the training pipeline are not available once they leave and report back to their ship or their follow-on command. Enabling automation and continued access is required and essential to provide similar and readily available training resources outside of the training pipeline.

The first challenge is that the Navy's current training architecture requires significant overhead to execute virtual training. Teams of engineers, simulation operators, and exercise controllers are required to manage network and training system connections as well as provide scenario control for training events. A single ship qualification event typically requires eight engineers to establish and manage the training network, modeling and simulation systems, communications, data link, and command and control systems. Four to six simulation operators are also required to execute the training scenario. Larger training events with multiple live or virtual participants have more complicated architectures and can require hundreds of technical support personnel and simulation operators. As the requirement to support more LVC training events grows annually (Molenda, 2023), a lack of personnel resources is creating a bottleneck at distributed training sites where lower priority units do not receive virtual training event support.

The second challenge is overcoming the technical difficulties that individual units face when aligning their combat systems for training. The requirement for remote support to access the training architecture means that ships' crews must schedule dedicated test time with distributed training centers well ahead of an LVC event to ensure they are technically ready to participate in the exercise federation. Ships need the ability to test, validate, and troubleshoot their ability to connect to training architectures on demand, rather than having to wait for support.

NCTEnDO will automate much of the workload required to connect individual units to the training architecture and remove the requirement to schedule support weeks or months in advance. Additionally, NCTEnDO will allow individual units the capability to validate their combat systems alignment before regularly scheduled events, saving them precious time during their workup cycle, as well as coordinate their own events on demand. Initial NCTEnDO project efforts focused on automating the network and training system configuration without the engineering resources at distributed training centers.

Phase One Approach – 2016

In 2016, the Office of Naval Research (ONR) and Tactical Training Group Pacific-Detachment Yokosuka engineers identified a means to automate the initialization of one key NCTE component, the shipboard Software Aware Router (SAR). The SAR is the ship's NETTN access point and exchanges simulation data with BFTT or ATD, depending on the class of ship, which then stimulates shipboard systems. Figure 1 depicts basic data flow and network connections for a shore-based training site connecting to ship, pier-side, for training.

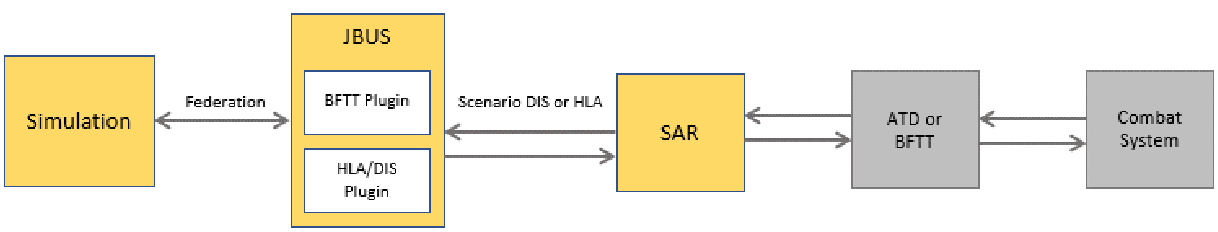

Figure 1. Shore-based Training Site Connecting to a Ship Pierside for Training

The phase one NCTEnDO prototype included a web-enabled server and client application "game room" interface for a shipboard operator to select, initialize and launch a virtual training scenario. An "Auto configuring SAR" script, initialized upon SAR power on and boot-up automated this process and removed or reduced human-in-the-loop requirements. Figure 2 shows the initial proof of concept test architecture.

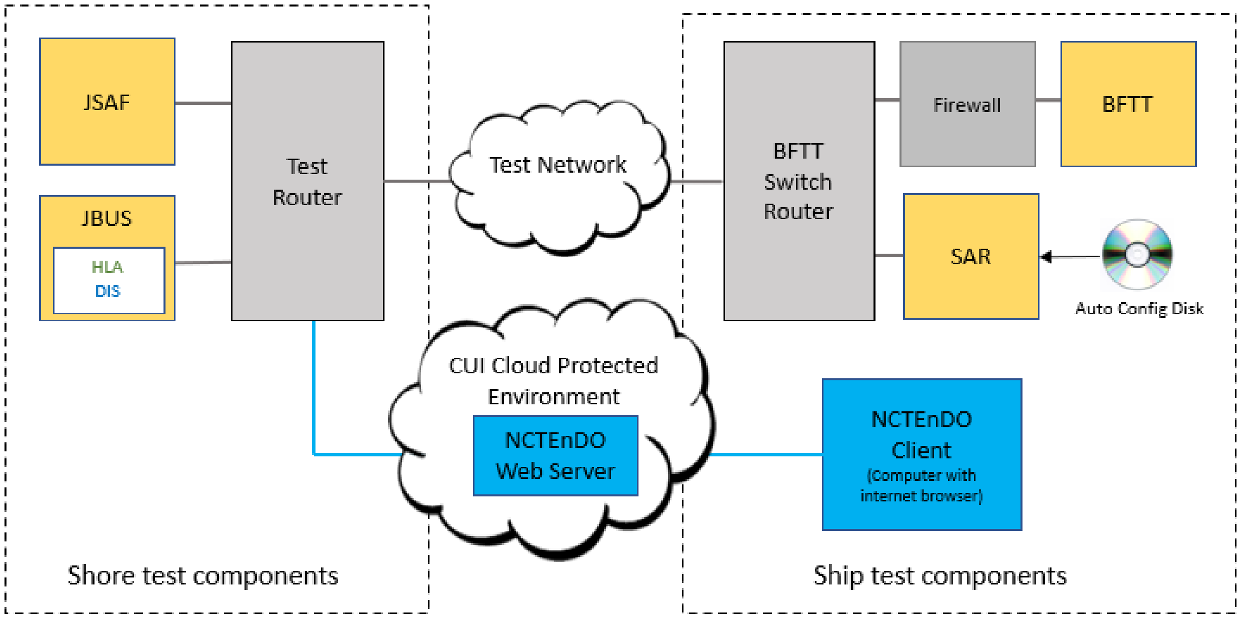

Figure 2. Initial NCTEnDO Concept Test Environment

Initial testing of the Auto-Config SAR script and NCTEnDO Tomcat web server occurred at L-3 Unidyne facilities in San Diego, California. Tests included automated configuration of the SAR for multiple BFTT baselines and testing functionality of the web-based server. The test environment consisted of simulated shore-based and ship-based systems (virtual machines) emulating relevant NCTE components as used in the current FST architecture. The key shore-based systems included the Joint Semi-Automated Forces (JSAF) simulation and Joint Simulation Bus (JBUS) system integration tool. Key ship-based systems included a virtualized BFTT system, BFTT networking hardware and a SAR. A standalone local area network (LAN) connected test systems with an additional network path to the L-3 corporate internet router, which connected shore-side components to the internet for testing of the NCTEnDO web server located in a controlled unclassified information (CUI) cloud protected environment.

Initial tests were successful at demonstrating the functionality of the auto-configuring SAR script with multiple ship baselines, using actual BFTT hardware configurations as well as the integration for the web-based server hosted in an external cloud environment with standard NCTE components. The 2016 proof of concept demonstrated the ability to automatically configure the SAR in a lab environment, but additional development and testing in an environment better representative of a deployed environment would be required. After a four-year pause due to a lack of funding, Phase Two development started in 2021.

Phase Two Approach – 2021 Onward

Phase Two is an ongoing and focused ONR effort to develop an on-demand wargaming capability that will facilitate mission rehearsal and fleet training while underway. In keeping with Phase One's conceptual prototype, this active effort seeks to provide ships the ability to train on-demand by accessing services through a web browser to access an online library of scenarios (challenge one) and assist with training systems configuration, readiness, and troubleshooting by providing administrative tools for ships, exercise directors, and technical integrators (challenge two). Together, the NCTEnDO components provide:

- Readiness testing for on demand training.
- Reporting and analysis data for use by a test team during training events.
- Data collection that is reflective of a ship's testing activities and performance.
- Database administration.

The NCTEnDO team uses an iterative approach to development and testing that combines the resources of industry, ONR, Naval Surface Warfare Center Dahlgren Division Dam Neck Activity (NSWCDD DNA), NSWC Corona, and Tactical Training Group Pacific to mature NCTEnDO with the goal of adding capability and complexity to each test event. Phase One demonstrated NCTEnDO in a closed industry lab and Phase Two is moving NCTEnDO to the NETTN - Research and Development, with the goal of transitioning to the NETTN Ops by the end of calendar year 2023 for testing with a live ship.

PHASE TWO DEVELOPMENT

NCTEnDO, at its core, is a wargaming web server that utilizes several existing components and protocols within the NTB to provide services to the fleet -- namely JSAF, JBUS, Acoustic Transmission Loss Server (ATLoS) and Environmental Data Cube Support System (EDCSS) for modeling the surface and subsurface environment. High Level Architecture (HLA), Distributed Interactive Simulation (DIS), and Link 16 are the common data protocols used for information exchange. NCTEnDO consists of several key software and simulation components including a web and database server, web application, database, the 'NCTEnDO Federate', scripts, and protocols. This section will describe NCTEnDO's components and maturation since 2021.

Phase Two development started in January of 2021 with the planning and design of the NCTEnDO web application that serves as the interface for end-users to access training scenarios on demand and run system configuration testing using the Embedded Shipboard Test Scenario (ESTS) through a web browser. NCTEnDO developers used Flutter, an open-source software development kit created by Google, to create the web application. The web application framework uses the programming language Dart, and when compiled, creates a web application package formatted as HyperText markup language (HTML), JavaScript, and JavaScript Object Notation (JSON) files. At this early phase, the development team hard coded ship configuration data, such as IP addresses, and SAR and BFTT versions, within the web application. In April of 2021, web server development commenced, removing the need to hard code ship configuration data. By the end of April, a custom Node.js web server could read and write entire JSON files to the web application. The prototype web application and server proved ready for testing.

NCTEnDO Initial Test – July 2021

Initially, NCTEnDO testing used virtual labs on the East and West coast connecting NSWC Dam Neck Activity's Naval Simulation Center Pacific (NSCPAC) and Naval Simulation Center Atlantic (NSCLANT). The purpose of this initial test event was to demonstrate the NCTEnDO web application for staff at Tactical Training Group Pacific (TTGP) and receive end-user feedback.

The center of gravity for FST Research, Development, Testing, & Evaluation (RDT&E) and Fleet warfighting training capability improvement, NSCPAC partners with ONR, the Command sponsoring test and experimentation efforts utilizing the facility, TTGP, the Command hosting the facility, NSWC Corona for NCTE management, and NSWCDD DNA to staff and equip FST efforts. Additionally, NSCPAC provides ONR a Science & Technology (S&T) platform to conduct research and apply S&T technology innovations supporting Naval warfighter performance improvement, provides TTGP a mechanism to assert Fleet training gaps and emerging needs for Fleet Training Wholeness, and is a technology incubator to introduce and validate developmental training systems before introduction into an operational FST or LVC exercise.

NSCLANT, as part of NSWCDD DNA, provides access to development and test laboratories for BFTT and ATD training systems, as well as virtual combat systems such as a Virtual Twin for the AEGIS Weapon System. BFTT and ATD training systems connect tactical shipboard systems to the training network and allow for stimulation of those shipboard combat systems by external simulations in the training federation. Both laboratories are connected to the NETTN R&D network and supported initial testing of the SAR configuration and Embedded Shipboard Training Scenario functions of the NCTEnDO application.

The virtual lab used for initial testing needed a powerful enough server set to run multiple virtual machines (VMs) and simulate standard NCTE servers. Due to COVD-19, a means for a geographically dispersed team to initialize servers using secured remote access needed to be established. Fortunately, a previous project left the team with some spare server racks and unused servers that the team converted into CentOS servers to serve as the primary test suite.

This test suite was provided by NSCLANT and was used to simulate various ships and the SAR systems connected to them. VMs simulating systems were secured and installed, giving the project team a fully functional test suite, even if the local network configuration (a local router) was not reflective of a true training site environment. To access the test environment, a Federal Information Processing Standards (FIPS) enabled virtual private network (VPN) connection into the system was secured which allowed VPN access for each developer machine to control the various VMs and server processes to facilitate testing. Figure 3 shows the structure of the virtual test environment.

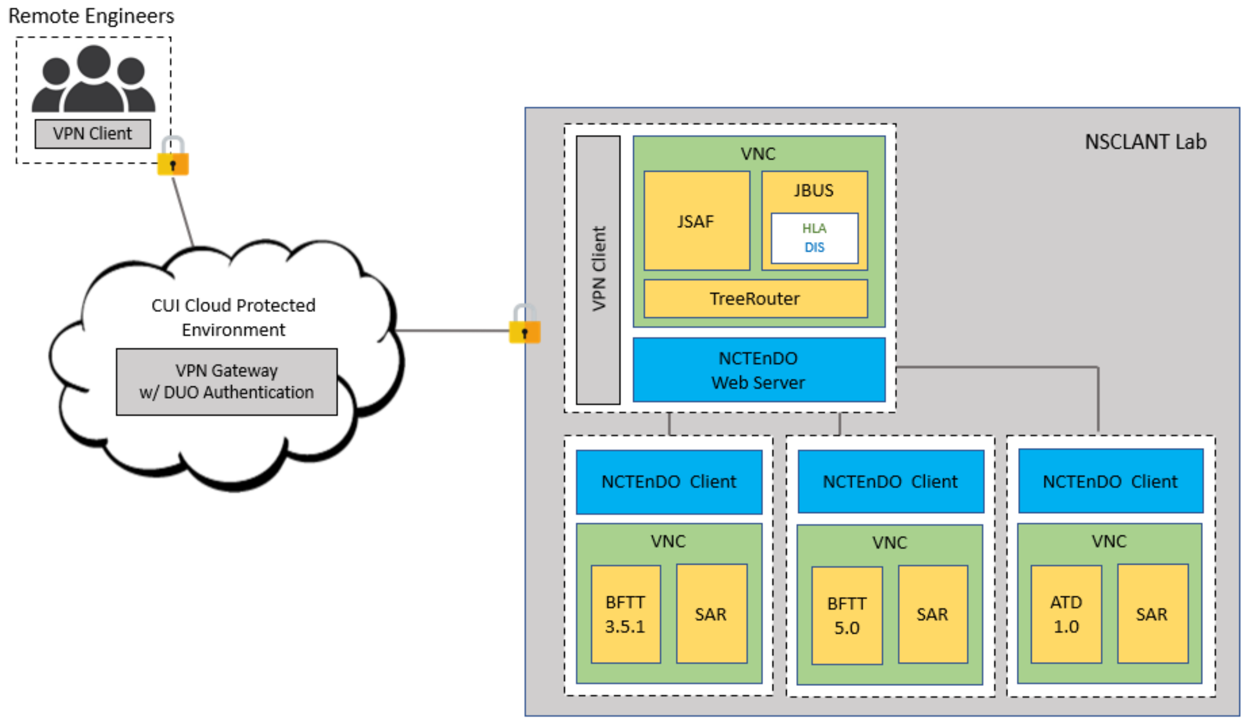

Figure 3. Remote NSCLANT Lab Architecture

The challenges of physically managing the systems and networks required seeking out a new solution. However, this test bed worked as a temporary stopgap in the early stages of development to provide a shared test suite for the team to access remotely.

TTGP staff immediately recognized the possible impact NCTEnDO and on-demand training could have on future training. This test validated the initial NCTEnDO architecture and informed future development. The need for a more representative development and test environment was a key takeaway from this early initial test. Migration to a cloud testing environment occurred shortly after the July 2021 test event.

Cloud-based Testing – NSERC Virtual Lab

Migration of the primary testing suite from a static server system to a managed cloud service alleviated many of the system management and network control mechanisms from the team's hands, shifting them to the professionals at the Naval Systems Engineering Resource Center (NSERC) control center. Transitioning from the static servers consisted of taking VM snapshots of the standalone "server" systems from the old blade servers, as well as the VMs used to represent ship systems, and transfer them to the NSERC cloud server. Although transition was ultimately successful, cloud migration posed several challenges.

Initial testing used VirtualBox virtual machines, which is incompatible on a cloud-based Windows 10 server system. If testing attempted to simulate a multi-system test, multiple virtual machines would become unusable. Additionally, several virtual machines used old versions of Red Hat Linux OS making them unsuitable for use in the cloud environment. The need for an improved test capability outweighed risks and the test suite transitioned VirtualBox virtual machines to Windows HyperVisor virtual machines. Unfortunately, the older ship system simulation VMs could not convert properly and are no longer usable, but the number of successfully converted virtual machines enables a full, cloud-based test suite. This test suite was used in October 2021 for NCTEnDO's second test event; this time performed on a Defense Research and Engineering Network (DREN).

NCTEnDO Test – October 2021

A second event in October of 2021 at NSCPAC sought to validate new NCTEnDO functionality and gain additional insight to the challenges of training in the FST environment through observation in the Distributed Training Control Center (DTCC) at TTGP as well as onboard the USS Fitzgerald. Test and demonstration occurred on the NSERC cloud-based server. The purpose of this event was to validate developments incorporated into the application and stress the virtual lab systems. Key performance parameters included validation of the ESTS test to ensure JSAF entities created in the ESTS pass through the SAR to a virtual BFTT.

A demonstration for senior TTGP stakeholders included the ESTS test, a newly created Administration Panel that shows ESTS results to the end user, and a multi-player, on-demand, training scenario between two virtual ships. Stakeholder feedback that ship leadership or training center evaluators should have the ability to see how ships are performing over time with readiness tests and the ESTS test; an indicator of a ship's ability to bring their systems into training mode successfully. To provide the desired functionality, historical test data from ships utilizing NCTEnDO would need to be stored, driving the decision to implement a database. Postgres was chosen for NCTEnDO's database needs as it is a well-developed and proven database solution and is readily available on the NCTE repository. The web server evolved into a web server and database server combination that is now the core component of NCTEnDO handling data management between the web application and database.

ESTS validation was a milestone event for NCTEnDO similar to testing remote SAR configuration. The development team could now implement system checks and check what a ship is reporting in the training scenario against ground truth. To do this, NCTEnDO needed the ability to query and evaluate state data from the federation. The NCTEnDO Federate and PostgreSQL database allow the system to do that.

NCTEnDO Federate and PostgresSQL Database

The 'NCTEnDO Federate' program is a standalone C++ application that ties into the Run Time Interface (RTI) simulation library allowing it to gather data from an NCTE HLA Federation. The federate program began as a way to tap into a defined HLA Federation and test to see if a particular ship (Ownship) was a participant inside of the federation and to verify the ship's location was correct. This was used as a test to validate that the federation was configured properly, and that the ship's training system was communicating with the SAR as expected or was "in place" for an exercise execution.

NCTEnDO Federate functionality grew to gather specific entity track and Link track data from the federation. NCTEnDO can now evaluate if a user is receiving and reporting the appropriate data during an ESTS test and can also take a "snapshot" of all the participants in a federation and diagnose if all participants are federating correctly. Incorrectly federated participants are flagged for further investigation.

The NCTEnDO database is an open-source object-relational database implemented through the PostgreSQL management system. It stores all relevant persistent data including ship, scenario, and test configurations. Additionally, it stores data relating to NCTEnDO application usage including diagnostic data for assistance with troubleshooting and results relating to testing performed to ensure readiness for on-demand training. The NCTEnDO Federate and PostgresSQL database were scheduled for testing in May 2022.

May 2022 – NETTN and In-Service Engineering Agent Lab Connection Test

The May 2022 test marked two major advances for NCTEnDO testing and future use as fielded training capability. First, NCTEnDO received approval from NCTE Information Systems Division to add the application to the NETTN-Research and Development Network Zone B Stage 1, a milestone for information security. Second, by operating on NETTN-RD Zone B, NCTEnDO could connect and test with actual ATD and BFTT In-Service Engineering Agent (ISEA) hardware located in laboratories at NSCLANT. The test itself was one of two planned test events to validate a key performance parameter, the ability to launch and push a JSAF scenario from shore, remotely using the NCTEnDO web application.

The ATD and BFTT labs were configured the same as fielded ship configurations with representative network connections, and to detect and report tracks back over a JREAP-C Link-16 data path, though Link data was not yet available. Testing validated that NCTEnDO could connect to the laboratories from a remote site and set the stage for the second test event. It was also the first time NCTEnDO used the PostgresSQL database in a test environment.

October 2022 – NCTEnDO Focused Test Event

In October 2022, a test was conducted using the ATD Lab and BFTT (ISEA) Labs at NSCLANT as representative ships responding to a JSAF scenario pushed from a NCTE facility in Norfolk, Virginia. This was the first test of NCTEnDO on the classified NCTE network and with actual (lab-based) ship systems. The test objectives were:

- Installation of NCTEnDO server software and database on NETTN-R&D Zone B Stage 2, another security milestone.
- Establishment of a Wide Area Network (WAN) communications path to ATD and BFTT ISEA labs.
- Validation that NCTEnDO can remotely initialize and configure an actual SAR, perform the ESTS, execute automated operations checks, and support both single and multiple ship scenarios.
- Stimulation of the AEGIS Weapon System (AWS) Virtual Twin's (VTwin) sensor suite.

Connectivity and configuration milestones were successful. Observation during testing of the BFTT Operators Console (BOPC) or JSAF Advanced Warfare Scenarios (JAWS) for ATD provided a visual means to validate that BFTT and ATD were exchanging simulation data with NCTEnDO. Stimulation of the AWS VTwin was not tested during the event. Figure 5 shows the laboratory and network configuration for testing. Future test plans include integrating the AEGIS Virtual Twin to test sensor stimulation and Link-16 testing during the Embedded Shipboard Test. The ATD/AEGIS Virtual Twin laboratory can also serve as a representative Combat Information Center (CIC) for execution of a full mission rehearsal test. Shore-based testing is critical to overall risk reduction prior to limited live ship testing opportunities.

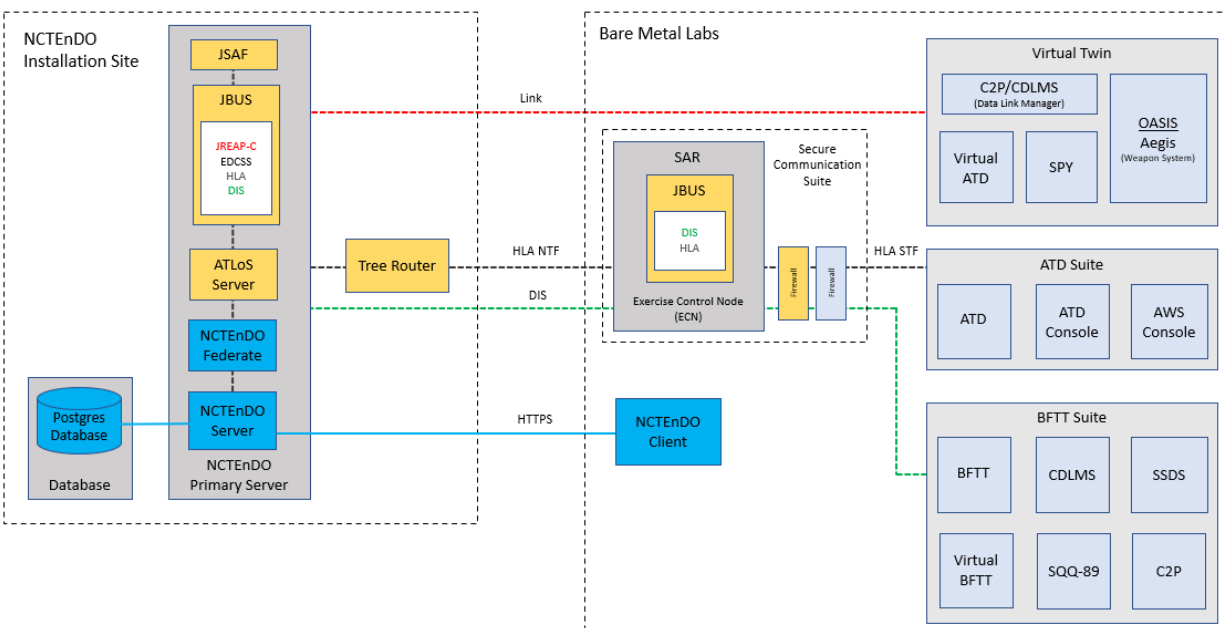

Figure 4. NETTN NSCLANT Full Test Environment

June 2023 – Live Ship Integration Test

NCTEnDO's first live ship integration test occurred in June 2023. The primary objective of this test was the validation of core NCTEnDO functionality with a pierside ship. The test included validating the receipt and processing of Link 16 within NCTEnDO. Though this was a highly anticipated test, given that Link data had not been available in the aforementioned lab environments, the results were not yet published prior to the submission of this paper.

FUTURE

The purpose of Virtual Training On-Demand is to put tools in the hands of sailors that create a more ready, more lethal Navy. To meet that goal, On-Demand training must be secure, current, and available, which requires accreditation and sustainment along with continued development. Initial accreditation will focus on moving the application from a research and development network to an operational training network for testing by obtaining an Interim Authority to Test (IATT). The IATT enables verification and validation of the proposed delivery architecture before requesting full program accreditation and removes the current requirement to bridge R&D and operational networks for live ship testing. Full accreditation using the DoD's Risk Management Framework (Office of the DoD Chief Information Officer, 2022) will realize Virtual On-Demand training allowing sailors to persistently access relevant, High-End Fight training and mission rehearsal on the Navy Enterprise Tactical Training Network. The industry government team developing and testing NCTEnDO have designed a capability that integrates with fielded training systems and the Navy's training enterprise to facilitate transition and sustainment. BFTT and ATD are sustained programs of record (U.S. Navy Chief of Information, 2023), as are JSAF and JBUS as part of the Navy Training Baseline and Navy Continuous Training Environment.

CONCLUSION

The evolution of the NCTEnDO application into a multi-layered project occurred iteratively through rapid prototyping and continuous engagement with intended users. Initially, NCTEnDO started out as a standalone web application with hard-coded data and web page integration. As the application grew and became more complex, data was separated from the application itself to allow for a more dynamic and fluid environment using Node.js and Express, which allowed for a simple, yet dynamic, tool set that provides data services for the NCTEnDO application.

Application configuration data was originally stored statically in JSON files and served to the main application through web services in the Node.js application. However, as the system evolved, data storage transitioned into a PostgresSQL database to facilitate both the service of static data, and the easy storage of collected data, and an NCTEnDO installer created a fully compiled and embedded webpage managed directly by the Node.js server.

The authors look forward to a continued partnership and the unique development and test capabilities that their partnership enables. The continuous engagement with end users during testing is invaluable and reminds us why what we, as training system developers do, is important.

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