Advanced Navigation Team Shipboard Simulation

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ABSTRACT

The Advanced Navigation Team Shipboard Simulation (ANTS2) project aims to address a training gap in Fleet Synthetic Training (FST) events by providing an immersive and interactive training environment for a ship's navigation team, integrated with existing shipboard training capabilities and with the combat system team. ANTS2 achieves this objective by utilizing emerging technologies such as Augmented Reality (AR), Virtual Reality (VR), and the implementation of a Commercial Solution for Classified (CSfC) Wireless Local Area Network (WLAN) implementing National Security Administration standards. The ANTS2 project focuses on developing an immersive FST unit-level training experience for the ship's bridge and lookout teams through a two-phased approach spanning two years. Phase one was designed to be conducted in a lab environment, and the second phase was intended to be conducted in a pier-side shipboard FST Unit level-(FST-U) architecture. The ANTS2 team, comprised of government and industry personnel, successfully completed the first phase in September 2019 and transitioned into the second phase in March 2020, which concluded in November 2021. COVID challenges resulted in additional lab-based validation using representative shipboard systems. The ANTS2 project's success hinges on its ability to provide a fully immersive and interactive training environment that integrates with the rest of the FST simulation. By utilizing AR, ANTS2 creates an "out the window" visualization of common FST scenarios that allow trainees to interact with the ship's navigation and handling systems within the bridge and the Combat Information Center (CIC). The application of CSfC provides an untethered network connection to the AR/VR headsets, enabling trainees to move freely within the ship's bridge, while remaining connected to the ship's secure embedded training system. In conclusion, the ANTS2 project aims to fill a crucial training gap in FST events by providing an immersive and interactive training environment for a ship's navigation, ship handling, and topside team.

ABOUT THE AUTHORS

Matthew Legg has a Bachelor's and Master's Degree in Computer Science from Old Dominion University. Matthew works for Naval Surface Warfare Center Dahlgren Division Dam Neck Activity. He has 25 years' experience in all aspects of software development and has been involved in designing and building capabilities for the Department of Defense for the majority of his career. For 10 years, Matthew worked with the Office of Naval Research with a focus on finding solutions for gaps in Navy training capabilities. Currently, Matthew is the software lead for the Joint After Action Review (JAAR) and Data Collection and Debrief (DCD) Program of Record (POR). He is interested in software engineering, systems engineering, and employing emerging technologies to solve Navy training gaps.

Corey Guilbault is a systems engineer with 8 years of training systems experience which started with the Battle Force Tactical Training (BFTT) In Service Engineering Agent (ISEA). He currently leads the Naval Simulation Center Atlantic lab. Within NSCLANT, Mr. Guilbault and his team, incorporate new and emerging technologies into the Navy's growing complexity of training systems and events in order to provide improved training and readiness. His years of work with integrated training systems combined with a passion for technology and improvement continues to provide support on fielded systems such as BFTT and Advanced Training Domain (ATD) as well as developmental projects including ANTS2, FleeT2, and Dahlgren NISE funded projects.

Richard Gaughen is a Senior Systems Engineer with 17 years of experience supporting Fleet Synthetic Training (FST) and LVC capability innovation, integration and event execution. Additionally, he has 26 years of experience with Navy surface combat systems and C4I systems operations and systems validation. He is currently serving as a Selected Reservist with CSG-15 as a Master Chief Petty Officer Fire Controlman and LVC training subject matter expert. He has a Bachelor's of Science degree in Information Technology and a Master's of Science in Unmanned Systems. His broad US Navy background and academic acumen has provided a steady rudder supporting numerous ONR S&T efforts that has resulted in successful capability transition to include HI-FAST Command, EDUCAT2E, ANTS2, and FleeT2 projects.

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EXECUTIVE SUMMARY

Advanced Navigation Team Shipboard Simulation (ANTS2) purpose is to fill a surface ship unit level training capability gap: inclusion of a ship's navigation, ship handling, and topside team in Fleet Synthetic Training (FST) events. ANTS2 aimed to fill this gap through the experimentation and prototyping of Augmented Reality (AR), Virtual Reality (VR) technologies, and the application of emerging standards of CSfC Wireless Local Area Network (WLAN) created by the National Security Administration (NSA). The objective is to provide the ship's bridge and lookout teams a fully immersive training environment aboard their ship that integrates with the rest of the FST simulation as depicted in Figure 1. Through the application of AR, ANTS2 immerses the training audience by creating an "out the window" visualization of the common FST scenario while still allowing the trainees to observe and interact with the navigation and ship handling systems within the bridge. Through the application of CSfC, the objective is to provide an untethered network connection allowing the trainee freedom of movement within the ship's bridge, while remaining connected to the ship's secure embedded training system.

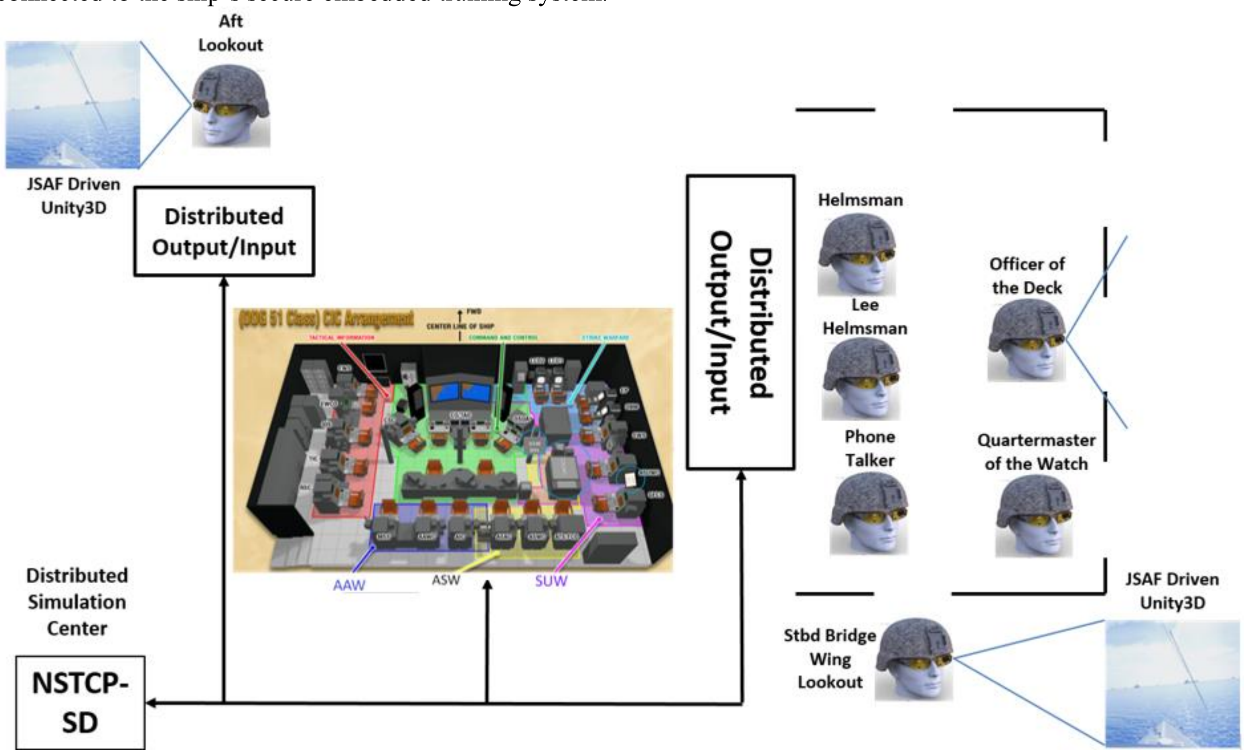

Figure 1. Proof-of-Concept Integration of the Shipboard Navigation Team into FST

BACKGROUND

Following two separate deadly navigation accidents at sea involving USS Fitzgerald (DDG 62) and USS McCain (DDG 56) in 2017, the U.S. Navy pledged to improve training and readiness prior to ships being deployed [1]. Historically, the ship's bridge watch standing personnel have not participated in pierside Live, Virtual, Constructive (LVC) training due to an absence of appropriate stimuli from the synthetic training environment, particularly the visual scene outside the bridge windows, as well as, the full spectrum tactical cues involved in the operation of bridge equipment. Currently, during FST, steering of ownship is conducted by the Battle Force Tactical Training (BFTT) operator and lookout reports are read from scripted material. The goal of ANTS2 is to incorporate full immersion of the ship's bridge watch standers in the LVC training environment leveraging the existing FST architectures utilizing High Level Architecture (HLA) [2] and Distributed Interactive simulation (DIS) [3]. The Office of Naval Research (ONR) team of performers focused their Science and Technology (S&T) efforts on developing Augmented Reality (AR), Virtual Reality (VR) and secure wireless networking capabilities through a series of lab tests. A proof-of-concept demonstration was conducted in the 4th QTR FY19 that was representative of a ship bridge navigation team fully immersed into the constructive simulation scenario that enabled watch teams to exercise navigations skills consistent with US Navy Surface Ship Navigation Department Organization and Regulations Manual (NAVDORM) [4] and the Convention on the International Regulations for Preventing Collisions at Sea (COLREGS) [5]. Uniformed Sailors participated as the Officer of the Deck (OOD), Conning Officer, Helmsman, Port/Starboard Bridge Wing Lookouts, and After Lookout watch standers. The watch standers were fully immersed into the scenario as if they were underway at sea through mixed and virtual reality secure wireless technologies.

Training Gap and alignment

The US Navy has identified navigation and seamanship training as an area that needs improvement consistent with Maneuvering and safe speed per COLREG [5], and NAVDORM [4] documentation. Currently, navigation team trainers are available in fleet concentration areas, however, the throughput of these facilities alone did not allow for full fleet needs in a timely manner. The ANTS2 effort explored a novel way of removing the team trainer shore facility bottle neck by researching how to accomplish team training aboard ship rather than an external facility. In addition, this capability improves integrated training between the navigation and combat system. This capability currently is limited to flash card style cueing of the navigation team to then communicate with combat.

TECHNICAL APPROACH

The ANTS2 project was developed to build upon AR and VR advancements made during FST research, development, test, and evaluations (FST-RDT&E) 2013 – 2016 in order develop an immersive FST-U-like experience for ship's bridge and lookout teams in a two-phased approach over a three-year period. Phase 1 was designed to be conducted in a lab environment. Phase 2 was designed to be conducted in a pierside shipboard FST-U architecture. Upon completion of phase 2, the science and technology (S&T) aims to transition to programs of record (POR).

The ANTS2 technical implementation involved the integration of innovative AR technologies such as Mixed Reality (MR) Glasses, Tracking, live-virtual object occlusion, and the NSA CSfC [6] wireless technologies in order to allow navigation team watch standers to train as they fight, in their own spaces, but with simulated objects and maritime scenarios superimposed over windows and consoles. This provided a mixed reality solution to present the navigation team with real world scenarios and training problems leveraging the FST and Navy Continuous Training Enterprise (NCTE) infrastructure. The shore based Joint Semi-Automated Forces scenario generation and control system provided the foundation tactical navigation scenario, integrated HLA[2] simulation protocol with embedded shipboard training systems via DIS[3]; the DIS data was shred with AR/ VR systems utilizing aa DIS-Unity gateway developed under ANTS2.

Phase 1 Efforts

During the initial stage of research determined that the ship's embedded training system, BFTT, included an navigation simulation (NAVSIM) capability; collectively BFTT and NAVSIM could stimulate ship's positioning and surveillance systems to support tactical training, but were not natively capable of interfacing with or stimulating ships' navigation systems to include the Ship's Control Consoles and helm. Therefor ANTS2 would need to implement a way for a helmsman to steer the ship, guided by direction and inputs from the OOD, lookouts and other navigation team members who would all need to be immersed in the training environment with the watch team also in training within the ship's tactical nerve center known as Combat information Center (CIC). ANTS2 development focused on integrating DIS-based BFTT its subsystems with new augmented and mixed reality system that could better enable a total ship training capability that could address navigation training shortfalls.

A legacy helm emulator titled Navigation, Seamanship and Shiphandling Trainer (NSST) was adapted to provide steering and propulsion inputs with BFTT and the NCTE. Proprietary legacy NSST hardware was replaced with a modern analog to digital converter and a Raspberry Pi computer to interpret positions via the wheel and throttle potentiometers. These positions were then turned into simple messages broadcast via User Datagram Protocol (UDP) replicating traditional BFTT Operator Console inputs; however, offering a control mechanism that replicated a helmsman's normal actions. In turn, the Distributed Interactive Simulation (DIS) Entity was being sent to BFTT, captured by the Joint Simulation BUS (JBUS), and converted via the High-Level Architecture (HLA) Plug-in for use in a larger FST-like federation [2] [3][7]. Conversely, the ANTS2 system was federated following NCTE Interoperability standards (NIS) [7] receiving entities provided by Navy training Baseline (NTB) Joint Semi-Automated Forces (JSAF) and interpreted by the Real-time Automated Visualization Environment (RAVE). These objects are then viewable by operators in the Mixed Reality (MR) scenario through the 'Magic Window" concept. Essentially, the "to scale" windows of a Guided Missile Destroyer (DDG) were overlaid on a physical banner providing an immersive experience of being on a bridge of a DDG, viewing land, sea, and air environments, while interacting with real world physical objects such as binoculars, where appropriate. This also allows watchstanders to view and interact with each other as they would in underway steaming conditions.

Additionally, ANTS2 solution incorporated bridge wing watch standers immersed in a virtual reality environment. The technical challenge was determining how to overlay an entire ocean while in mixed reality when located on the bridge wings. The solution was to allow the operator to transit through a virtual watertight door from the interior of the bridge in mixed reality and exit the door into a virtual reality environment on the bridge wings and vice versa. In order to further enhance the training experience, virtual binoculars and night vision goggles were developed using HTC Vive Pro Trackers. These trackers can be paired with headsets so that when a real world set of binoculars or night vision goggles are being used, with the tracker attached, a functional virtual set of binoculars are presented in the scene. Virtual Ship Platform (VSP), acting as a Navigation Sensor System Interface (NAVSSI), Output Data messages were produced and sent to the VMS as the ship navigational chart. The VMS digital output was encoded and presented to operators as a virtual display. This showcases the ability to overlay unavailable ship systems virtually, allowing operators to train to their system, even when such systems are offline when the ship is in port. Once again, incorporating Raspberry Pi technology, audio from a ships whistle and collision alarm was added to the solution. By interacting with a button for activation, a message was sent to the ANTS2 server which activated the relevant sound file. All of the interactions, messages, kinematics, and headset orientation data were captured by the Mentor Station system tom provide high-fidelity after-action performance assessment. Mentor Station also monitored operators' actions, including the position of the headset, allowing for detailed training review for instructors.

Phase 2 Efforts

As ANTS2 was funded for Phase 2 in FY20, many new features and capabilities were added. The goal for ANTS2 Phase 2 was to demonstrate the capabilities in FST RDT&E onboard a pierside DDG as the FY20 culminating event. As a result of the onset of the COVID-19 pandemic in March 2020, the team had to get creative in order to validate the capabilities being developed and show the viability of the software for shipboard use. As travel was restricted due to COVID-19, the team decided to utilize Amazon Web Services (AWS) as a means to conduct unclassified distributed test events via Virtual Private Network (VPN). The team implemented best practices for protecting Controlled Unclassified Information (CUI) by following industry standards including encryption and Multi Factor Authentication. As a result, the ANTS2 team was able to implement many new capabilities, models, and incorporate new systems. ANTS2 provides a fully modeled San Diego harbor with a host of navigation aids, landmarks, and other model enhancements to allow for visual navigation. Models were purchased and brought into Unity at appropriate latitude, longitudes, and elevations. The team developed a scalable means to easily bring in and place new assets as needed following a similar pattern used by the RAVE application.

A Navigation Status Federation Object Model (FOM) addition was made for the NTB following NIS guidance [7] with inputs from the collective ANTS2 development team. This FOM addition was developed with the intent of it being voted on at a future Interoperability Working Group (IWG) and incorporated into the NCTE Interoperability

Standard (NIS) [7]. In order to compliment this FOM addition, the team developed associated days shapes and night lights as referenced in the Navigation Rules of the Road noted within the COLREGS [5]. The navigation aids can be controlled using a special engineering build of JSAF which has both GUI changes, allowing the setting of the 'Navigation Status', and the incorporation of the new FOM. Collaborating with team members from Naval Air Warfare Center Training Systems Division (NAWC-TSD) and using the Mariners Skills Suite (MSS) application, ANTS2 incorporates the use of multiple suites of shipboard systems and sensor emulators. This was accomplished by incorporating an HLA gateway into MSS bypassing the native Instructor Console (IC) scenario traffic and ownship, and using the JSAF federation traffic and ownship produced by ANTS2. Utilizing the fully emulated SPS-73 radar produced by MSS, ANTS2 was able to use this radar as a part of the navigation training toolset in order to correlate visual navigation aids with those observed on the radar. MSS brings the added benefit of having a native interface to VMS, the navigation chart application used on the bridge. In contrast to Phase 1, where ANTS2 produced the ownship as a DIS entity, BFTT modeled ownship in Phase 2. This was accomplished by taking the same helm inputs as used in Phase 1 to produce the DIS[3] Ownship entity. ANTS2 produced BFTT Client Server (CS) messages. These CS messages were sent from ANTS2 directly to BFTTs Gateway application which routed them to BFTTs Navigation Simulator (NAVSIM), allowing BFTT to model and produce the HLA[2] ownship object.

TECHNOLOGY OVERVIEW

At the commencement of each ANTS2 Phase, the team researched current commercial and government technologies in order to focus project objectives based on operational effectiveness, suitability, risk, and potential life cycle cost. The following is a discussion of the technologies reviewed or selected for ANTS2.

Unity Development Environment

Unity is a cross-platform game engine developed by Unity Technologies, first announced and released in June 2005 at Apple Inc.'s Worldwide Developers Conference as a Mac OS X-exclusive game engine. As of 2018, the engine had been extended to support more than 25 platforms. The engine can be used to create three-dimensional, two-dimensional, virtual reality, and augmented reality games, as well as, simulations and other experiences. The engine has been adopted by industries outside video gaming, such as film, automotive, architecture, engineering, and construction.

As Unity was the development environment of choice for the RAVE becoming the NIS[7] approved image generations and 3d modeling simulation environment. Based on interoperability compliance with NIS and previous experience gained from earlier ONR projects, developing ANTS2 AR/MR capabilities around Unity was a natural choice as it offered NIS compliance, the ability to integrate with HLA[2] and DIS[3] shore and shipboard simulation systems, and the potential to integrate with other future training systems utilized in FST. Figure 2 depicts how Unity is used to only provide simulation on designated areas in the scene. In this case the ANTS2 development team chose to overlay the augmented reality only over the windows looking out form the DDG bridge.

Figure 2. **ANTS2 Window View Using Unity**

Model Libraries

Unity Asset Store and TurboSquid were selected because they are the industry standard for providing a library of 3D models for purchase and it would have been cost and time prohibitive to build the 3D models from scratch. The 3D models are described in greater detail in the Unity 3D Visualization section below and all models and videos can be viewed with the accompanying ANTS2 Media Packet; additionally, they were shared with the NTB repository to be used by Real-time Automated Visualization Environment (RAVE) and future compatible image generation and 3D modeling systems.

NTB Simulation Components

The NTB simulation components consisted primarily of JSAF with its associated Run Time Infrastructure (RTI)[5] running a custom scenario produced by the Naval Simulation Center Pacific (NSCPAC) OPS team. A JSAF federation was established for interested systems to federate and receive OwnShip. In support of the ANTS2 system, a Joint Simulation Bus (JBUS) was run in the background to translate the Distributive Interactive Simulation (DIS) Entity State Protocol Data Unit (PDU) from the ANTS2 application into HLA for the federation of systems. In order to support the secure wireless system, TreeRouter was utilized to translate the HLA signals to and from the backpack PC's securely [7]. With the incorporation of BFTT producing the Ownship HLA object. The JBUS was further utilized to bridge the ANTS2 federation with BFTTs different version of the RTI. The RTI Tree Route application was used to transit multicast over wireless and to handle router hops, effectively translating UDP Multicast to UDP Unicast.

RAVE

The NTB RAVE product was selected for the ANTS2 visual scenes because it provided Earth Centric Earth Fixed (ECEF) coordinate conversion to the Unity Flat World System. RAVE is produced with a High-Level Architecture (HLA) gateway and was packaged with an existing suite of 3D models consistent with NIS [2][7]. The alternative solution was to create the coordinate conversion, HLA gateway, and build the 3D models which were time prohibitive given the project timeline.

BFTT

In Phase 1, the BFTT System was a passive participant in the ANTS2 demonstration, consuming navigation and ownship information via the DIS EntityState PDU from the ANTS2 application. This demonstrates the capability of steering the BFTT ownship as it would be accomplished by the Navigation Simulator (NAVSIM) component allowing stimulation of ship systems connected to BFTT. In Phase 2, BFTT became the model and producer of the HLA ownship object. The helm was used to drive the ship by having ANTS2 create the Client Server messages and pass them to BFTT.

Voyage Management Systems (VMS)

In Phase 1, ANTS2 leveraged existing capabilities inherited from previous ONR projects to stimulate the VMS using Virtual Ship Platform (VSP) in order to integrate with the ANTS2 HLA federation. This provided an ownship position with the proper course and speed displayed on the VMS digital chart that was synchronized with helm rudder and throttle commands initiated in the ANTS2 Helm Simulation subsystem and BFTT. Additional integration with MSS and VMS interfaces was not integrated during the FY19 ANTS2 development cycle; however, it should be explored in subsequent related projects. As a result of MSS utilization of the HLA gateway in order to receive scenario traffic and ownship, MSS is able to leverage the native interface with VMS.

Mariners Skills Suite (MSS)

The ANTS2 team developed an HLA interface with MSS, allowing it to receive scenario traffic and ownship. MSS bypassed its normal use of the Instructor Console for scenario control and received inputs from the ANTS2 federation and ownship. This allowed the suite of applications and ship sensor emulators to be utilized for navigation training (i.e. SPS-73 radar and navigation chart software). Additionally, MSS provides a native interface to VMS allowing the ships chart to be a part of the training scenario.

Helm Simulation Systems

Helm systems are centered on a familiar tool utilized by the Navigation training community. The Navigation, Seamanship, and Shiphandling Training (NSST) helm steering console subsystem, was integrated with a Raspberry Pi processor in order to interpret user interaction with the physical steering and speed controls. This is accomplished by decoding the analog potentiometer positions of the throttle and wheel. The Raspberry Pi system then rebroadcasts the signals collected from the controls to the ANTS2 application for translation into ownship steering/control commands. The ANTS2 application modeled ship physics and used dead reckoning in order to steer and move ownship. The steering commands were interpreted by the server and rebroadcast and redisplayed as speed/rudder angle/requested speed onto dials displayed in each of the Unity scenes. The Helm integrated two separate Raspberry Pi systems that were built out to simulate realistic ship horn and collision alarms which also broadcasted to the ANTS2 application. In Phase 2, the BFTT Client Server messages were populated with the desired speed and turn rate received from the helm which allowed BFTT to model and publish the ownship object.

Raspberry Pi

The Raspberry Pi is a low cost, credit-card sized computer that plugs into a computer monitor or TV, and uses a standard keyboard and mouse. It's capable of doing everything one would expect a desktop computer to do, from browsing the internet and playing high-definition video, to developing spreadsheets, conducting word-processing, and playing games. Additionally, the Raspberry Pi has the ability to interact with the outside world and has been used in a wide array of digital maker projects. Due to the ease of wiring a Raspberry Pi to external hardware/electronics systems and subsequent programming to this interface, it became an easy choice to utilize as an interface device for external hardware/direct and user input devices.

Audio Simulation Systems

Audio Simulation Systems allowed for user interactive ship's whistle and collision alarm triggers associated with the helm and rebroadcast to the ANTS2 server component. Upon sound triggers, sounds were played back through the primary server running the ANTS2 server. Ocean sounds were also simulated through wave playback on the ANTS2 server. Additionally, the ANTS2 application collected data on all these inputs and rebroadcast them to the Mentor station for data collection purposes.

HTC VIVE Pro

The HTC VIVE Pro (Figure 3) was selected over Microsoft HoloLens, Samsung Odyssey, and Meta 2 because it provided the industry leading standard that balanced cost and features. The HTC VIVE Pro had a comparable field of view and resolution to other headsets; however, it provided the benefit of being immediately compatible with the Unity 3D game engine.

Figure 3. HTC VIVE Pro with ZED Mini Stereo Camera

ZED Mini

The ZED Mini was selected for its integration with the HTC VIVE Pro to provide accurate occlusion, video pass through, and depth sensing. While the HTC VIVE Pro does provide camera pass through, the resolution of the headset was not capable of producing required visual acuity for human perception and systems tracking. The ZED

Mini is produced by Stereolabs, a leader in Augmented Reality (AR) and Virtual Reality (VR) camera optics and tracking. The ZED Mini mounts directly to the front of the HTC VIVE Pro and provides the additional capability to produce Mixed Reality (MR) content. MR content is the blending of both AR and VR in a single frame or display. Additionally, the ZED mini was chosen for its depth sensing capabilities. Utilizing the hardware, the ANTS2 team was able to include basic hand and object occlusion on the emulated bridge of the ship. Collaboration among organizations of software developers allowed the ANTS2 team to achieve the best possible results for the emulated ship bridge view portal windows. The ANTS2 team collaborated with the developers from Stereolabs in order to fine-tune the AR/VR occlusion techniques used in the ANTS2 application. One of the most difficult things to occlude in AR using head mounted steroscopic cameras are human hands. Figure 4 and Figure 5 depict the successful results of the collaborative efforts between the ANTS2 team and industry partners allowing for rapid improvement of fidelity using the ZED mini.

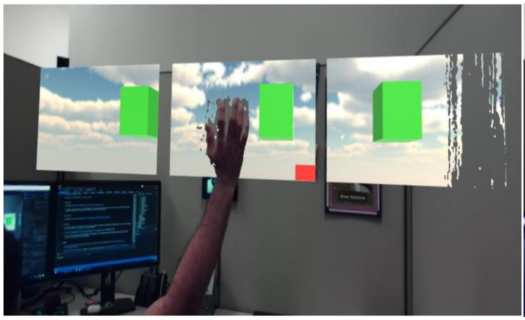

Figure 4. Example of Full Hand Occlusion

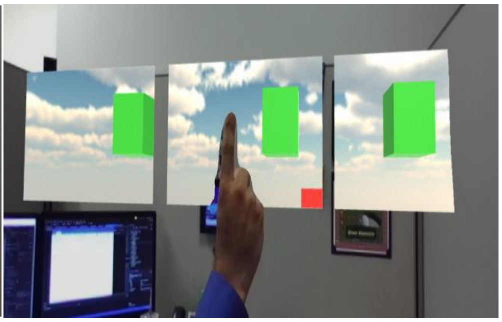

Figure 5. Example of Single Finger Occlusion

SYSTEM ARCHITECTURE

ANTS2 provides a system of system approach in its solution. Where possible, existing system capabilities are utilized to bring an even more robust training experience to the user. The ANTS2 system has inputs into BFTT via its DIS Entity State. The entire solution is federated with JSAF acting as the scenario generator. Voyage Management System (VMS) acts as the ship's Electronic Chart Display and Information System (ECDIS) with inputs provided by the federated VSP application creating OD17 and OD19 messages. The solution is scalable with additional backpacks and headsets requiring only the application and an initial calibration. In Phase 2, the MSS system was able to federate bringing its suite of ship system applications and emulators. MSS has a native VMS interface and can take the place of the VSP used in Phase 1. ANTS2 communicated directly with BFTT via the Client Server (CS) messages in Phase 2 allowing the NAVSIM to model ownship. This BFTT generated ownship was driven from the NSST helm and produced DIS entities. ANTS2 produced the appropriate CS messages in order to act as a BOPC, to generate and maneuver ownship. Additionally, JBUS was used in this configuration to bridge the D32 RTI federation that BFTT uses with the D37 Federation consistent with NIS [7]. MSS was brought into the architecture via an HLA interface which allowed it to federate with the ANTS2 system. MSS was able to utilize the BFTT generated ownship and other JSAF driven scenario traffic in order to populate its emulated sensors, charts, and radars.

Secure Wireless Development

The Team established technical designs for use of secure wireless on NCTE that is compliant with NSA guidelines for CSfC networks [6]. The Technical design includes an interim architecture housed in a Portable Embarkable Kit (PEK) for use on a US Navy ship or test facility. The ONR team that includes NSWC Dahlgren has developed plans for ship-based enhancements that will work with the enterprise network design. This was a critical technology needed in order for the capability to be useful. It allowed the operators to move untethered throughout the game space and would allow for the same on the bridge of the ship. Additionally this wireless architecture was compliant with the NCTE architecture allowing for all the simulation traffic to be passed into the virtual environment and stimulating the various AR/VR scenes needed for training.

Unity 3D Visualization Environment

“Magic Windows” is a phrase used during the development stage of the ANTS2 project. The “magic windows” concept originated from the idea of portals into another world, a concept that is often portrayed in modern virtual reality games. The virtual bridge windows on the front of the ship act as a mask between the interior of the ship and everything else outside the ship. In order to achieve this effect, the ANTS2 team took advantage of rendering the pipeline inside of Unity in order to create a few different shaders. The shaders were created in order to make the “magic window” effect utilizing a concept known as stenciling. Stenciling which involves the use of different shaders resulting in control of stencil buffers. The stencil buffers are primarily used to render parts of an object while discarding others. In ANTS2, the team used two different stencil shaders. The first shader was used to mark the areas of the virtual window. The second shader was used to read the value of the first shader, compare the two shaders, and render the result to the game window. In order to achieve this effect, the ANTS2 team was required to define which shader renders first and second. This is easily performed by modifying the render queue itself.

Instances when watchstanders transitioned from AR to VR only situations required the development of an approach to seamlessly transition between the two visual rending approaches while maintaining a cohesive simulation to ensure the trainee continued immersion in the simulated environment (Figure 6). The effect is achieved by switching the user’s camera inputs from the ZED to Pure VR cameras upon collision with the trigger “Walls” within the scene, allowing for a near instant switch from Pure VR to Mixed Reality, and vice versa.

The AR to VR transition approach was extended to the binocular view by re-using the code base and adding an extra “zoom frame” which inserted a “zoomed-in, binocular view” to the user, when the appropriate tracker object triggered a “collision” with the user’s avatar object within the scene. This allowed the user to bring the binoculars up to their head and switch to a zoomed view, giving the appearance of looking through the binoculars in order to view distant objects.

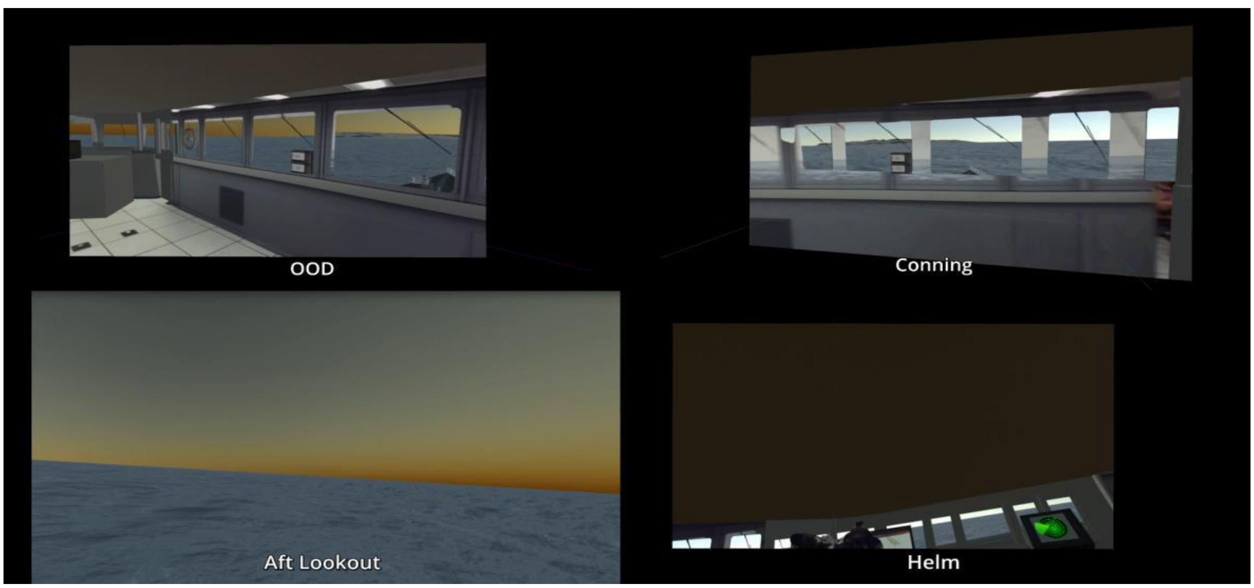

Figure 6. Magic Windows View and Transition to Lookout View

Navigation Status Additions to NTB Federation Object Model (FOM)

The ANTS2 team designed and implemented software additions and modifications to the NTB JSAF application in order to support the Navigation Rules HLA FOM for use in training operations. This provided the appropriate stimuli from the synthetic training environment in order to allow for a previously unavailable visualization, audio processing, and sailor response based on the defined attributes in order to enhance the navigation training objective. The addition of Navigation Rules is generic and can be used and applied to a variety of training scenarios across multiple platforms, as well as, setting the conditions to repeat this process for other training use cases and efforts (i.e. common environment and other visual platform indicators).

Designed and implemented an attribute for the HLA FOM Platform object that defines the state of a vessel as it pertains to navigation: Day shapes, running lights and sound signals. Although all are fully present in the model, only day shapes and running lights were demonstrated prior to the end of the project where the capability will allow for navigation status to be defined and controlled from within JSAF, and visually represented in the ANTS2 Unity 3D scene as day shapes and night lights via HLA object subscription. The NAVStatus FOM includes navigation attributes that are mapped to an HLA representation, controlled through JSAF, and visually represented in Unity 3D.

MSS Integration

Naval Air Warfare Center Training Systems Division (NAWCTSD) implemented a NIS [7] compliant HLA gateway to provide ownship and scenario traffic data to MSS applications. MSS applications correctly display the appropriate data in the relevant applications, such as the SPS-73 radar and chart view. The MSS NAVSSI application provides ownship navigation messages to VMS, and the MSS Automatic Identification System (AIS) application receives AIS data from the HLA gateway for scenario traffic and provides the appropriate AIS serial messages to MSS . Global Positioning System (GPS) jamming capabilities were explored, but not fully implemented due to the required GPS plugins not being part of the test environment. The SPS-73 and other systems were able to be captured from the native MSS application space and rendered in the Unity 3D scene by copying the MSS visual contents to a Unity 3D texture seen in Figure 7.

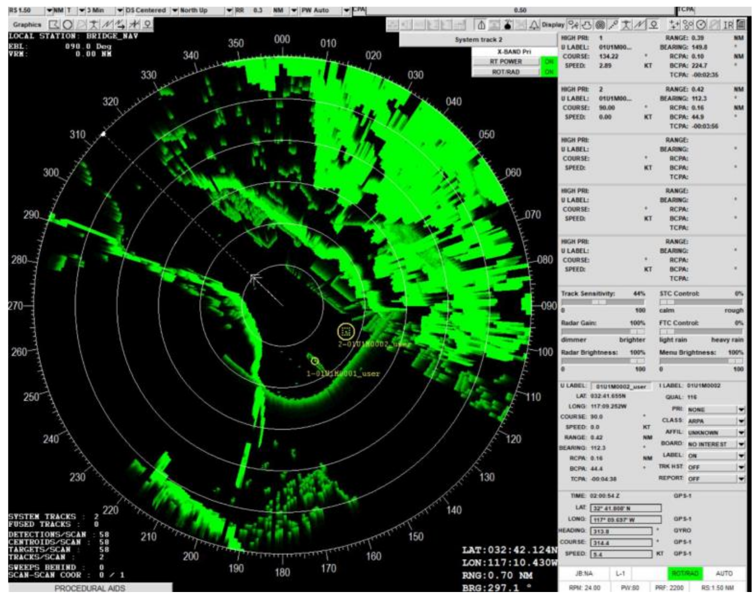

Figure 7. SPS-73 Radar with Coronado Bridge and Track Hooked

Navigation and Maritime Shipping Training

The intent of ANTS2 is to provide sailors the technology to create a truly immersive AR and VR experience in order to augment navigation, ship handling, and maritime shipping training within a FST-U environment. Currently during FST-U events, handheld visual aids and scripts are used by watchstanders/roleplayers which lacks the immersion into a real-world simulated environment.

ACCOMPLISHMENTS AND CONCLUSIONS

The ANTS2 prototype system successfully demonstrated that using augmented reality for navigation training is viable, as a training method. The use of augmented reality for training enables improved integrated training between navigation and combat teams. The effort also provided novel solutions to simulate legacy systems that do not have an effective system interface for distributed training.

Helm: Use of AR technology that permits the helm operator to steer the emulated helm, monitor heading and speed, and view through the bridge windows (magic window banner) the synthetic environment to include seas, land mass, navigation aids, military and commercial craft, etc.

Lookouts (Port & Stbd): Use of AR and VR technology that permits the port and starboard lookouts to view from inside the bridge (AR) or transition to the bridge wings (VR) to observe and report the synthetic environment to include seas, land mass, navigation aids, military and commercial craft, etc. The lookouts have access to hand-held binocular views with magnification levels and night vision goggle capability. Additionally, the lookouts will have access to the virtual alidades on the bridge wings that will permit viewing of true bearings to visual navigation aids, as well as maritime shipping.

Lookout (Aft): Use of VR technology that permits the after lookout to view and report the synthetic environment to include seas, land mass, navigation aids, military and commercial craft, etc. The lookout has access to hand-held binocular views with the same capability as the Port and Starboard binoculars.

OOD/JOOD/Conning Officer: Use of AR and VR technology that permits the OOD, JOOD, and Conning Officer to move freely in the bridge in AR mode or transition to the bridge wings in VR mode. Observed views can be augmented with binoculars or night vision goggles through the bridge windows (magic window banner) or bridge wings within the synthetic environment to include seas, land mass, navigation aids, military and commercial craft, etc.

Visual and Radar Navigation: Visual navigation is achieved through the use of the VR technology by taking visual bearings using the virtual alidade of navigational aids including lighthouses, piers, towers, etc. Radar navigation is achieved by taking ranges to fixed locations on land using the simulated SPS-73 radar produced by the MSS. Visual and radar fixes will be correlated for accuracy and the position of ownship will be entered into the VMS software.

Shipping: Maintaining situational awareness of the maritime shipping picture is achieved through the use of lookout reports of military and commercial craft in the vicinity of ownship, as well as, contact reporting of radar returns displayed on the simulated SPS-73 radar. Recommendations regarding the maneuvering of ownship will be based on the fusing of all contact reports.

Observations

Throughout the ANTS2 development, the team was able to identify multiple areas that were not originally scoped for the effort.

- For augmented reality to be accomplished aboard ship, a method for initially mapping the bridge, then overlaying the augmented environment, would be required each time.
- This process was not explored during ANTS2 but was identified as a critical step for a shipboard training system to be fielded. during the second phase of the effort, we studied what technology roadmaps for augmented reality looked like over the next 2-3 years and determined that it would be 5-7 years from the end of the project before augmented reality hardware would have the requisite fidelity to be implemented in our operating environment.
- Three years after the conclusion of ANTS2, the conclusions drawn regarding the state of technology appears to be an accurate trajectory. The augmented reality headsets currently available are making strides in increased resolution, tracking, and comfort; however, the length of training scenarios employed with ANTS2 need to be evaluated against published research for wear-ability of existing AR headsets.
- Wearable computing environment also requires improvement prior to a transition in to program of record. The HP backpack style computer was comfortable, but the battery life was unusable for a fielded system. HP has since abandoned that form factor which requires future teams to re-evaluate the computing environment needed to have untethered augmented reality.

Due to live navigation safety concerns, ANTS2 was designed as an in-port training capability and could not be utilized for ships underway. The bridge of a Navy ship cannot support a live team actively handling the vessel, and a simultaneous training event with augmented visuals. In addition, the motion of the ship, not matching the augmented visuals in varying sea states, would likely cause significant sim sickness, even in short scenarios.

Challenges

The objective of ANTS2 Phase 2 was to conduct the final proof-of-concept demonstration with the AR, VR, Mentor, and Secure Wireless technologies onboard a pier-side DDG within a FST-U type of environment. However, due to constraints imposed by the onset of the COVID-19 global pandemic, the event was cancelled and the technology was not tested within a shipboard environment.

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