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Abstract

This paper will address the ability of recent technological advances in Virtual Worlds (VWs) to affect better submarine C2 design via increased participation by the fleet personnel in design and experimentation. With the rapid emergence and evolution of VWs over the past three years, the US Navy has investigated and applied multiple applications of this technology to the undersea warfare (USW) domain. One area of application that is currently being supported is C2 collaborative engineering and concept of operation exercises (COOPEXs). VWs enable all stakeholders to remotely, distributively, and collaboratively participate in the design of prototype systems in real time while utilizing video, voice, chat, and intuitive build tools. These prototypes can then be used to analyze pre-recorded C2 events for the purpose of exposing information flow through a C2 space and visualization of C2 metrics. In addition, VWs allow these virtual prototypes to be evaluated by fleet personnel immersed into the environment with enough fidelity to allow operator performance assessment. This is because VWs allow for live connections with full control to real-world tactical systems. These capabilities are currently being utilized by multiple USW programs for next generation submarine attack center design.

Introduction

Over the past two decades technology to aid in USW system design, assessment, experimentation and training has seen dramatic advancements. Like the Computer Aided Design (CAD) revolution in the 1990's, the 21st century is posed to exploit a new technological revolution that is human-centric, enabling new methods of collaboration. Today's virtual environments now combine the power of CAD (the foundation for most synthetic environments) with technology such as Web 2.0, gaming engines and distributed Modeling & Simulation (M&S). The result is not just a more capable synthetic environment but rather a fully immersive *Virtual World* (VW) where people can come together to innovate. Distributed teams can now design, create, and experience any workspace of their choosing while enjoying full social interaction with each other via presence and voice. Like the vision portrayed in popular science fiction films such as *Tron (1982)*, *The Matrix (1999)*, and *Avatar* (2009) – today VWs are helping build the foundation for full human immersion into synthetic environments. [1]

Figure 1. VW Program Lead, Mr. Steven Aguiar, on Virtual USS Virginia

VW Characteristics

While there are a number of definitions, simply speaking, a VW is a three-dimensional (3D) computer environment, often created in real time by the user community, and in which users are uniquely represented on screen as themselves and are able to interact with other users. [2] A key trait is that this environment is immersive, allowing users to feel like they are truly resident in the “world” with other users. In particular, Web 2.0 has allowed VWs to become social environments where users interact with each other both audibly and visually. This Web 2.0 toolset provides a blank palette for users to create and control their own environment based on their individual interests, needs, and requirements. VWs are a user-created experience.

Due to the fact that most VWs can be thought of simply as an immersive interface to an existing network, they allow collaboration to be performed remotely and in a distributed manner. This means that all participants that are on the same network (whether a private, secure enclave or the open Internet) have the ability to participate from their own remote locations while interacting with each other as if they were co-located in the same physical space. Additionally, some VWs like Second Life™ provide simple Microsoft PowerPoint™-like build tools so that participants can build content easily, collaboratively and in real-time. [3] User-generated content is the power of Web 2.0. Multiple VW products also support the reuse of existing 3D models in wire mesh formats such as Computer Aided Three-dimensional Interactive Application (CATIA) created from external 3D modeling applications. This prevents the user from having to rebuild complex models in the VW if they already exist.

VWs and Submarine C^2 Design

Historically, submarine attack center spatial designs have used miniature 3D physical mockups. Although these mockups did not allow for any human interaction, they did allow for the visualization of spatial command and control (C^2) relationships. For example, Figure 2 shows a design team surrounding a small-scale replica of a submarine attack center space. In the 1980s this was an efficient way to visualize and evaluate physical spaces. But even this process was costly and time consuming. Validation of these C^2 prototypes still required construction of a full scale mockup in plywood for further spatial evaluation. This is because C^2 is (and will be in the foreseeable future) a human-centric activity since the attack center arrangement needs to support optimized C^2 decision making and team interaction.

Figure 2. 1982 Attack Center Design Team

In support of designing next-generation C^2 spaces, VWs allow all stakeholders (including fleet, civilians, and contractors) to participate collaboratively to design, build, and assess virtual layouts. Participation can be collocated through a single VW designer acting as an interface into the VW or in a distributed fashion with each participating through their unique avatar. [4] Several US Navy programs are tasked with investigating various aspects of future submarine C2 design and are planning to conduct experiments to improve the current Virginia Class submarine attack center design and provide design inputs for the Ohio Replacement Program (ORP), in order to achieve better performance across a greater variety of mission areas.

As an example, in October 2010 a program under the Office of Naval Research held a week-long arrangement studies workshop in Groton, CT, in which submarine crews, with the aid of C2 subject matter experts and cognitive scientists, generated 10 separate Command and Control Center (CACC) arrangements in real-time. One such arrangement in which Ship Control is moved aft and Command is provided with a 360 degree overhead display is shown in Figure 3. In this depiction the VW CACC is kept simple (block-like as in Figure 2) to facilitate more emphasis on function and location and less emphasis on chassis and monitor details. These models were then provided to the ship builder, Electric Boat, to implement in CAD for the purpose of ensuring that the fleet concepts could be built (with modifications).

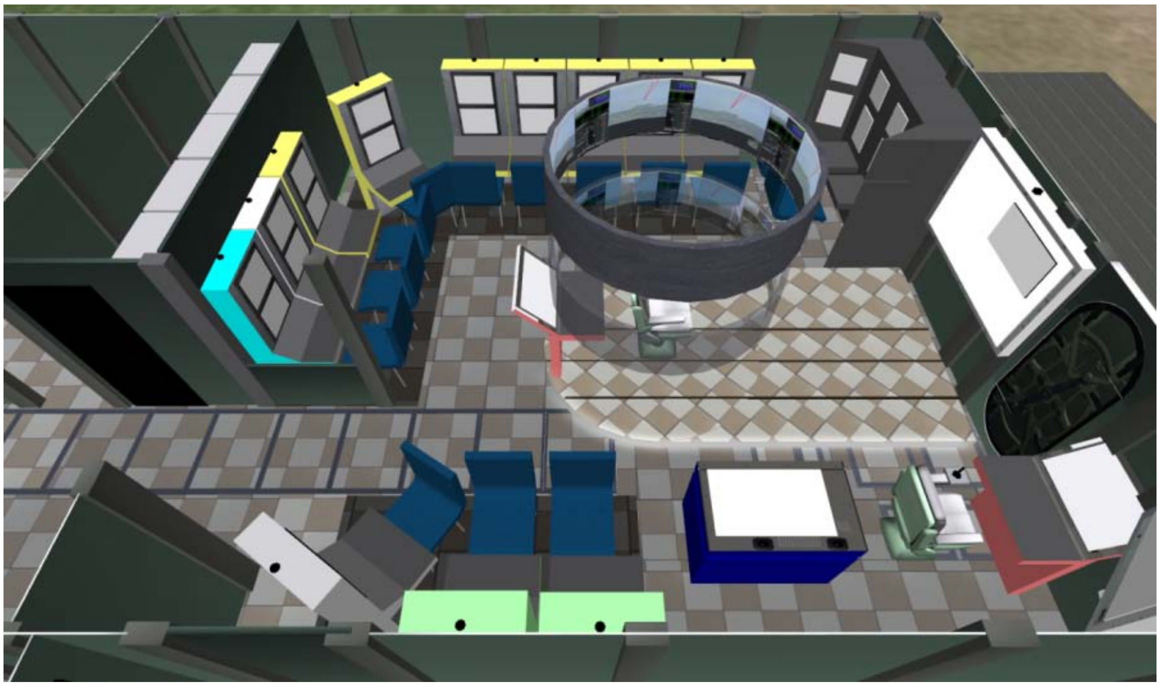

Figure 3. Fleet-generated CACC using VW model

The design process is iterative, providing a full concept evolution maintained with linkage to source material such as 3D models of hardware systems, documentation of utilized software systems, and related websites – all provided alongside a specific design. The design is not a single model but rather a documented evolution of the design process that captures its pedigree. (See Figure 4). As arrangement decisions are reviewed, a complete evolutionary string affecting that particular decision is available literally as a walk-through of the evolutionary process. Persistence with linkage to source material provides knowledge management.

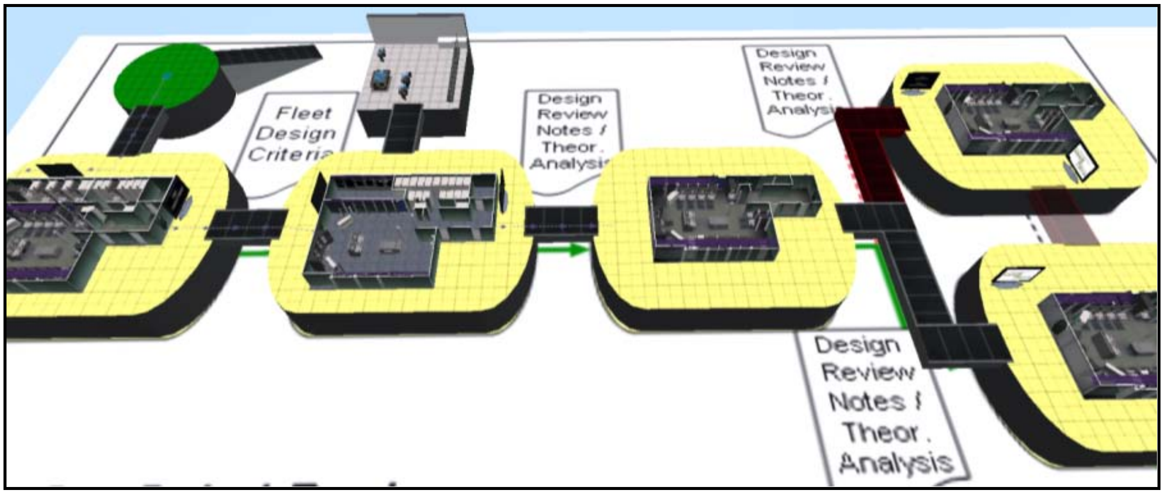

Figure 4. A collaborative environment in Second Life™ documenting the evolution of a submarine C^2 center.

VWs and Submarine C^2 Visualization and Analysis

As a next step to the design phase, Visualization and Analysis aims to understand all components that affect C^2 decision making in a Virginia class submarine CACC. Beyond simple console arrangement, C^2 is impacted by Information Architecture types and processes such as workspace, human communications, Human-System Interface (HSI), team structure, work flow, task flow, automation, training, etc. The goal is to expose visually each architecture component as it impacts a specific mission scenario. For example, in the notional depiction of an ASW mission string in Figure 5, human communications are depicted as green (visual), blue (audio), white (control) and magenta (electronic) information paths that can trace information from earliest detection (in theater) to a command decision being made. Other components such as task flow can be depicted by linked, dynamic Mind Maps located above the appropriate watch team

Figure 5. C2 Information flow visualization in a submarine CACC

member. Initially, the intent is to be able to first play a high-fidelity recorded event within a fully virtual environment, and then for a particular mission string (e.g., ASW kill chain) expose only those information architecture components at the appropriate scenario time that are impacting / contributing to the command decision. This supports the determination of which measures/metrics to employ in an actual experiment as well as to document the a priori expected performance of a future CACC design.

VWs and Submarine C^2 Experimentation

An early Concept of Operation Exercise (COOPEX) to support development of submarine advanced combat systems was conducted in December of 1984. This COOPEX was designed to show how the fleet would interact with the proposed system's highly advanced operational characteristics. The COOPEX served to define when and how individual consoles would be used by watch station personnel and to define coordinated team operation. [5] Since then, there have been several additional full-scale C2 experiments conducted resulting in important validation of CACC designs, though at a significant cost in time and dollars.

With the recent advances in VWs, for the first time the potential exists to cost effectively perform similar human-in-the-loop experimentation in a virtual environment. [6] Not only do VWs provide the communication mechanisms and the ability to model a physical space, they have also been demonstrated to provide interaction with real or simulated hardware and software systems essential for full C^2 functionality. For example, Virtual Network Computing (VNC) allows any system running a VNC server to be accessible from any other computer connected to the same network giving the user full interactive control, via mouse and keyboard, of the remote system. Virtual world service providers like Teleplace™ and more recently Second Life™ have successfully integrated the VNC capability into their VW platforms. The implications of this are that once a virtual CACC (or any other physical space) is mocked up in the VW, the corresponding systems that drive the displays can be connected, visible, and fully accessible from within the virtual world.

NUWCDIVNPT leveraged this capability to run a proof of concept pilot study to assess the maturity and potential to support a full interactive CACC in support of a virtual COOPEX. In August of 2009, the VW team ran an experiment to characterize the performance of fleet operators in a VW compared to a physical world. The experiment involved two groups of fleet personnel (each group containing two individual operators) performing submarine Target Motion Analysis (TMA) in order to identify, classify, and track a contact of interest. Each team ran through a TMA scenario twice - one trial allowed the operators to access the submarine combat system from the actual CACC hardware, and the other allowed access via the VW CACC. Figure 6 shows the virtual COOPEX setup. Once logged in and sitting at a console, the users' avatars were focused on the virtual screens connected to the real tactical hardware. Using VNC, the virtual screens were controlled by fleet operators using a standard keyboard and trackball mouse.

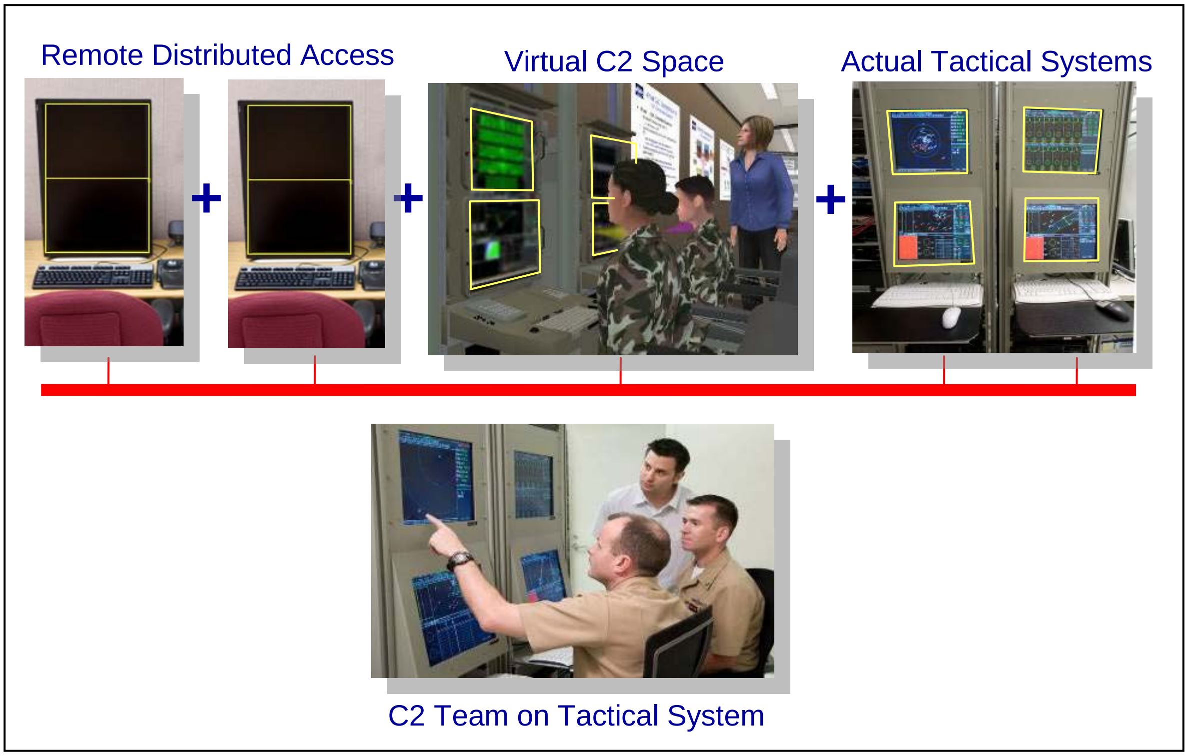

Figure 6. Virtual COOPEX Setup

The results of this experiment were very positive. They indicated that for this particular tactical function (i.e., TMA) operators performed equally well in both experiments. Novice operators (who had no experience with the specific version of the system) found the virtual C^2 system facilitated better performance when being presented with the real system (actual CACC hardware). Expert operators experienced medium to high confidence levels in their decisions using both systems. The only noticeable detriment was up to 1-second lag induced via VNC. The findings of this proof of concept experiment have led to the implication that C^2 dynamics from within a remote, distributed virtual environment are comparable (and hence measurable) to operation in the physical environment. The potential implications are that it is possible to create any virtual C2 environment (platform level or theater level or combination), insert real fleet operators (all blue or blue on red), give them access to actual tactical displays (with real or simulated data) and prototyped functions and be able to conduct experiments assessing team performance or the environment's performance compared to a baseline.

Implications and Conclusion

Of course, there are significant barriers for the wide-spread adoption of any new technology and VW technology is no exception. Information Assurance is critical to success, especially as it eventually makes it way to the warfighter. But what is essential to protect the Navy's information also constrains its ability to exploit key VW social features such as Voice over Internet Protocol (VoIP) and Instant Messaging (IM). The challenge is to bring the military and VW industry partners together to develop and deploy secure VWs. Another challenge, perhaps even more profound, is the psychological and sociological implications about moving more work – conferencing, training, collaboration, experimentation – into an immersive environment where the user is perceived first by their avatar and not their physical persona. [7] While this may be less of an issue for people who are accustomed to working in virtual environments (i.e., digital natives) other people will no doubt have difficulty initially adjusting to an immersive virtual environment. Virtual World acclimation (as opposed to training) will be an important S&T area in the decades to come.

The US Navy is at a point in its history where technological advances in virtual environments offer promising and cost-effective opportunities to conduct design, analysis, experimentation and training at unprecedented levels of collaboration. While research into the efficacy of Virtual Worlds is still in its early stages, the technology has been applied to a number of programs with positive results. Users of VW technology have reported increases in the rate of innovation, and collaboration at levels that would otherwise be unaffordable. NUWCDIVNPT will continue to work closely with industry, academia, and the military to explore how Virtual World technology can best support the Fleet.

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