APPLYING SIMULATION BASED VIRTUAL ENVIRONMENTS FOR SURFACE COMBATANT TRAINING

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Abstract

In current Navy surface combatant training, new crews are trained using real combat consoles in a classroom environment. This approach has disadvantages that include the considerable expense of supporting, maintaining, and reconfiguring the real consoles used in these facilities. As visual simulation and virtual reality (VR) have increased in capability and decreased in cost, these technologies can provide cost-effective solutions for training. The Naval Research Laboratory is currently using virtual reality, simulation, and multimedia tools to develop a Distributed Synthetic Combat Information Center (CIC) for the surface combatant training. The goal of the project is to create a distributed, immersive virtual reality system to complement current training capability. This will allow surface ship CIC crew members at different geographical locations to perform team training in a virtual ship environment. The virtual environment offers a true interactive 3D view of the interior of the CIC. This system will provide the feeling of real presence for surface combatant crews in a realistic combat engagement atmosphere instead of a classroom-like environment. It also simulates the equipment that the crew can interact with to perform detection, classification and target engagement activities. Information visualization will aid students in learning different tactical doctrines. Intelligent agents will be used to compensate for different educational levels of recruits and to reduce the number of instructors. The system will accommodate geographically distributed sites and provide better system availability. The virtual CIC's network capability will be implemented through a High Level Architecture (HLA) federate: crew members within the Federation Object Model (FOM) will communicate with each other, and a FOM representing the entire ship's CIC can participate in HLA exercises. This paper describes the project requirements, technical approach, system tradeoffs, current accomplishments and future direction.

Authors Biography

Henry C. Ng is the Head of the Visualization and Computing Systems Section of the Advanced Information Technology branch in Naval Research Laboratory. He has been actively involved in simulation and modeling over twenty years. Prior to joining NRL, he was the Head of the Simulation and Modeling branch of the Warfare Analysis department of Naval Surface Warfare Center, Dahlgren Division (NSWCDD) in White Oak, Maryland. He was the principle architect of a large scale sea, space, and land battle force level simulation model known as MARS (Multi-warfare Assessment and Research System).

Dr. Ali Farsaie is a technical consultant providing system engineering services for the Navy and DoD clients in the areas of virtual environment, training, 3D imaging technology, 3D model construction, and visualization. He was previously employed as Chief Engineer for NSWCDD, where he conducted and managed R&D projects of novel approaches in advanced information technology, robotics, man-machine interface, training and system engineering to meet long term Navy mission requirements.

Les Elkins received a B.S. from the West Virginia Institute of Technology in 1990, and an M.S. from the Johns Hopkins University in 1994, both in Computer Science. For the past several years, he has been working with virtual environments, building applications for training, battlefield visualization, and prototyping. Before joining LNK, he was a computer scientist at NSWCDD.

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Background

In current Navy surface combatant training, new crews are trained using real combat consoles in a classroom environment. This approach has disadvantages that include the considerable expense of supporting, maintaining, and reconfiguring the real consoles used in these facilities. This expense limits the number of real consoles available for all students to use at any given time. In addition, there is a large lag time between the creation of advanced concept systems and their deployment and acquisition by the training facility. As visual simulation and virtual reality have increased in capability and decreased in cost, these technologies have shown promise in providing cost-effective solutions for training (Bessemer, 1991), as well as virtual prototyping and engineering design (Farsaie, 1996). Naval Sea Systems Command has tasked the Naval Research Laboratory (NRL) to apply Virtual Reality coupled with simulation to develop a distributed virtual surface ship Combat Information Center (CIC) training system to complement current Navy training capabilities.

System Requirements and Objectives

The ultimate goal of the project is to develop a distributed virtual surface ship CIC training system which allows 10-12 crew members, each at a different geographical location, to be immersed in the same virtual CIC environment in order to conduct team training simultaneously. In addition, the system will also allow the instructor to view the actions and performance of the students at the same time.

The virtual CIC works in conjunction with a simulation engine, as shown in Figure 1. The

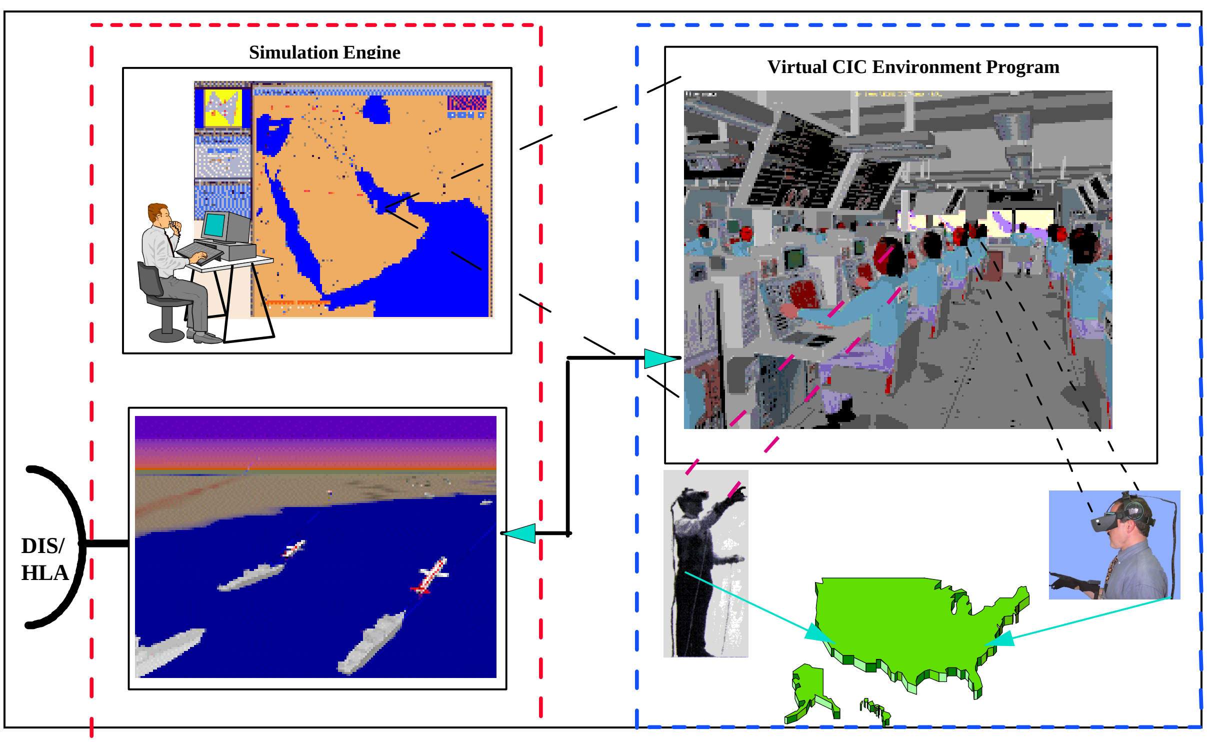


Figure 1 System Overview

simulation is controlled by an instructor, who can interact with the simulation to create, remove, and control entities in the simulation. The simulation engine functions either independently or with other simulations through Distributed Interactive Simulation (DIS) or the High Level Architecture (HLA). This structure also allows ground truth and stealth displays of the world state.

The visual simulation portion of the virtual CIC is intended to provide the 'look and feel' of the actual CIC through the use of extensive 3D models, phototextures, and sound clips. During the training session, the virtual CIC represents one surface ship entity in the simulation scenario, allowing the virtual CIC users to interact with it through the virtual CIC's consoles and computer systems.

The system requirements dictate a variety of user interface options for the virtual CIC. Three interface options have been implemented in the current system (Figure 2), and are described below.

Desktop VR. At a minimum, the use of a monitor with CrystalEyes stereo hardware combined with an input device such as a Spaceball allows an inexpensive three-dimensional presentation to the user. This configuration permits students to conduct training and system familiarization at little additional cost over the use of a standard monitor.

Semi-Immersive VR. By presenting the video on a large-screen display rather than a monitor, and using datagloves as user input devices, a greater sense of immersion is obtained. This configuration has the advantage of allowing multiple people to view the large screen display at the same time, allowing an instructor and/or audience to view the student's performance during training sessions.

Immersive VR. By using a head mounted display and datagloves, the user is entirely immersed in the environment. This approach is most useful with a fully distributed system that allows a completely immersive presentation of the environment, complete with avatars or mannequins for other users.

Each of the three options has different advantages and disadvantages, allowing tradeoffs in cost, portability, and the amount of 'immersiveness' in each. Future options may include force and tactile feedback, which will provide further utility (again at greater cost).

In order to support team training objectives, the system also will support multiple users in the same virtual environment. Each watchstation operator will then be represented as an avatar (mannequin) in the virtual environment.

The objective of the virtual CIC project is to allow watchstation operators to be immersed in a shared virtual environment, where all consoles and computer equipment will be operational within this virtual world.

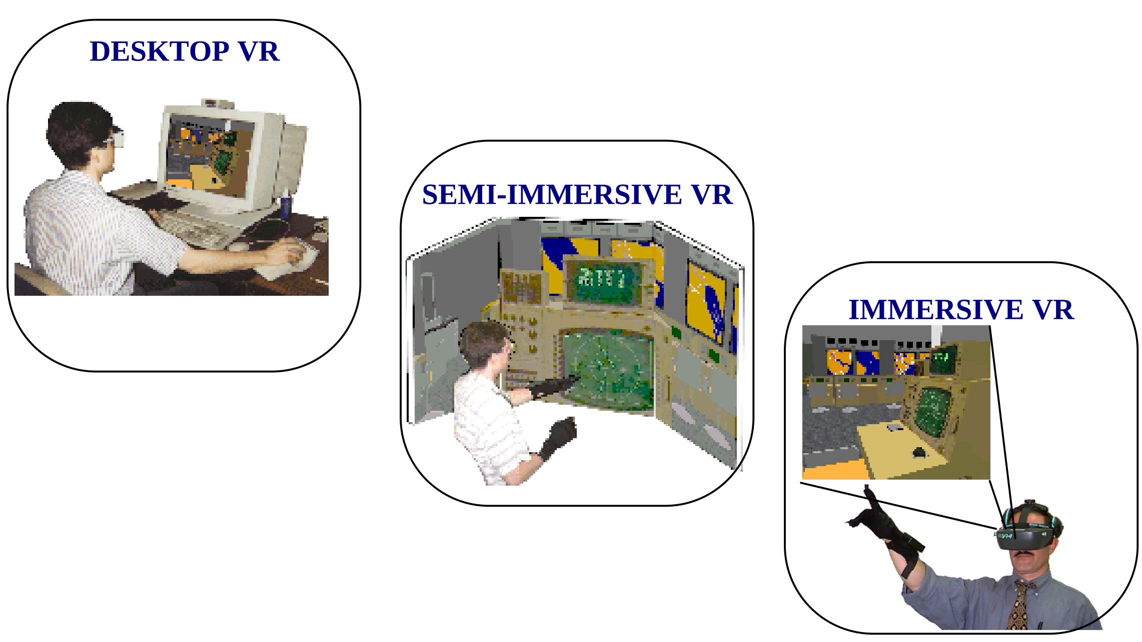


Figure 2 Interface Options

Technical Approach

Before the system was developed, many sessions and discussions were held with the Navy instructors and students to solicit their inputs and requirements for the system. Based on these discussions, an overall system architecture and implementation plan for the virtual CIC was devised. The development of the distributed virtual surface ship CIC training system consists of four phases.

Phase I: CIC Walkthrough/Tutorial

The purpose of the Phase I CIC work is to provide a virtual environment used for basic CIC familiarization training. This is used as a stand-alone system to allow new users with no previous knowledge of the CIC consoles, command structure, or operations to walk through the CIC, examining the layout, crew functionality, and console functionality. This type of virtual presentation has been shown to be effective in naval training systems previously (Hribar, 1993).

Phase II: Individual Crew Training

In Phase II, the virtual CIC is expanded to support the modeling of several consoles. This allows individual crew training at several consoles, by allowing them to use the virtual consoles to interact with other simulated entities through the virtual CIC's controls.

Phase III: Same Site Cooperative Team Training

The Phase III work will expand on the Phase II, extending the support for single consoles into a distributed model of the virtual CIC's internal state. This will allow multiple users to participate in the same environment, interacting with one another and the simulation. The first set of consoles to be fully modeled and shared in the virtual environment will be in one functional area, to allow end-to-end engagement training in some scenario (for example, a SLQ-32 and radar console to allow hardkill/softkill engagement training).

Phase IV: Distributed Site Cooperative Team Training

In addition to the complete modeling of the desired CIC consoles to support multiple mission areas, Phase IV will incorporate tools to allow the instructor to perform training and scenario management functions over the network, allowing true distributed, cooperative team training without regard to geographic location of the instructor or trainees.

Current Status

Currently, Phase I of the virtual CIC is completed and deployed, and examination of follow on work is underway.

CIC Walkthrough

This initial version functions as a virtual walkthrough with tutorial and some operational capability. The user can travel through the virtual CIC, viewing the consoles and watchstations (Figure 3).

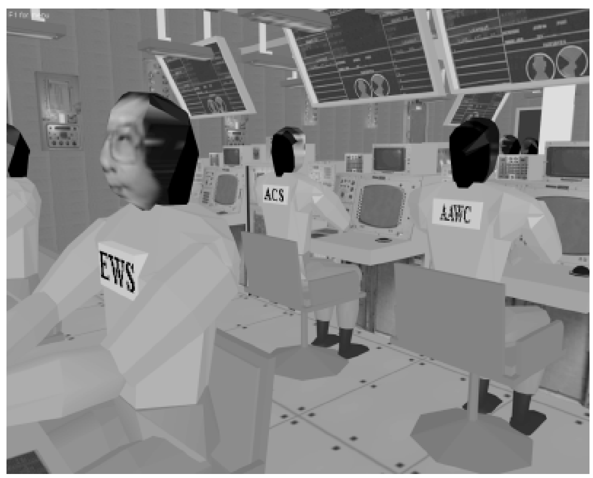
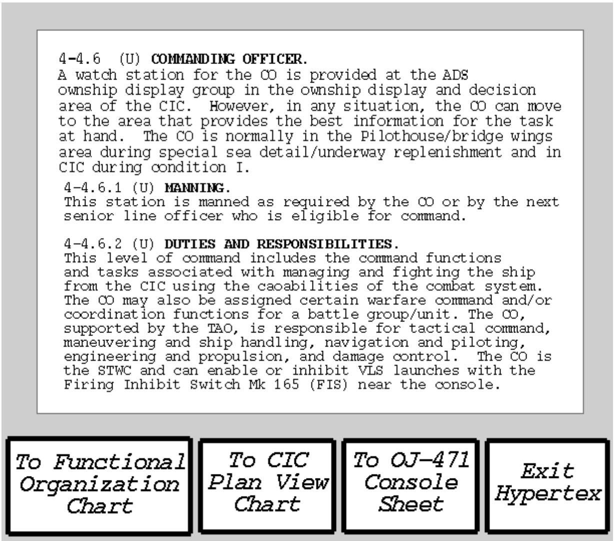


Figure 3 Virtual CIC Walkthrough

Console & Watchstation Hypertext Tutorial

The console operators are represented by mannequins. These mannequins can be queried by virtually touching them, which will launch a hypertext description of the watchstation duties and responsibilities (Figure 4). The hypertext pages also show the watchstation's position in the CIC's command structure. From the watchstation descriptions, the user can also jump to pages containing the overall CIC command structure, a plan view of the CIC, and descriptions of individual consoles (Figure 5).



4-4.6 (U) **COMMANDING OFFICER.**
A watch station for the CO is provided at the ADS ownship display group in the ownship display and decision area of the CIC. However, in any situation, the CO can move to the area that provides the best information for the task at hand. The CO is normally in the Pilothouse/bridge wings area during special sea detail/underway replenishment and in CIC during condition I.

4-4.6.1 (U) **MANNING.**
This station is manned as required by the CO or by the next senior line officer who is eligible for command.

4-4.6.2 (U) **DUTIES AND RESPONSIBILITIES.**
This level of command includes the command functions and tasks associated with managing and fighting the ship from the CIC using the caoabilities of the combat system. The CO may also be assigned certain warfare command and/or coordination functions for a battle group/unit. The CO, supported by the TAO, is responsible for tactical command, maneuvering and ship handling, navigation and piloting, engineering and propulsion, and damage control. The CO is the STWC and can enable or inhibit VLS launches with the Firing Inhibit Switch Mk 165 (FIS) near the console.

Figure 4 Watchstation Responsibilities

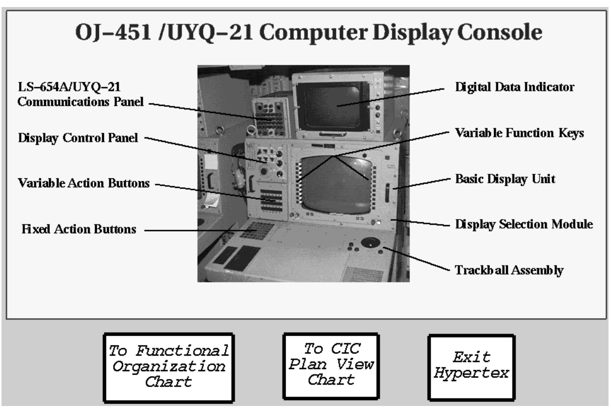


Figure 5 Computer system description

Figure 6 Ship Command Workstation

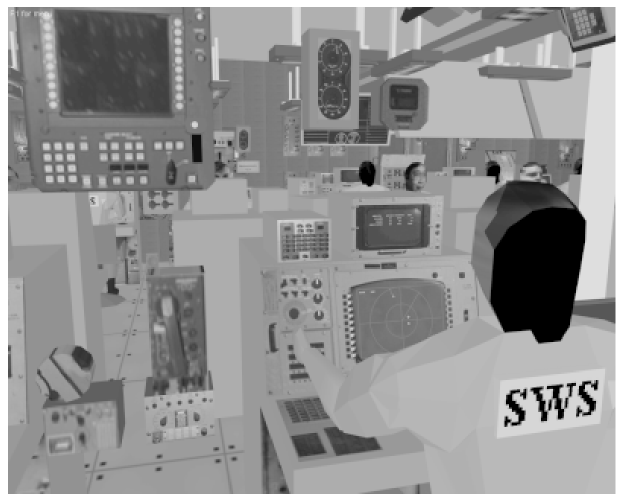


Figure 7 Warfare Operator

Console and External Interactions

The virtual CIC allows the user to interact with the simulated ship's combat system by touching the buttons and keys on the virtual consoles, and viewing the system's output through the console displays. For example, the user can use the Tactical Action Officer (TAO) console position to turn on the large screen displays in the CIC, scrolling around the map and viewing the contacts detected by the radar, and zooming in and out of the map view (Figure 6). The user can also interact with a basic radar console, controlling the radar state (turning it on and off in the simulation) and seeing the contacts appropriately on the graphical screen and on a Cathode Ray Output (CRO) display in the virtual environment with range, bearing, and track information (Figure 7).

System Architecture

The virtual CIC does not exist only as a single standalone virtual environment. It is linked to a simulation engine through a network interface. The simulation manages a theater-level wargame. The particular ship that the virtual CIC is part of is represented as an entity in this simulation. In this way the virtual CIC can interact with the simulation by, for example, controlling a sensor (turning a radar on), and can 'see' other entities in the simulation through the information returned by the ship's sensors. The simulation is currently DIS compliant, so it can interact with other simulations and simulators over a LAN/WAN with other activities or services.

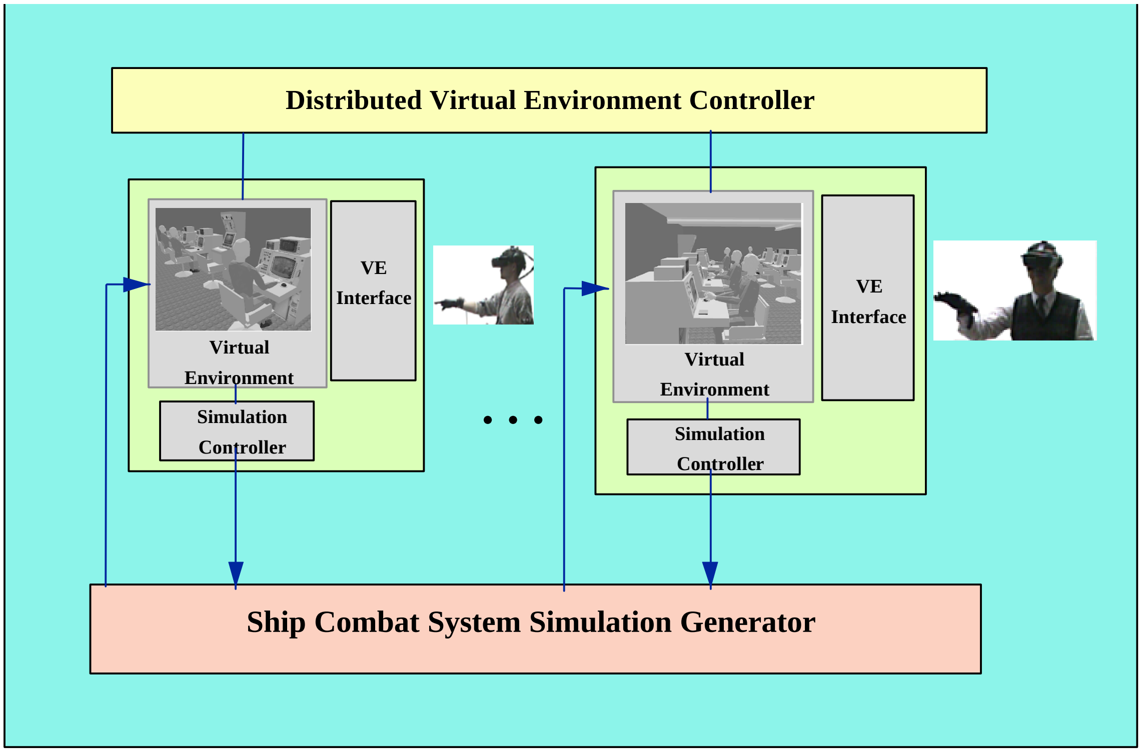


Figure 8 System Architecture

The overall system architecture for the virtual CIC training system is shown in Figure 8. It consists of three major components: a simulation generator, a virtual environment, and a distributed virtual environment controller.

A theater-level model with ship combat system capability is used as the simulation generator for the virtual CIC. It also provides a preprocessor which allows the instructor to create and modify scenarios.

The virtual environment provides a true interactive three-dimensional view of the interior of the ship's CIC. This system provides the feeling of real presence for surface ship combatant crews in a realistic combat engagement atmosphere instead of the current classroom environment. It also simulates the equipment that the crew interacts with to perform detection, classification, and target engagement activities.

The distributed virtual environment controller manages system registration, and information control. It keeps track of the virtual CIC federation state information, as well as initializing each student's virtual environment when the student first joins the federation, and synchronizes each student's virtual environment with the federation state during system operation.

Distributed capability

The support for multiple students or crew members in the virtual CIC will be implemented through HLA. The virtual CIC federation is used by individual CIC users, and this federation (itself representing an entire surface ship) is a member of the battlefield federation representing the larger world view. In this case, the virtual CIC federation is for intraship operation and the battlefield federation is for external ship interactions (Figure 9).

HLA for intraship communication. The virtual CIC's intraship data exchange capability will be implemented through an HLA federate. This will allow crew members within the FOM to communicate with each other and change the state of the CIC. Thus in the future multiple operators will combine to form a FOM representing the crew of a ship's CIC in order to participate in HLA exercises.

HLA for simulation host/outside world interconnectivity. Currently the simulation engine

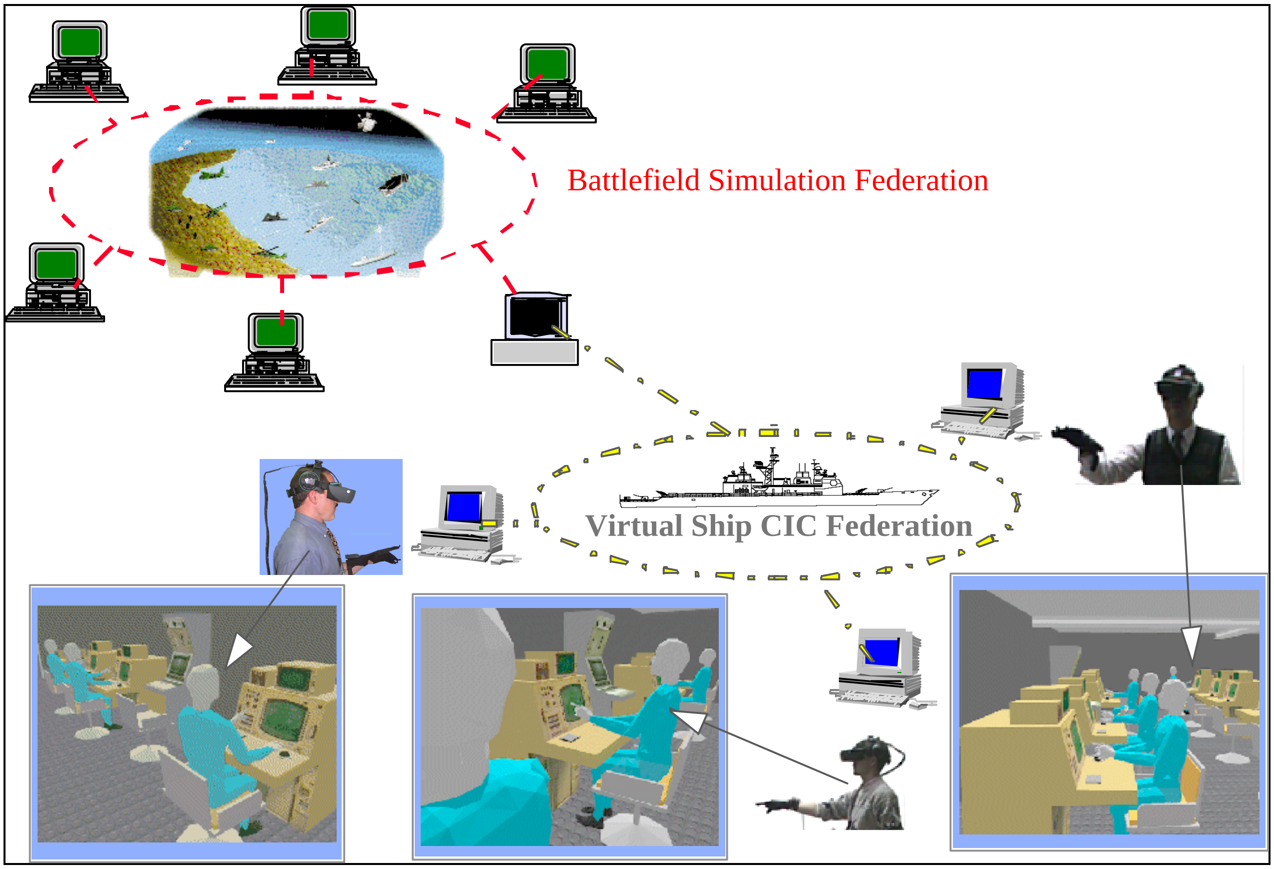


Figure 9 Multiple HLA Federations

can communicate with the outside world through DIS. The simulation will be upgraded from DIS to HLA due to recent DoD mandates. It will then be able to join other battlefield federations, allowing an entity representing the ship to participate in HLA exercises.

Information Visualization for crew training. Since the scenarios presented to virtual CIC users are simulation-driven, it is possible to generate interactive three dimensional views that display force interactions in a distributed computational environment that represents the full technical complexity of the exercise (Dennehy, 1994). Graphical 3D object representations will be loaded from HLA Federation Object Models and placed in their environment, allowing information such as sensor and weapons envelopes and antiaircraft ranges to be visualized immediately (Figure 10). This stealth or God's-eye-view can be used in combination with the virtual CIC presentation of the data, so a crew member will be able to 'see' simulated radar contacts through the radar display, then view the scenario's ground truth database with all entities, dynamic terrain, and weather events. Additional information can also be displayed in this 3D visualization system, such as regions representing sensor and weapons coverage, allowing students to visualize such things as emissions restrictions and doctrines from both the shipboard and battlespace perspectives. This information visualization can be very useful in teaching complex topics involving interactions between the ship and the environment, enhancing a student's situational awareness (Darken, 1996).

Future Plan

This is an ongoing project. The future work will develop the full virtual CIC, which involves expanding the number of consoles, ensuring that these consoles are modeled to a high degree of fidelity. This will initially involve modeling the consoles for a small team within the CIC, such as radar and SLQ-32 consoles to allow hardkill/softkill exercises. The CIC functional model will also be expanded to allow efficient communications among

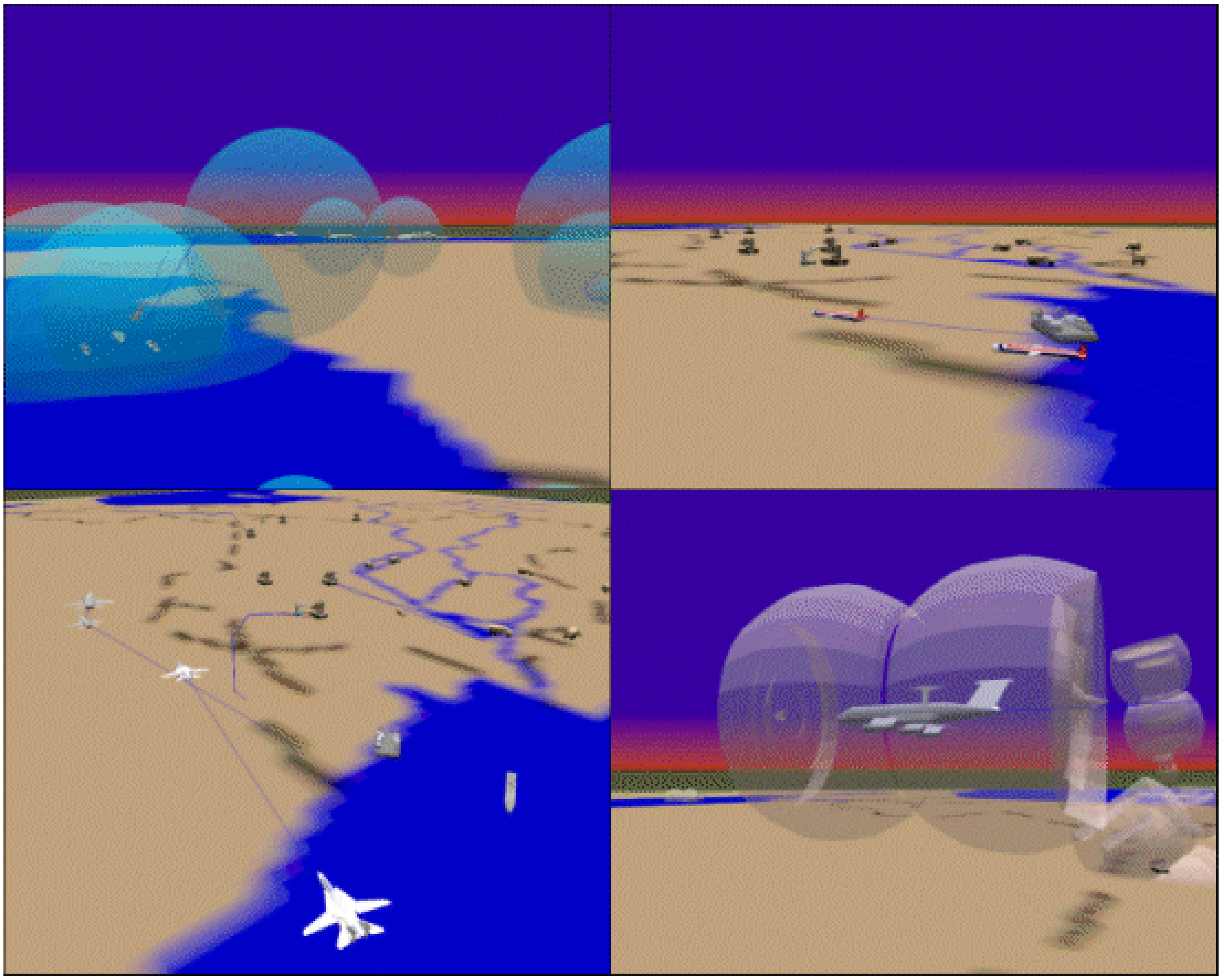


Figure 10 God's eye view of simulation environment

the various users on multiple workstations, allowing for distributed team training without regard to geographic considerations.

Most of the consoles in the real CIC are replicated in the virtual CIC, however only a few are currently functional. We plan to complete the virtual CIC by working in two areas: increasing the quality of the 3D visualization by increasing the number and quality of the geometrical models used, and expanding the usability of the virtual CIC by adding more detailed functionality for a greater number of consoles.

The main focus in the geometry is to fully populate the CIC. Work is also underway to increase the realism of the virtual CIC by adding structural detail, such as overhead ductwork, piping, and other related geometry. While this detail is not directly related to the functionality of the CIC, it does add to the sense of realism, as the lack of this detail makes the virtual CIC seem much more open and empty than the real CIC.

For the simulation and interface with the consoles themselves, the current simplistic state-machine console model will be expanded to support more detailed models which better reflect the console functionality.

Currently the virtual CIC is being implemented as a stand-alone, simulation-driven system. In order to provide a well integrated training environment, it is desirable that this system be combined with tools that support computer-based training at a high level. LNK is currently building a computer-based training system, called the Intelligent Tutoring System (ITS), for a related project. In the future we hope to expand the ITS by providing an HLA interface. Thus the ITS and virtual CIC could be linked through a common HLA federation that will provide the ability to share CIC user (student) information, and will allow the ITS to drive the virtual CIC at a high level. The ITS will provide the lessons and context to drive a scenario, and the virtual CIC will provide an integrated environment for presentation of the scenario and will provide methods for obtaining student response. Tools will be used to examine a given student's effectiveness. Based on these assessments, the ITS will be able to make conclusions about the appropriate cognitive areas that need to be reinforced or expanded. This will drive the selection of scenarios or engagements, and the virtual CIC will present these to the students.

By incorporating intelligent agents into our system, the user can perform after action reviews, analyze users' responds, and to provide feedback to the user. This task will provide added capability for capturing human expert knowledge and to provide this information as a "lessons learned" tool for applications such as training, mission rehearsal or engineering designs.

Summary

VR has permitted a more realistic training environment comparing to a class room-like environment**.** The phase I work described in this paper has been implemented and delivered to the training command. The feedback from students and instructors has been favorable. Work is underway to continue development of this system, incorporating changes and improvements suggested by the users. By incorporating information visualization tools, the students were able to learn and understand warfighting operations faster than in a regular class room environment.

By combining the virtual environment with a ship simulation model, operational procedures under various tactical scenarios were explored and refined. Simulation-based virtual environments allowed systems to be stressed in a realistic scenario without risking accidents or tying up operational hardware.

As the capabilities of VR hardware and software tools increase while their cost decreases, the virtual CIC training environment can provide an efficient and cost-effective tools for training in the future.

References

Bessemer, D. W. Transfer of SIMNET training in the Army Officer Basic Course. Technical Report 920, U.S. Army research Institute for the Behavioral and Social Sciences, January, 1991.

Darken, R. P., Hill, T. A., Solan, B. T., and Brooks, C. B. "A Hybrid Virtual Environment Interface to Electronic Warfare Information". In the Proceedings of the ASNE Modeling, Simulation, and Virtual Prototyping Conference, June 24-26, 1996, Crystal City, VA, pp. 247-259.

Dennedy, M.T., Nesbitt, D. W., and Sumey, R. A. (1994). "Real-Time Three-Dimensional Graphics Display for Antiair Warfare Command And Control". Johns Hopkins APL Technical Digest, 15(2), pp. 110-119.

Farsaie, A., Elkins, L., Ng, H., Vallo, A. "A Simulation Based Test Bed for Virtual Prototyping". In the Proceedings of the ASNE Modeling, Simulation, and Virtual Prototyping Conference, June 24-26, 1996, Crystal City, VA, pp. 281-284.

Hribar, D. C., May, D. C., and Probsdorfer, J. A. "Virtual Environment Training: Auxiliary Machine Room (AMR) Watchstation Trainer". Journal of Instruction Delivery Systems, Spring 1993, pp. 9-17.