A DISTRIBUTED VIRTUAL ENVIRONMENT FOR ARMY COMMAND AND CONTROL

Abstract: Army Command and Control facilities need the ability to function more effectively, with smaller staffs spread over a geographically dispersed area. As communications capability, visual simulation, and virtual reality (VR) have increased in capability and decreased in cost, these technologies have made distributed virtual reality applications attractive solutions for such problems.

This project is developing a set of tools which will allow distributed users to interact with existing Army command and control systems through a virtual environment. To provide immediate familiarity for existing users, the system will use a virtual model of a standard Tactical Operations Center (TOC) as the virtual environment. The system will support multiple users, allowing prototyping, evaluation, and training to be carried out in the virtual environment by users who are geographically distributed.

This paper describes the project requirements, technical approach, system tradeoffs, current accomplishments, and future direction of the project.

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Mr. Elkins received an M.S. from the John Hopkins University in 1994 and a B.S. from the West Virginia Institute of Technology in 1990, both in Computer Science. For the past several years, he has been working with virtual environments, building applications for training, battlefield visualization, and prototyping. At LNK he has worked on various virtual environment projects ranging from prototyping and engineering applications to simulation control and visualization, using both conventional human/machine interfaces as well as full immersion environments using tracked data gloves and head mounted displays. This work included design and programming for the latest revision of a virtual model of an AEGIS cruiser combat information center. He has also worked on computer vision applications, including a system for landmark recognition in an unmanned ground vehicle.

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BACKGROUND

Tactical Operation Centers (TOCs) are being given increased responsibility as command functions are being pushed to lower levels. At the same time, modularity, mobility, and survivability concerns are driving TOC designs towards distributed layouts with smaller footprints.

To meet these needs, Army user communities are creating new TOC layouts. These users need the capability to rapidly evaluate TOC designs in a realistic environment, without the expense of physical mockups. The increased capability and decreased cost in visual simulation and virtual reality (VR) tools make VR solutions attractive for such prototyping experiments.

This project is developing a PC-based environment that will facilitate design and evaluation of Command Post (CP) structures. It allows creation of and immersion into a TOC designed from a library of currently available (or new) developmental components. This will allow prototyping new equipment in a realistic virtual environment. In this environment TOC components are driven by simulations, with active interfaces and displays as well as interfaces to the outside world through High Level Architecture (HLA) and other standards.

The result of this work will be a set of tools that allows Army users to rapidly design TOCs and to evaluate them in simulation-driven environments. Users will be able to create TOCs from a library of existing and notional equipment, immerse themselves in a virtual mockup of this equipment, and interact with the equipment as it is driven from external simulations. These tools will allow Army users to rapidly evaluate the utility of new conceptual TOC equipment and layouts, train officers in TOC design, assess new or modified equipment in the TOC, and evaluate new TOC concepts in a simulation based design environment. Potential commercial applications of this technology include similar systems for architecture and engineering design teams as well as emergency and disaster response.

This effort builds on past work for the Navy, as described in a previous I/ITSEC paper (Ng, 1997). In this work we developed a synthetic Combat Information Center (CIC) for surface combatant training. The goal of the project was to create a distributed, immersive virtual reality system to complement current training capability. This allows 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. It also simulates the equipment that the crew can interact with to perform detection, classification and target engagement activities. By linking with external simulations, the virtual CIC's computer consoles can be driven by external simulated entities, including those received over Distributed Interactive Simulation (DIS) and HLA. The distributed mode of operation allows multiple users to work together in the same virtual environment regardless of physical location. Other work performed by the authors and others has dealt with prototyping of various engineering issues inside immersive virtual environments (Farsaie, 1996). This new effort extends the simulation-based design work to the user in a virtual TOC mockup.

The work described in this paper was performed as a Phase I SBIR for U.S. Army Communications-Electronics Command (CECOM). In this work we build on these previous virtual environments to address requirements for Army TOCs.

OBJECTIVES

For this project, the initial goal was an immersive virtual environment tool for command and control. As we developed the concept and spoke with the sponsoring organization and the user communities that they support, we broadened the scope to address their requirements. The proposed work will provide for:

- Rapid layout of notional tactical operation centers,
- Prototypes of Computer Aided Design (CAD) items in a virtual environment,
- Test and evaluation of equipment in a virtual environment, and
- Connection with external simulations to drive virtual equipment.

Meeting these goals will allow a system that meets needs for prototyping, design, and training. Users will be able to create and evaluate TOC designs for officer training and for new concept exploration, insert new TOC components into a realistic environment in order to evaluate them, and perform familiarization training on this new equipment before it is constructed.

As of this writing, the preliminary requirements have been formulated for the proposed system. The remainder of this paper will discuss these requirements and their planned implementation.

SYSTEM COMPONENTS

The architecture of the system is shown in Figure 1. Three groups of tools are required to support the shared, distributed virtual environment for the TOC. The first group - prototyping tools - deals with the capability to prototype TOC layouts, including the ability to support CAD formats directly, the ability to include prototype equipment, and the ability to use this data to build TOC layouts. The second group - virtual environments - includes the tools to create the virtual environment that will use the TOC layouts created, that will display the virtual environment to the user, and that will support the definition and functionality of the active components in this environment. The third group - connectivity - will provide capabilities for objects in the virtual environment to interact with the outside world and with other users of the TOC through HLA and other networking standards.

These tools are discussed and illustrated in more detail below.

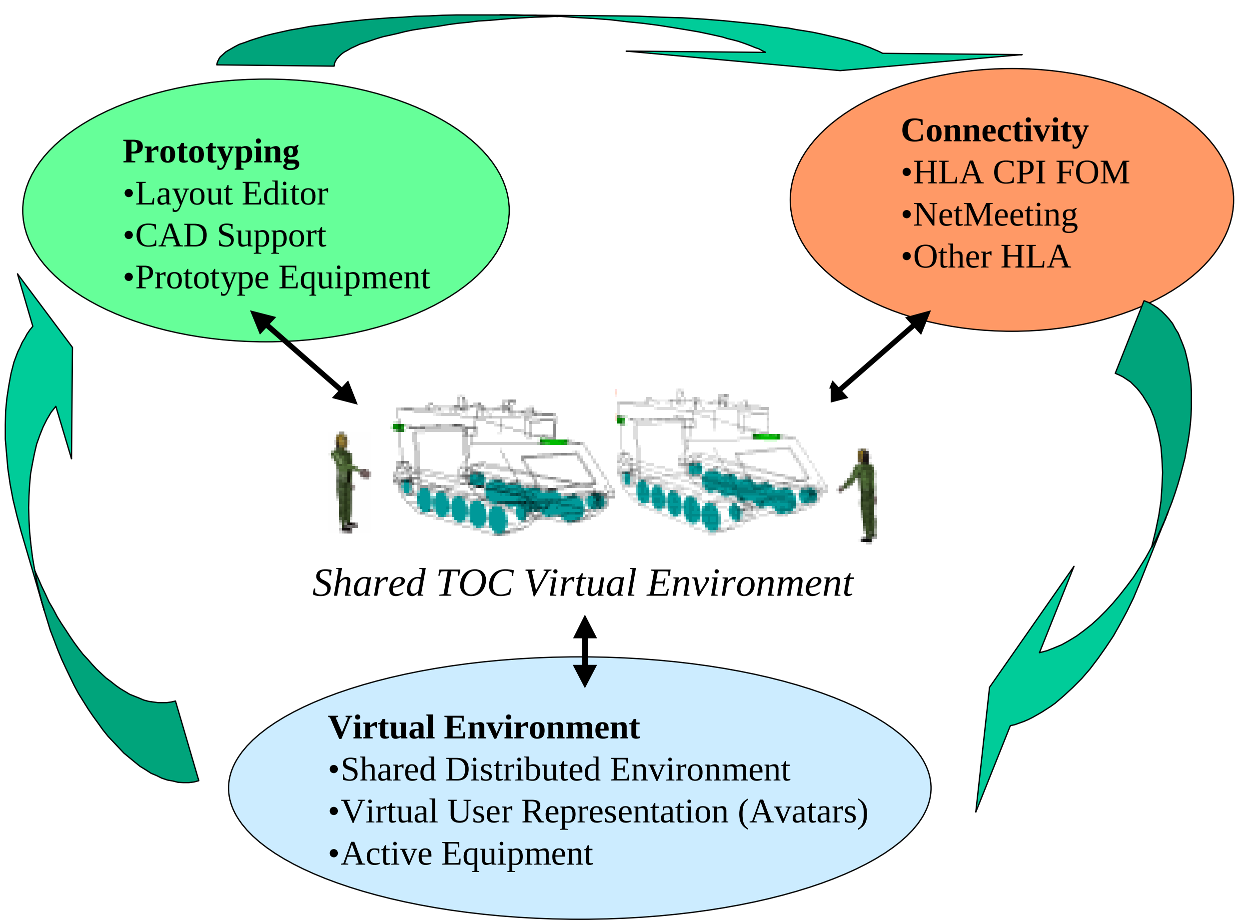

Figure 1. Overall Proposed Architecture

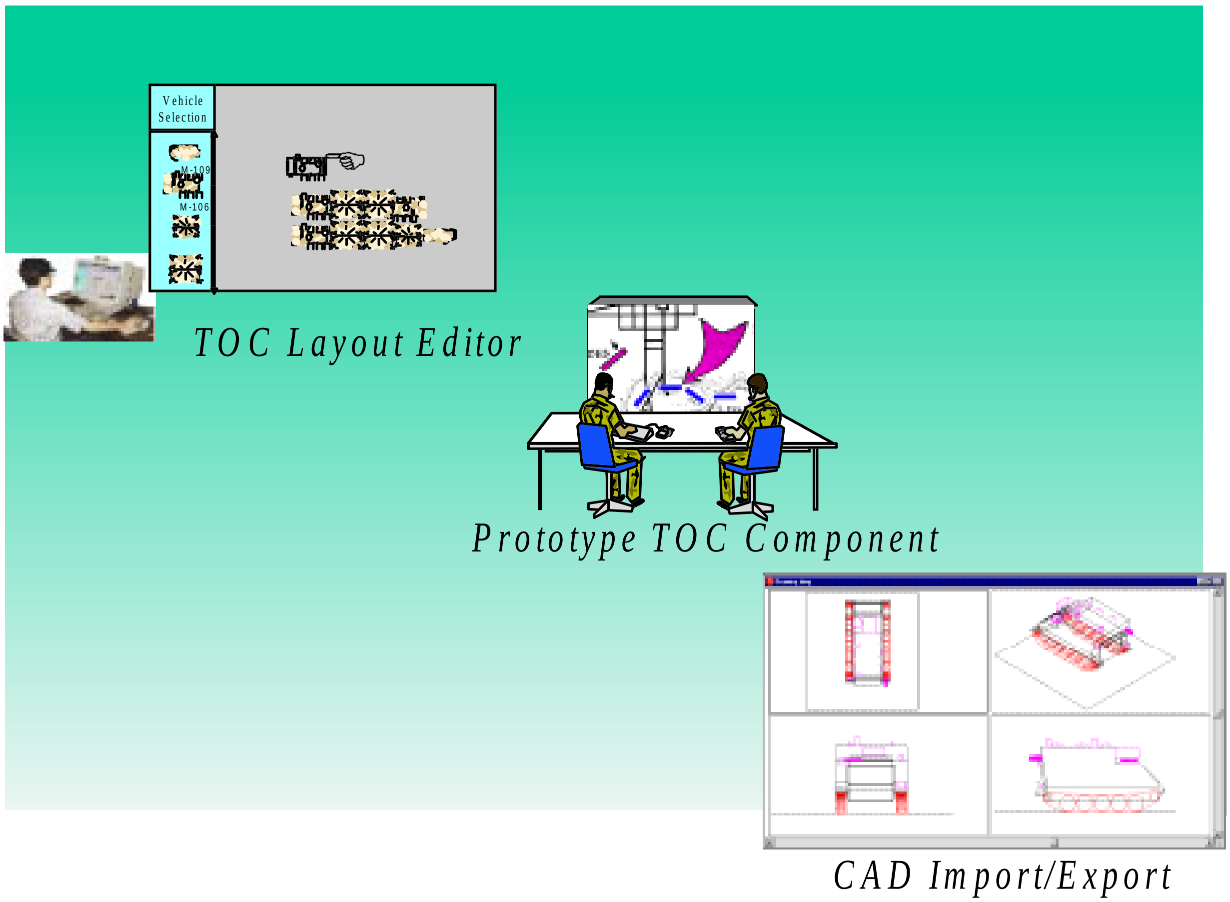

Figure 2: Prototyping Tools

Virtual TOC Editor

The capability to rapidly generate TOC layouts is critical for this project. The requirements for such an editor include:

- The ability to support CAD data directly - as well as OpenFlight and other vis-sim model formats
- The ability to operate in a distributed mode so that multiple users working together can create a TOC layout
- The ability to export the layout into a form that can be rendered by a virtual environment
- The ability to export the layout back into a CAD usable format for documentation purposes

The tools for prototyping, as shown in Figure 2, will allow the user to quickly generate TOC layouts for design or training. Facilities to read and write CAD files will be included as well as the capability to insert object models from prototype CAD files or the design studies.

An editor capable of allowing the user to rapidly create TOCs must be provided. It must allow straightforward creation of the TOC layout from a library of components. It must also be capable of operating in a distributed mode, where users will work together to create a common design at networked computers. These requirements rule out most CAD and visual simulation editors.

The requirements for the finished tools are:

- The ability to take a library of common TOC components and build an arbitrary TOC from them
- The support of visual simulation formats such as OpenFlight, and CAD formats such as Pro/E, and CATIA, required by the user community
- The ability to create custom behaviors to manage desired additional functions, for example, Center of gravity computation
- The ability to take the created layout and be read it into a virtual environment
- The ability to allow users to create and edit the TOC layouts in a collaborative environment thereby allowing multiple users to work together at different computers connected by a network

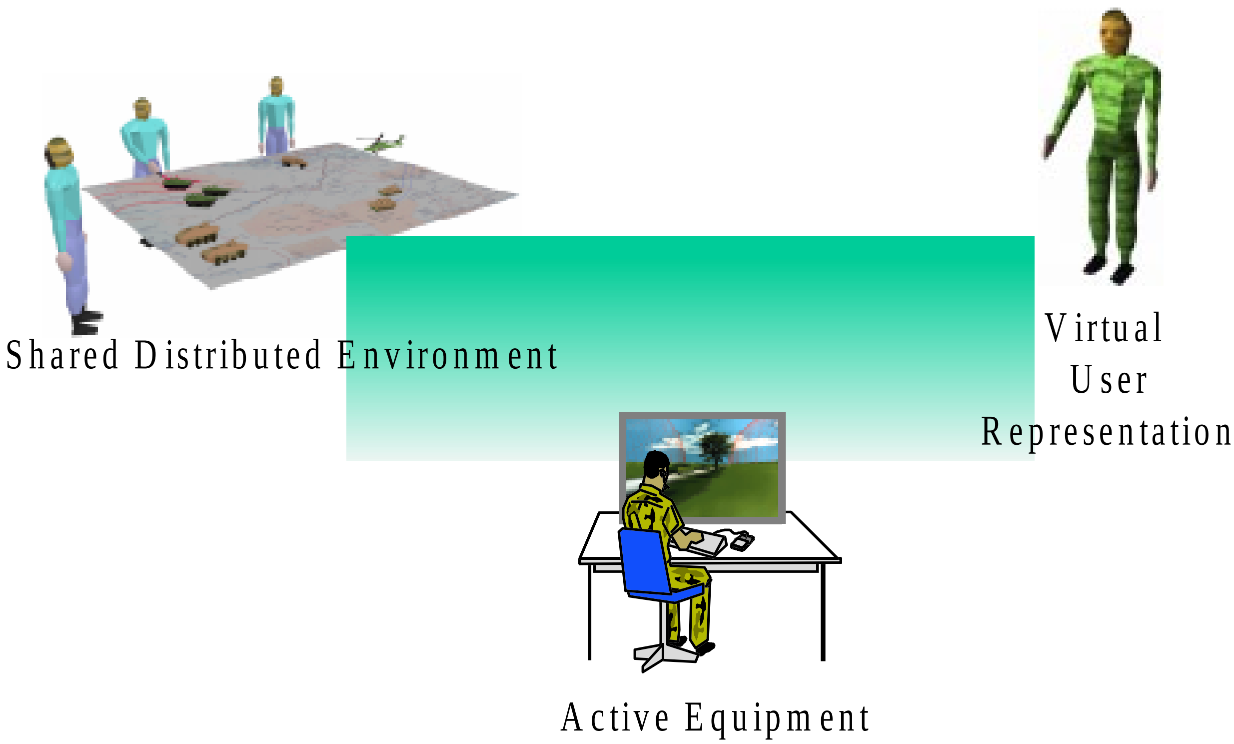

Figure 3: Virtual Environment Tools

As part of our initial study, we have examined and evaluated related COTS software that allows rapid generation and analysis of databases from CAD data. While these packages seem promising for performing the basic TOC editing functions, they seem to lack the capability to support the immersive environments that we require. Our current plan is to use COTS software as practical. As the project continues, we will continue to evaluate our needs, and when the time for implementation comes we will choose among available COTS offerings or a custom implementation based on the Microsoft/SGI Fahrenheit visualization environment.

TOC Virtual Environment

Figure 3 shows a set of tools that will allow distributed users to view and interact with the virtual environment. A shared virtual environment shell will manage the presentation of the shared TOC to the multiple users of the system. The virtual environment shell will allow active equipment components to be loaded based on the TOC layouts previously generated. While the users are immersed in the virtual environment, their presence will be communicated to the other distributed users through avatars and other collaboration techniques.

The component layout created in the TOC editor will reflect the geometric arrangement of the TOC. However, we would like to be able to view active displays on equipment and to let the user work on this equipment in the virtual environment. Furthermore, we would like to do this while that equipment is communicating with the external environment. We also wish to be able to use Head Mounted Displays (HMDs) and other immersive peripherals to gain a first-person view of an active TOC, and we plan to create a visualization system built on Fahrenheit for rendering. This shell will load in the TOC layouts created with the editor and generate the background simulations for the active equipment. The user will be able to move through the environment with either the mouse/monitor or the glove/tracker/HMD, and interact with active equipment appropriately.

VE Shell

A system that will load and manage scene components (humans, active equipment) will be written using Fahrenheit to do the scene graph management. The shell will manage human models and equipment that will exist in the form of lists of C++ objects. Each object will contain a set of base interfaces that the shell will use to interact with the object. Particular models will be driven by a class derived from the base class, so the shell can use polymorphism to call the appropriate methods in a given object without requiring knowledge about the object's particular class. The base class will be discussed later in this article.

Human representation. Each user's representation will be projected into the virtual environment. Each client station will be able to reflect the position and intention of its user into the virtual environment. The reflected humans will be visible to all users. This work will leverage off the HLA Starter Federation Object Model (FOM) under development.

COTS tools will be used for the human model. In the distributed environment, each shared TOC application will control one human model. Each time the user's position in the environment is updated, the application will reflect the new position information to the other applications.

Additional functionality will also be added to provide hand position by examining tracker information and using inverse kinematics to generate appropriate arm positions. For non-immersive applications, the human's position will be modified by appropriate keyboard/mouse commands and hand positions will be generated to point at items clicked on or otherwise selected by the user.

Voice communication in the virtual environment. In a distributed environment, users might be working or training together in the virtual environment, but physically located in different rooms or different states. Voice communication in this environment will be required for user interaction. We plan to use the NetMeeting Application Programming Interface to integrate voice communication over the network at the application level.

User interface. We plan to develop modules for the VE shell that handle user interactions in an independent manner. Handlers will be created to support the expected user controllers and output mechanisms. These will include keyboard/mouse for through-the-window views of the virtual environment. Planned support for virtual reality hardware includes the Polhemus FasTrack position trackers, 5th Glove data glove, and display to Virtual i-o HMD for immersive environments. Supporting these virtual reality peripherals will allow the system to operate in CECOM's existing Soldier Station testbed.

Active Objects in the Virtual Environment. In work related to this project, LNK and SIS populated virtual environments with active, functional equipment by creating a class library to encapsulate the functions of each object, and to associate that functionality with the geometric representation in the virtual environment. This project uses a similar approach. The TOC editor creates TOCs by building them up from component libraries. The components are managed by a set of C++ classes that contains the state information for the various pieces of equipment. Each class manages the state, response to user interaction, displays, and input/output of the particular equipment. Base classes and polymorphism are used to simplify the architecture of the virtual environment handler, as well as to make it easy to extend the number and type of equipment supported by the system.

The user interaction managers work with the virtual environment to enable each piece of equipment to – for example - respond to user input by touching buttons or moving components.

The active equipment in the TOC layouts have screens which display their outputs in the virtual environment. This may be done by two methods: OpenGL data rendered into the virtual environment or bitmaps rendered as textures. More complex displays - particularly those that display video - require bitmaps to be rendered in the virtual environment. Furthermore, displays in the virtual environment are designed to be readable by the users. The issue of resolution of the virtual displays was resolved by introducing the capability to map a given display to the user's full screen if necessary.

Object Connectivity. Interaction between the equipment handler classes and the external environment is supported by two mechanisms: NetMeeting and HLA. To allow multiple distributed users the ability to interact with external applications from inside the virtual environment, we use NetMeeting - a Microsoft standard and the API for performing conferencing tasks in Windows environments. By employing this standard and integrating it into the virtual environment, we will be able to support many Windows applications as well as conventional audio and video teleconferencing.

In order to interact with several existing CECOM applications, this work will also develop an HLA interface to the CECOM Collaborative Planning Infrastructure (CPI). The CPI currently supports several command and control applications developed in CECOM. In order to interface with this work, we have designed an HLA application that will allow components in the TOC virtual environment to interact with other CPI applications. An HLA gateway will be implemented that links the CPI environment with HLA, communicating CPI events to an HLA FOM and vice-versa. Creating this gateway will allow the equipment

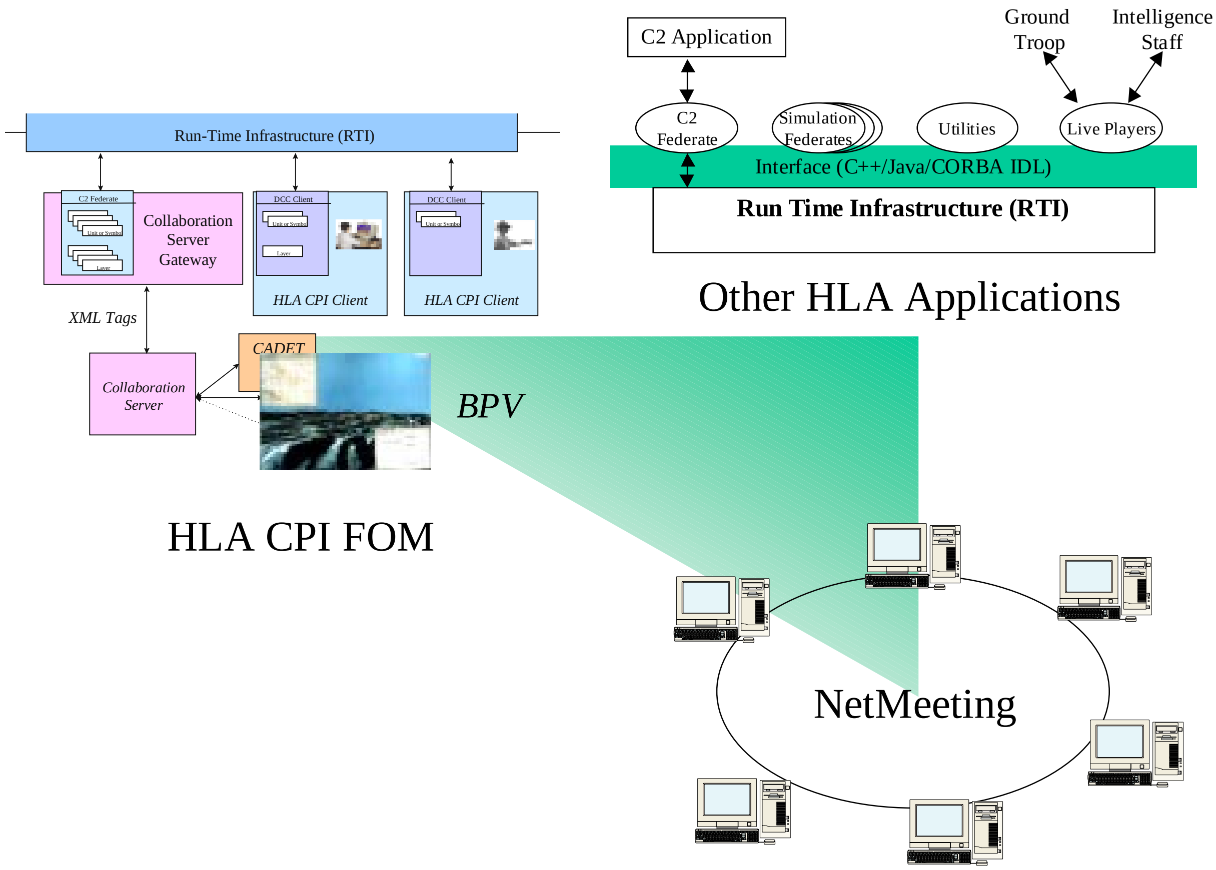

Figure 4. Connectivity Tools

in the virtual TOC to access to several existing C2 tools, and will allow CPI applications to interact with other environments over HLA in the future.

Figure 4 shows the tools that will provide connectivity for all of the TOC active components. The interrelationships that exist among the CPI HLA FOM, Net Meeting and the other HLA Applications are shown schematically. These tools allow the TOC components to communicate with each other and the outside world. The major components are the HLA CPI FOM, Net Meeting software and other HLA applications.

EDUCATION AND TRAINING

The initial focus of this work was to support evaluation of new TOC concepts in a realistic virtual environment. However, this capability easily lends itself to supporting training initiatives on several levels.

First, the ability to create custom TOCs and evaluate them in a virtual environment is useful for new officers being trained in TOC design. Trainees can assemble standard TOCs and modify them in the virtual environment. This will allow them to gain insight into the design choices made, envisioning the tradeoffs selected above and beyond what they can do with the 2D drawings currently used.

Additionally, the capability to interact with the TOC equipment in the virtual environment makes it possible to familiarize operators with the equipment they will be using in the virtual environment before having to go to a mockup or real TOC to see it in operation. This will allow lower level training to take place in equipment operation on a low-cost PC, freeing expensive equipment in the real TOCs for use at later stages of training.

The distributed nature of the system allows multiple users to operate in the same virtual TOC through HLA. Users can train together in the same TOC, on the same tasks, over network connections. This allows trainees to work together even if they are geographically distributed.

Finally, driving the simulated TOC from external simulations allows scenario-based training. Teams can be run through an engagement in the virtual environment, interacting with the simulated outside world through the virtual TOC equipment.

FUTURE PLANS

As of this writing, the Phase I research project is almost complete. Our plans to implement and extend this work are discussed below.

Address Simulation Based Design/Acquisition. The initial work proposed for the Phase II will provide a realistic environment to test and evaluate conceptual systems, built from a library of existing and notional equipment, shelters, and vehicles. With the ability to stimulate these systems with simulated data, we will be able to provide a testbed to support simulation based design and acquisition programs. During the course of the Phase II development we will work towards a system that includes the necessary hooks and interfaces to provide this capability to address simulation based design needs.

Support for needs of user community. During the Phase I research we spoke with potential users of this work at CECOM and Fort Leavenworth. While we have attempted to address the majority of their needs in the work plan, the number of users we spoke to makes it impossible to address all of their requirements in this stage of development. As the work progresses, we plan to work with the various communities to integrate particular simulations and equipment models of interest into our virtual environment.

Integrate with related CECOM efforts. By supporting CECOM's Collaboration Server and adding an HLA interface, we will be able to provide a backbone for C2 communication among HLA-enabled systems. Extending this portion of the work to support other related CECOM simulations and systems is of interest to us.

Development of the work described in this paper will enable us to address the needs of a wide variety of users. We will provide support to simulation based design for the developers of experimental TOC equipment, support to the officer in school learning the tradeoffs of various TOC designs and finally support to the officers in the field working to rapidly create a TOC design to meet the particular situation's needs. Thus we will have built a tool that meets the requirements of a number of users.

ACKNOWLEDGEMENTS

This work was supported by the Army SBIR program and CECOM. We are grateful to Dr. Israel Mayk for providing guidance as the COTR and to John Langston of EER Systems for providing assistance with the user community at Fort Leavenworth.

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