

## VICC: Virtual Incident Command Center

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### Abstract

*This paper describes an application of telepresence technology to the incident management domain. The system combines national guidelines for incident management with many aspects of collaborative virtual environments to enable effective communication between first responders in the field and remotely located command personnel. A brief overview of existing incident management systems is given followed by a set of requirements for future systems. We then describe our virtual incident command center (VICC) prototype, explain how it addresses the requirements, and outline our future plans. Finally, we report feedback from ongoing demonstrations of the prototype system that supports our contention that VICC represents a unique solution to the incident management problem.*

**Keywords---** incident management, incident command, virtual incident command center, VICC

## 1. Introduction

Recent world events have highlighted the need for standardized processes for incident management that span organizational, geographic, and political boundaries. The terrorist attacks on the World Trade Center and the Pentagon, the hurricane Katrina disaster, and the Indian Ocean tsunami of 2004 are just a few examples of large-scale catastrophes that underscore the need for technologies and procedures to enable on-the-spot decision-making, interagency coordination, and the ability to rapidly adapt to changing circumstances. Incident management systems are used by emergency responders to address these problems by establishing command structures, supporting approved operational procedures, and managing resources during an emergency. Communication and coordination between responders is a critical element of incident management. Interactive communication typically takes the form of face-to-face meetings, phone calls, or radio exchanges. Additionally, incident management requires persistent documentation and tracking of resources, organizational structure, and task assignments. These forms of communications include whiteboards, paper documents, and more recently online database systems for data management. Incident management operations become more complicated if: (i) the personnel involved are

geographically dispersed, (ii) the topics of discussion require visual information such as maps, diagrams, photographs, and documents, or (iii) the results of discussions need to be documented and communicated.

This paper describes the *Virtual Incident Command Center* (VICC), a prototype application that supports incident command by integrating interpersonal communications with collaboration capabilities involving shared materials like documents, images, and 3D location data. VICC uses a 3D room metaphor to give geographically dispersed users the experience of being present at the same location and engaging in face-to-face interactions. The VICC user interface utilizes three-dimensional maps and interactive displays that can enhance users' awareness of an incident site and give them more control over their information management and decision-making processes. Participants can join or leave conversations as needed, allowing the summoning of remote expertise when necessary.

We begin with an overview of incident command systems and requirements; then, we describe the VICC system and its features.

## 2. Incident Management

Incident commanders have unique needs for information from the incident site, for additional information from multiple agency and emergency operations center databases, and for sharing information about the incident with key federal, state, and local government agencies. These needs present a complicated technology challenge. The technology needs to be able to provide real-time communications, data transfer, heterogeneous database access, and interoperability for voice and data communications.

### 2.1. Incident Command System

The Occupational Health and Safety Administration of the Department of Labor maintains documentation and training information for an Incident Command System (ICS) [1] in support of a National Response System. ICS had its origin during the California wild fires of the 1970's. These fires quickly spread across several counties involving many jurisdictions and many different agencies. A common system was needed to manage administration, planning, logistics, finance, and command operations for all of the agencies involved. As a result, the California fire service created ICS to be an emergency management system standard. Its goal was to eliminate problems when supervising people and

organizational structures, site information, communications, coordination, planning, terminologies, technologies, and the conflicting objectives of different agencies by specifying rules of hierarchy and interaction between these parties.

ICS was created to provide a management structure as well as a system of best practices for conducting on-site operations. It is applicable to small-scale daily operational activities as well as major mobilizations. ICS provides command center and operational staff a standardized operational structure and common terminology. Hence, ICS is a useful and flexible management system that is particularly adaptable to incidents requiring multi-jurisdictional or multi-disciplinary responses. ICS provides the flexibility needed to rapidly activate and establish an organizational format around the functions that need to be performed during an incident.

There are several disadvantages with this system, however. One is the requirement that all management personnel be collocated in order to work together. This not only increases the time to create an ICS but also makes it vulnerable to failure or attack. On September 11, an ICS was setup at the incident site itself inside the World Trade Center. It was lost when the building collapsed. Another disadvantage is that ICS does not specify ways to leverage technology in order to make incident management processes more effective. These disadvantages led to the development of Virtual ICS.

## 2.2. Virtual ICS

Virtual ICS is a concept wherein command center participants can share information, make decisions, and deploy resources without being physically present in the command center. Computer terminals and computer networks are used to communicate and share data. This shortens the time needed to setup a command center while also making the command center more resilient by allowing it to continue operating even if one part becomes damaged. These systems rely heavily on web-enabled software. Virtual ICS allows participants to work from their normal workstations, from home, or in the field. Emergency plans and reports are available at any location. All information can be maintained in a central database that is available to command center participants from anywhere in the world. There are many commercial virtual ICS software products available.

These systems are a definite improvement on the basic ICS approach but they give up some of the intangible benefits of the original. Because participants can be remotely located, their ability to collaborate is hampered. Communication is limited to video conferencing at best, but typically uses phone lines. The ability to read body language and gestures is lost. Information sharing is also hampered by this approach. In the classic ICS methodology, the participants can open up a map, lay it on the table, draw on it, point to features, and plan with it. This interaction is lost in virtual ICS. These key sources of information and

methods of planning must be communicated by low-technology means. Each participant's information is limited to the size of his display, providing a small portal into the world. This may require the use of multiple displays or it may force the participant to supplement what is on his display by other means (e.g. sticky notes) to organize information that cannot otherwise be displayed.

## 2.3. National Incident Management System

In 2003, the presidential directive HSPD-5 called for the creation of a national incident management system (NIMS) [2] to provide a consistent approach to federal, state, and local operations when responding to domestic incidents of any size and nature. HSPD-5 required all federal government agencies to adopt NIMS as part of the National Response Plan. The NIMS plan goes beyond ICS by addressing multi-agency coordination issues (i.e. unified command) organized by functional discipline (e.g. fire, law enforcement, medical, etc.) NIMS also called for research and development to solve operational problems and develop new incident management capabilities.

## 2.4. Unified Incident Command and Decision Support

The National Memorial Institute for the Prevention of Terrorism (MIPT) published a plan, "Project Responder: National Technology Plan for Emergency Response to Catastrophic Terrorism," [3] recommending technology investments in specific areas to improve the twelve National Terrorism Response Objectives it identified; chapter IV in particular focuses on unified incident command, decision support, and interoperable communications. Multimedia Supported Telepresence (recommendation UIC.5) is expressly identified as one of the Needed Functional Capabilities and Priorities for unified incident command. This report assessed the current and near-term telepresence capabilities for incident management to be marginal.

Building upon the recommendations in Project Responder and the NIMS research recommendations, the Department of Homeland Security (DHS), through its Advanced Research Project Agency (HSARPA), solicited proposals for an information management and sharing architecture to support emergency responders and commanders in their tasks [4]. Section 3 of this solicitation notice contains the requirements for a unified incident command and decision support system, henceforth referred to as the UICDS requirements. These requirements subsume the ICS/virtual ICS features, Project Responder recommendations, and NIMS requirements. The UICDS requirements are divided into five broad categories:

1. Seamless Integration
2. Information Integrity
3. Comprehensive Information Management
4. Information Sharing

## 5. Multimedia/Multimodal Communication

### 3. Virtual Incident Command Center

We developed the Virtual Incident Command Center (VICC) with the UICDS requirements in mind. VICC brings together many different technologies and integrates them into a powerful new tool for first responders. VICC uses 3D graphics technology to bring people and multimedia data together for easy and effective collaboration in a virtual meeting space. Issues of information overload are addressed by organizing the space in layers where the individual's specific tasks are displayed in the foreground, an incident scene map annotated with responder information is shown in the center of the space, meeting collaborators are arranged around the scene map, and streaming media resources are presented in the background. VICC is intended to permit a geographically dispersed command team to efficiently communicate about an incident and also to enable remotely located subject matter experts to quickly join and participate in the incident management process.

#### 3.1. Architecture

**3.1.1. Flexible Design.** For a command center to be effective it must be easy, simple, and quick to establish. VICC is a TCP/IP-based client-server system in which the individual clients (i.e. participants) only need to know the IP address of the server to establish a connection. Clients connect via a fast, automated process through which the server configures them based on their access privileges and needs. This provides a flexible design in which new clients and devices can be integrated into the system simply by assigning them (or identifying their existing) IP addresses. This has the added benefit of being able to work with any national incident management infrastructure and eliminates the need to have on-site hardware at an incident location.

Clients can access the system through different devices. There are only a few requirements for these devices. They should have Java virtual machines, 3D graphics capabilities, and minimal amounts of memory to run the client application. They should also be easily configurable or pre-configured to work with simple intuitive user interfaces so that participants can focus on the incident instead of the devices. Once a client is activated, it connects to one or more servers to retrieve lists of available users and organizations. The participant can then immediately begin to interact and collaborate with these groups.

**3.1.2. Scalability.** Incidents may start small and then grow larger over time. VICC was designed to be scalable to handle large numbers of participants who simultaneously log into the system, organize themselves, and share information. The maximum number of participants in VICC is only limited by the available network bandwidth; the number of participants that the system can support decreases as the amount of data they

share increases. As more participants are added, the data transfer rates between the clients and servers will also be affected.

**3.1.3. Multiple Platform Support.** The client application was developed using Java to be platform-independent. The graphics are based on an OpenGL implementation of the Java Mobile 3D Graphics (M3G) API for J2ME [5]. This API has a small footprint so that it can be used on small handheld devices as well as large workstations, supporting our goal of enabling many different devices to access the system.

**3.1.4. Fault Tolerance.** VICC was designed to be robust in the face of connectivity problems. If network connections are temporarily lost, both client and server attempt to reestablish the connection. If a server is temporarily disconnected from the clients, the clients will update the server with their current states upon reconnecting. If a client was temporarily disconnected, the server will reset the client's state after reconnecting.

#### 3.2. Collaboration

Enabling collaboration is the fundamental reason VICC was developed. Participants should be able to customize their environments to display data that is relevant and appropriate for their tasks. They should also be able to organize and control the flow of data so they aren't overwhelmed but have access to the critical information they need for decision-making. They should be able to draw on, point to, and manipulate a 3D object like a map of an incident site in real time in conjunction with other remotely located participants. Their interactions should be as natural as if they were seated around the same table. All body language and gesture communication should be preserved while still leveraging all the qualities of a virtual ICS.

**3.2.1. Virtual Environment.** VICC is a fully interactive 3D virtual collaborative environment designed to meet incident command requirements. VICC can be viewed on a variety of displays: head-mounted displays (HMDs), computer monitors, wall projectors, and handheld device displays. Computer monitors and wall projectors offer the best views of the virtual environment as far as clarity and size are concerned as well as simple interaction capabilities via keyboard and mouse connections whereas HMDs create a more immersive experience but make interaction more difficult. Figure 1 shows a screenshot displayed on a computer monitor of an Operations Center room within VICC from the point of view of one particular participant. This room contains several big screens on the walls for displaying live video feeds, still images, documents, or applications. There is a virtual table around which other participants may be "seated" as they join the room. There are panels around the room with various customizable buttons and displays. The buttons can be set to trigger applications or events and the

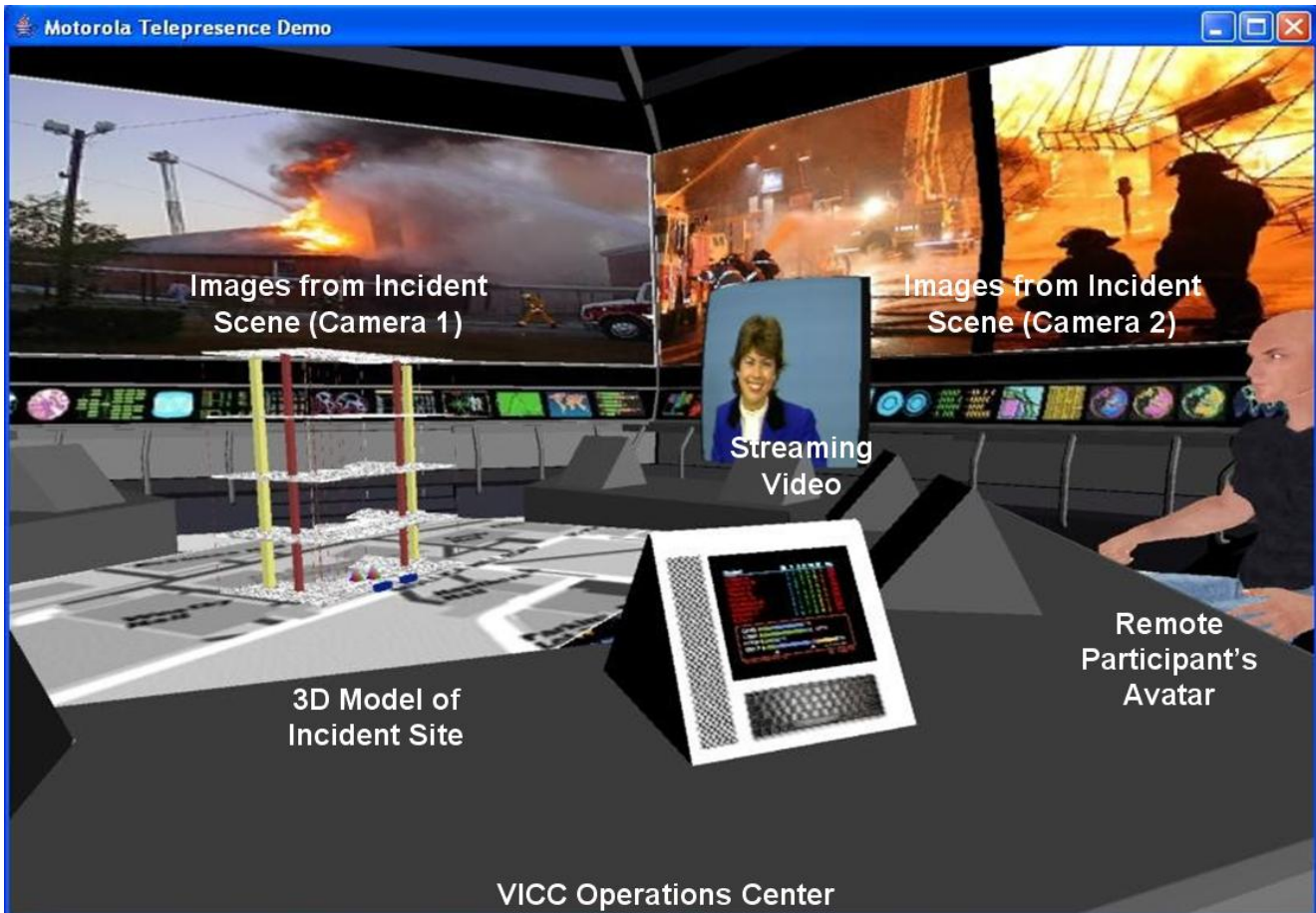


Figure 9: Virtual Incident Command Center Operations Center Screenshot

displays can be configured to show any content source associated with the room. This room is only one possible configuration among many; by modifying the underlying 3D model, we can change the appearance and layout of the room.

A key aspect of 3D environments is perspective. VICC incorporates this concept to give participants a common context when discussing elements of their shared environment. For example, if participant A is to the left of participant B, participant C will see the same relationship between A and B from his viewpoint. This gives consistency to verbal descriptions given to other participants, e.g. “look at the image over participant D’s right shoulder...” This is an example of the quantitative awareness described by Greenhalgh and Benford [6] and also an application of the “What You See is What I See” and “Peripheral Awareness” principles highlighted by Redfern and Naughton [7] as crucial to computer-supported collaborative work environments.

Another important capability of 3D environments is the incorporation of visualization tools. VICC supports both 2D and 3D visualization tools as well as multimedia applications. These will be discussed later.

**3.2.2. User Interface.** The VICC user interface was designed to be very user friendly. Originally there was

no graphical user interface (GUI) beyond a client window into the 3D environment that allowed interaction through keyboard and mouse events. However, as more features were added to the system, a minimal GUI was added to manage group affiliations, active user lists, and a few client applications that were integrated with VICC. The latest GUI is still simple, but intuitive to use and thus easy to deploy. New users will not be overwhelmed by the complexity of the GUI nor will they need to read through extensive documentation to begin using the system.

**3.2.3. Levels of Interaction.** There are various levels of interaction in VICC. VICC participants can easily interact with each other through their avatars and voice communications. Participants can interact with the environment through the GUI and client applications such as a 3D pointer to share and exchange information.

Each VICC participant is represented by an avatar. The avatar is the virtual representation of the participant in the virtual environment. It handles all communication and interpersonal interactions. The avatar can be something as simple as an image or an icon or it can be something as complex as a realistic three-dimensional full-body model of the person that is animated by parameters calculated through motion and position

tracking algorithms. Three-dimensional avatars are preferred because they can be manipulated to show viewpoint and attention, although it is understood that not every client will have the necessary hardware or capacity to use utilize such an avatar. Such participants can, however, still be represented by a static full-body avatar with audio capabilities. Alternatively, they can participate via an audio/video connection as described by Sun et al. [8].

Participants will always convey their presence in the conversation regardless of how they connect to the system. For example, if a participant is in a fully immersive setup, his avatar will appear in the conference fully animated and fully expressive. But another participant who is connected via a desktop PC may only have an avatar that conveys audio.

In support of the interactive nature of the environment, each participant's avatar will have a mouse-controlled 3D pointer to indicate or manipulate objects in the virtual environment. The pointer's orientation, length, and appearance can be modified by the participant or hidden if not needed. Figure 2 shows a participant viewing an object being indicated by another participant's pointer.

Every object in the virtual environment can be selected and manipulated. For example, the material properties of any virtual object's surface can be changed by first selecting it with the pointer and then changing the desired property via a popup dialog window. Objects can be moved and rotated to enable viewing fine details if necessary. As an example, a 2D map may be loaded into the room and rotated or scaled to enable the participants to identify important sites or routes.

**3.2.4. External Data Sources.** VICC currently maintains a database of virtual objects and their states to synchronize the views of all the active clients. However, the Seamless Integration and Comprehensive Information Management portions of the UICDS requirements call for the capability to access predefined data sources and use easy-to-construct/integrate databases. VICC does not yet have the capability to integrate existing databases, but it does have the capability to access predefined data sources. For example, VICC can receive streaming biometric data from first responders and then display that data to the incident commander.

**3.2.5. Standard Terminology.** VICC is intended to be a solution satisfying the UICDS requirements subject to the common terminology and nomenclature specified in the NIMS standard.

### 3.3. Information Management

**3.3.1. Multimedia Support.** VICC supports the simultaneous display and presentation of many different data sources. The virtual environment can contain multiple display screens, each of which can display a

separate video stream. For example, multiple cameras may be set up around an incident site to provide different views of the scene that can simultaneously be viewed by the incident commander. A participant in such a scenario may need to selectively tune out distracting elements and focus on a single, important video source if necessary (Goebbels and Lalioti [9] investigated factors affecting collaborative virtual environments, including video and audio.)

The display screens can also be used for other content, e.g. still images or slide shows that can be controlled by the participants. Alternately, text documents, web pages, and streaming data can also be displayed. Software applications could be incorporated into VICC if desired, although VICC was not built upon groupware foundations as described by García et al. [10] or embodied in Tixeo's Workspace3D product [11].

The display screens do not have to be fixed to the room. They can be free-floating "billboards" that can be moved around, made translucent, or completely hidden to give the participant leeway to organize the information and layer it in a useful and appropriate way to prevent information overload.

**3.3.2. Selective Information Sharing.** VICC was developed around a multiple work context paradigm to organize and selectively share information. Different work contexts are represented by virtual rooms in the shared environment. A virtual room is the space where all dialogs and interactions take place, similar to Huang and Ma's concept [12], except in 3D. Virtual rooms can contain tables, chairs, screens, and other objects in the same way that physical rooms do. Virtual rooms can change in size and appearance and can be customized to meet the demands of any situation.

Participants can be invited to a room to join a conversation or collaborative session. Given appropriate permissions, participants can be present in many different rooms at once, although only one room will have the participant's focus at a time.

Participants can alternately be prevented from entering a room based on access privileges and security protocols. Private rooms can be created for selected individuals to discuss confidential information in parallel to public meetings taking place in other rooms.

In support of NIMS and the UICDS requirements, participants may be grouped together by functional areas, security levels, and/or areas of expertise. Each of these groups can have its own room.

As an incident grows from small to large, new rooms can be added. For example, the finance department of the incident command team may require the addition of several people to its staff. A new finance room can be created to contain all the people needed to manage the budget of the incident. The lead finance team member can maintain a presence in both rooms to manage the finance operations and report to the incident commander.

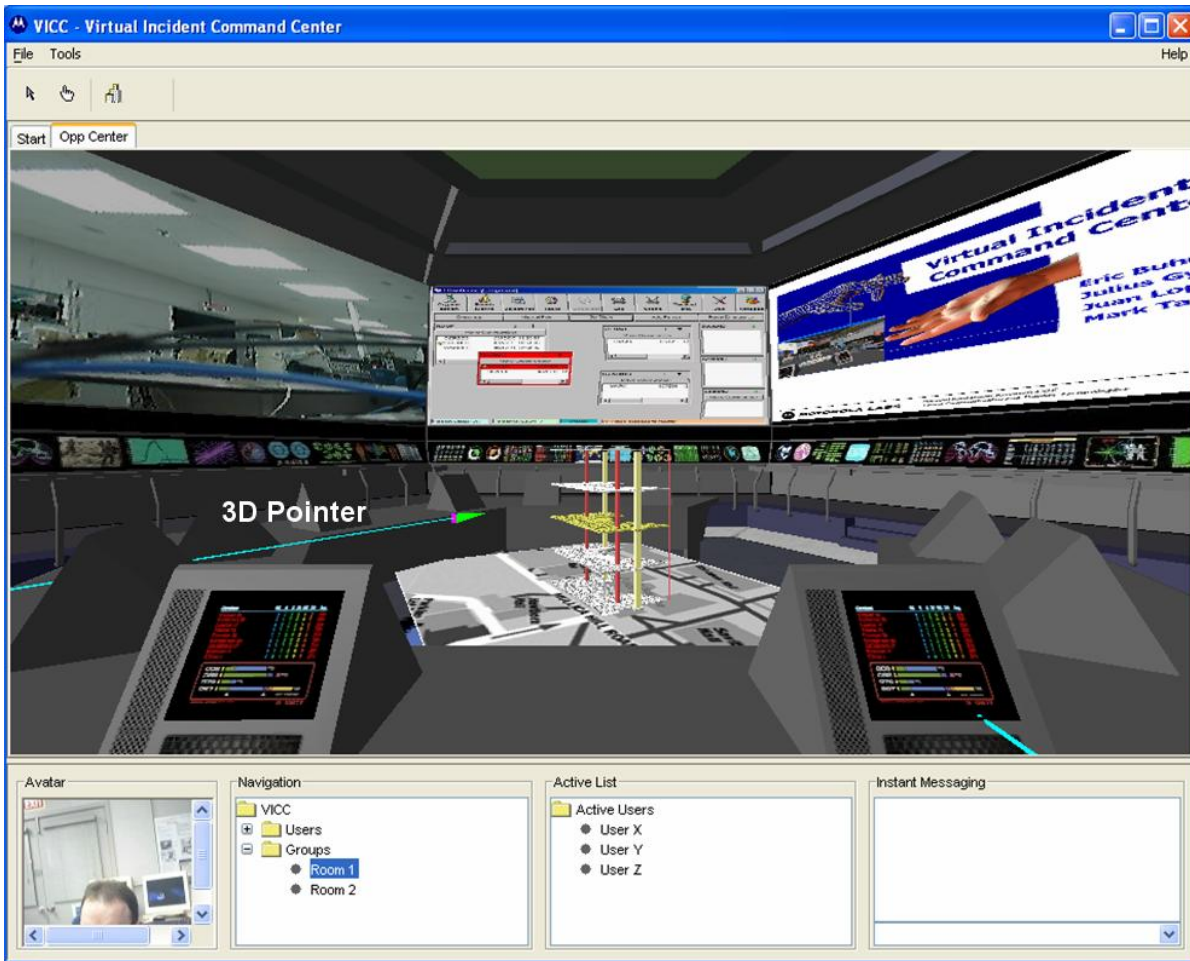


Figure 10: Remote Participant using 3D Pointer to Indicate Model of Incident Site

**3.3.3. Graphic Location Displays.** Yet another benefit of the 3D world is the ability to include three-dimensional objects in a discussion. These objects can be analyzed, manipulated, and animated (see Pinho et al. [13] for a cooperative object manipulation framework and Hindmarsh et al. [14] for an object-focused interaction study.) One example of such an object is a building model. A 3D model of an incident can be loaded, if available, and manipulated, viewed, and annotated by the participants to examine floor plans, evacuation routes, etc. Additionally, if streaming location data is available for the responders on the scene, this data can be mapped in real-time onto the build model to help keep track of everyone.

**3.3.4. Logging Incident Information.** VICC currently maintains logs of system calls, object state changes, and client-server messages. However, in order to be fully compliant with the information logging requirements of the Comprehensive Information Management portion of the UICDS requirements, we will need to add the capability to record all the actions that take place in the virtual environment to provide

source material for post-mortem evaluations of incident responses and lessons-learned documentation. It will also be necessary to add the capability to index and cross-reference this information with other data. These last two capabilities are currently lacking in our system but will be dealt with in the context of decision support.

**3.3.5. Decision Support Capability.** Decision-making is a key duty of an incident commander. Decision-making requires timely access to information, logging the processes involved, gaining rapid access to subject matter experts, and getting rapid approvals. Decision support capabilities in VICC will augment the incident commander's own competencies with knowledge management applications to assist these activities. We are currently investigating this area, including existing work in the area of situation awareness in command in control settings such as the TADMUS project [15].

Table 1: VICC Features Mapped to the UICDS Requirements.

		DHS UICDS Reqs				
		Seamless Integration	Information Integrity	Comprehensive Information Mgmt	Information Sharing	Multimedia/Multimodal Communication
Architecture	Flexible Design	✓	✓			
	Scalability					✓
	Multiple Platform Support					✓
	Fault Tolerance		✓			
Collaboration	Virtual Environment			✓		✓
	User Interface			✓		✓
	Levels of Interaction	✓		✓		✓
	External Data Sources	✓	✓			
	Standard Terminology	✓				
Information Mgmt	Multimedia Support			✓		✓
	Selective Information Sharing			✓	✓	
	Graphic Location Displays			✓		
	Logging Incident Information			✓		
	Decision Support Capability			✓		

### Conclusions

We have developed a functional prototype of a virtual incident command center that addresses many of the UICDS requirements (see table 1 for a mapping of VICC’s features to these requirements.) We described the current capabilities of the system as well as planned future enhancements. We are also pursuing the possibility of commercializing the system by transferring this technology to a product development organization that would then perform systematic user testing and trials before creating a finished product. Beyond this, we plan to conduct more research into virtual collaboration and develop additional use cases for VICC outside of incident command.

VICC has been demonstrated numerous times to many different individuals and organizations, almost always resulting in great enthusiasm from those who have viewed it. We have demonstrated the system to local law enforcement officials and fire officials who have expressed interest in using it as soon as it is available. In addition, the system has been shown to governmental officials at the local, state, and national levels. The system has also garnered international exposure through demonstrations to officials from the governments of several foreign countries. These demonstrations also stimulated discussions regarding

user interfaces to unified incident command, maintaining situational awareness, and dealing with information overload. Based on the amount of positive feedback we have received, we are confident that VICC represents a step forward in incident command and that it is a novel application of telepresence technology to this domain.

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