EMERGENCY ROOM SIMULATION PROTOTYPES FOR INCIDENT MANAGEMENT TRAINING

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ABSTRACT

First responders and incident management personnel need better training resources to prepare for future disasters. Live training exercises while valuable are often very expensive to organize and conduct. Training using modeling, simulation, and gaming technologies could help to prepare for a more diverse range of scenarios than live exercises, as well as support individual, team, or multi-organizational training needs at lower cost. Effective, technically sound, and commercially available standards-based solutions are needed. A concept demonstration has been developed at the National Institute of Standards and Technology (NIST) to facilitate the identification, development, and deployment of standards that enable the integrated use of modeling, simulation, and gaming technology for incident management training, mission planning, and operational support. One of the simulation tools selected in the concept demonstration was ProModel. It was used to model a hospital Emergency Room (ER) in Washington DC. The concept demonstration was also used to identify use case scenarios, integration requirements, interoperability issues, standards needs, and available solutions.

1 INTRODUCTION

There is a growing need for preparedness for emergency response both for man-made and natural disaster events. Effective emergency response presents a number of challenges to the responsible agencies. One major challenge is the lack of opportunities to train the emergency responders and the decision makers in dealing with the emergencies. The responsible agencies have tried to meet the need through the organization of live exercises, but such events are often difficult to organize and expensive to conduct. Modeling, simulation, and visualization techniques can help address many of these challenges. The limitations of live exercises can be overcome through use of integrated gaming and simulation models that allow emergency response personnel across multiple levels in multiple agencies to be exposed to the same scenario. Use of integrated gaming and simulation over a distributed network can allow people to participate from different locations and thus provide some flexibility in scheduling the resources. A preliminary investigation (Jain and McLean 2003a) indicates that a number of modeling and simulation applications for analyzing various disaster events exist. These need to be brought together for studying the impact of disaster events as a whole.

In the following sections, the NIST approach of integrating gaming and simulation systems for training of decision makers and responders on the scenarios preparing them to work together as a team is described. A proposed integrated systems architecture is briefly reviewed (Jain and McLean 2005). A concept demonstration use case scenario is introduced. A simulation model of a hospital emergency room, issues, and standards needs are also discussed.

2 EMERGENCY RESPONSE TRAINING SYSTEM ARCHITECTURE

Simulation and gaming-based technologies can together provide a highly effective means for incident management training if integrated correctly using an appropriate architecture. Simulation involves defining the rules of operation, the probabilities of paths of action, time durations, and letting the events unfold. Gaming relies on a trainee's actions to determine the course of events under defined rules and probabilities. In the context of incident management, simulations are suitable for training emergency managers and decision makers of involved agencies. Gaming is suitable for training first responders. As illustrated in

Figure 1, the architecture proposed by Jain and McLean has two major subsystems – simulation and gaming. Simulation and gaming subsystems could have individual communication integration infrastructures. This is based on the fact that currently the gaming and simulation worlds favor different integration mechanisms. The two infrastructures will be linked through a data synchronization and transfer processor as shown in the figure.

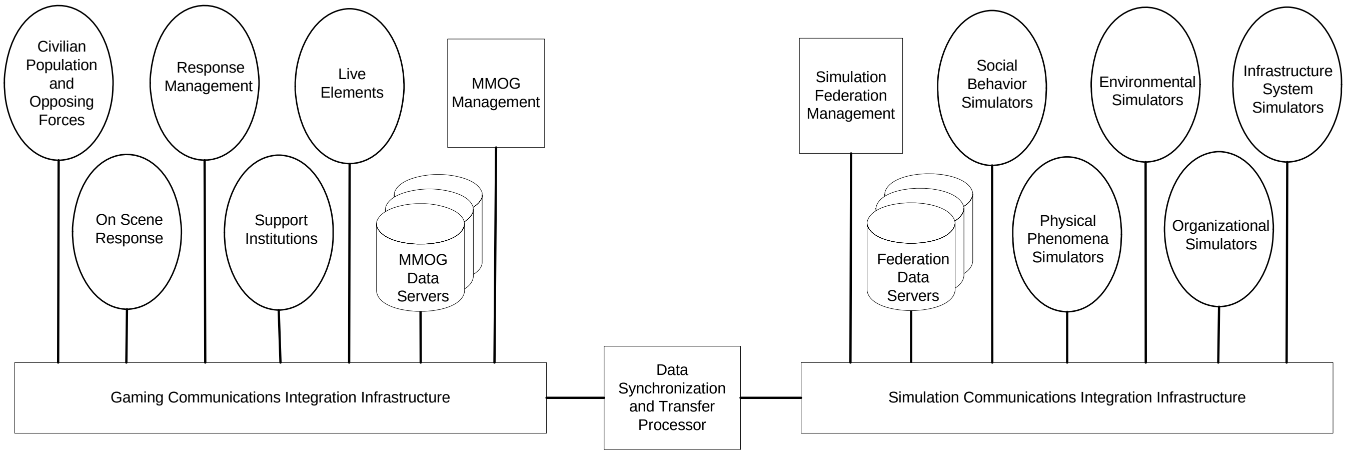

Figure 1: Architecture concept for simulation and gaming emergency response training system

The simulation subsystem will contain a number of modules within each of the groups as shown in Figure 2. The individual modules will model an aspect of the incident or response. They will interact with other modules based on the scenario. All the interactions will go through the simulation communications integration infrastructure. The gaming communications integration infrastructure may be based on the Massively Multi-player Online Gaming (MMOG) architecture. The MMOG architecture needs to be enhanced to meet the requirements of incident management training and the need to synchronize with the simulation subsystem modules.

The proposed architecture will allow the training environment to be highly configurable. Simulation and gaming components can be selected and integrated based on a defined scenario. A scenario involving a terrorist attack using a dirty bomb can be modeled using components of the proposed system. The simulation modules employed for such a scenario may include crowd, traffic, explosion, plume, weather, fire, law enforcement, health care, transportation, and communications. The gaming modules for the scenario may include victims, general public, terrorists, fire, police, emergency medical technicians (EMTs), hazardous material teams, hospitals, shelters, and public transportation. A natural emergency event such as a hurricane would require a different set of modules. The available modules in the proposed architecture can thus be configured to train incident management personnel across a range of scenarios.

3 SIMULATION SUBSYSTEM

The architecture description in the previous section showed two major subsystems - simulation and gaming, each with a number of major groupings. In this paper, we focus on the modeling of a simulation subsystem.

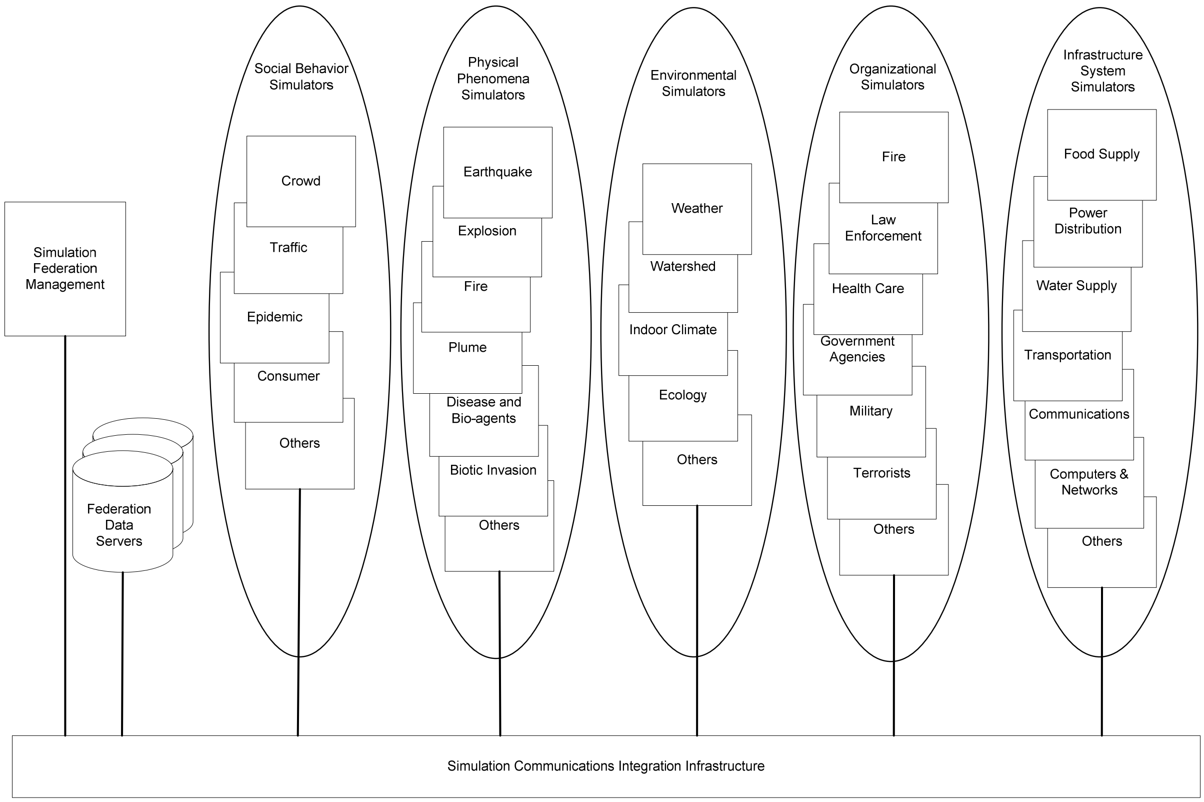

Figure 2: Simulation subsystem and its modules

The simulation subsystem includes simulators that model the major capabilities and phenomena involved in emergency response. The simulation subsystem will create the emergency incidents in the virtual world. The ability to represent the incident in the virtual world together with the associated major aspects and the creation of unanticipated interactions will provide a valuable training environment. The description of the simulators below provides a brief description of their capabilities. The Social Behavior Simulators will simulate collective behavior phenomenon created through actions of multiple individuals. These include modeling of crowd, traffic, epidemic and consumer behavior. Physical Phenomena Simulators will model the physical phenomena involved in the creation and growth of the emergency incident. These may include such physical phenomena as earthquakes, explosions, fires, chemical, biological, or radiological plumes. Environmental Simulators will model the environmental phenomena that may affect the growth or containment of the emergency incident, its impact on the population or on the efforts by responding agencies. Such environmental phenomena include weather, watershed, indoor climate, and ecology. Organizational Simulators will model the actions of the organizations involved in any aspect associated with the incident. The organizations modeled may include fire departments, law enforcement, health care, other government agencies, and even terrorist organizations. The Infrastructure System Simulators will model the behavior of the infrastructure systems following the occurrence of an emergency incident. They will model the propagation of the impact of damage throughout the infrastructure system based on the damage to one part due to the emergency incident. In this paper, a transportation model of a hospital emergency room will be discussed in more detail.

4 CONCEPT DEMONSTRATION USER CASE SCENARIOS

The architecture for simulation and gaming for incident management training allows for the creation of a federation of simulation and gaming modules to represent the defined incident management scenario. The goal is to establish an effective, technically sound, and commercially viable standards-based solution for the development and integration of a simulation-based incident management training system. It is also to facilitate the identification, development, and deployment of standards that enable the integrated use of modeling, simulation, and gaming technology for incident management training, mission planning, and operational support. A concept demonstration has been developed to illustrate the potential benefits of integrated modeling and simulation tools for emergency response and incident management training. It is also useful in helping to identify use case scenarios, integration requirements, interoperability issues, standards needs, and available solutions. It will serve to help government, industry, and academia develop, test, and deploy required data standards in key mission areas.

A scenario of a terrorist attack using a dirty bomb in Washington DC on Fourth of July was defined for the concept demonstration. The concept demonstration system elements include simulation modules, gaming modules, and data server and information flow. A serial of simulators and gaming engines were selected to model the following simulations, a database system was also developed to provide the simulation with required data.

- Incident management strategy gaming
- Plume simulation
- Crowd simulation
- Emergency vehicles response simulation
- Incident area traffic simulation
- Triage gaming
- Metropolitan train system simulation
- Hospital emergency room simulation

In this paper, the hospital emergency room simulation is discussed in detail.

5 HOSPITAL EMERGENCY ROOM SIMULATION MODEL AND INTEGRATION REQUIREMENTS

The emergency department simulator is a discrete event simulation model of an emergency patient’s flow in a hospital. The purpose of this simulation is to provide a small but realistic model of resources and patients’ flow and congestion in the ER of the hospital in response to an emergency incident including the deployment of resources and actions for triage and treatment of injured, movement of casualties to hospitals, and treatment at the hospitals. The model demonstrates how the incident affects: dispatch of ambulances to transport injured to the hospital, as well as the waiting time in different areas, and evaluates the resources needed according to different scenario. The simulation will allow hospital management teams to train by responding in real-time to crises that affect ER flow and evaluate the impact of their decisions. Although it is important to understand the types of data required and how they should be represented, precise validated models are not critical to the demonstration scenario.

The model logic includes relevant policies and procedures for emergencies including calling in medical staff, using temporary accommodations for the injured, acquiring needed supplies and equipment. The simulation was developed using ProModel simulation software.

The model covered the whole hospital although we will concentrate the emergency department. The primary entities are patients, medical records, and soiled linen; resources are medical staff, specialists, emergency vehicles, triage and exam rooms, test lab, and other bedding. Patients are modeled as first in – first out queues. The model uses the PROMPT statement, allowing the user to make modifications to selected model parameters. If desired, the user may change the number of patient arrival quantity and the average number of trauma and average number of cardiac patients per day. There are trauma rooms, cardiac room and specialty treatment rooms. Ambulatory and ambulance entrances exist as patients arrival points. The arrival of a cardiac or trauma patient, who will use of more resources, will cause the backlog of regular patients.

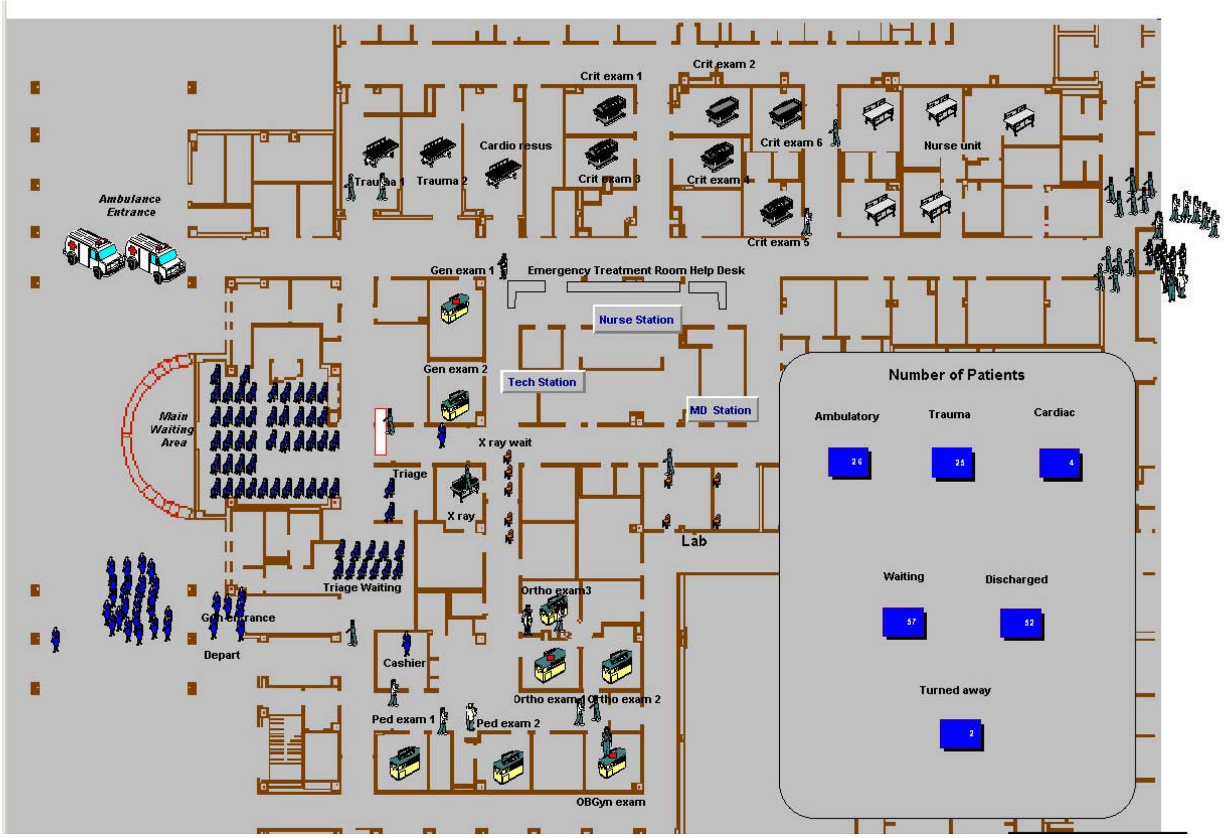

Figure 3 ER Model Overview

5.1 Model Inputs

The inputs of the simulation model are listed as follows: Patient's arrivals are modeled using statistical distributions.

- Number, location and type of casualties
- Availability of staff at work and off (on-call)
- Availability of resources
- Time and resources required for attending to each casualty type
- Probabilities of death from different casualty types over time.
- Hospital location
- Layout of the hospital
- Process stations
- Station capacities
- Processing times
- Patient arrivals rate
- Hospital shifts
- Medical resources
- Symptom-treatment profiles

5.2 Model Outputs

The outputs of the simulation model may include the operation of the health care system over time such as:

- System utilization
- Utilizations of process stations and resources
- Updates of the status of the patients and medical staff
- Number of people treated and released, admitted, dead, waiting for treatment over time
- State of the staff and facilities (to determine their capability to deal with another incident)
- Run Time Interactions
- Simulated clock time – from Execution Control Supervisor
- Number of EMTs and ambulances dispatched over time to Traffic Simulation
- Number of ambulances and casualties arrivals over time from Traffic Simulation

5.3 Model Logic

Figure 3 shows the model overview. There are two kinds of patients as arrival entities of the model: Ambulance and General. Ambulance patients are those patients who are in critical situation, such as trauma and cardiac patients. There are limited rooms and beds for ambulance patients, if all the rooms are occupied at the time; the patient has to be redirected to an alternate facility. After a patient is taken into the room, Technician and Registered Nurse (RN) will treat the patient right away, create a medical record, and take the patient to the Medical Doctor (MD) for review, the MD will make a decision, and the patient will be moved to the nursing unit when the necessary procedures are done. General patients are ambulatory patients who can walk in to the hospital and wait for an exam and treatment. They have to go through the triage process first, if all seats are taken, and a triage-waiting area is provided. After the triage, patients are sent to the main waiting area waiting for calls to the different exam rooms based on their categories. Exam rooms include general exam, orthopedic exam, OB/Gyn exam, pediatric exam, and critical exam rooms. If it is not critical, the patient can be discharged. If further tests or X rays are needed, patients have to be in the queue for these procedures. Figure 4 shows the general entrance and waiting area and Figure 5 shows the display of model data.

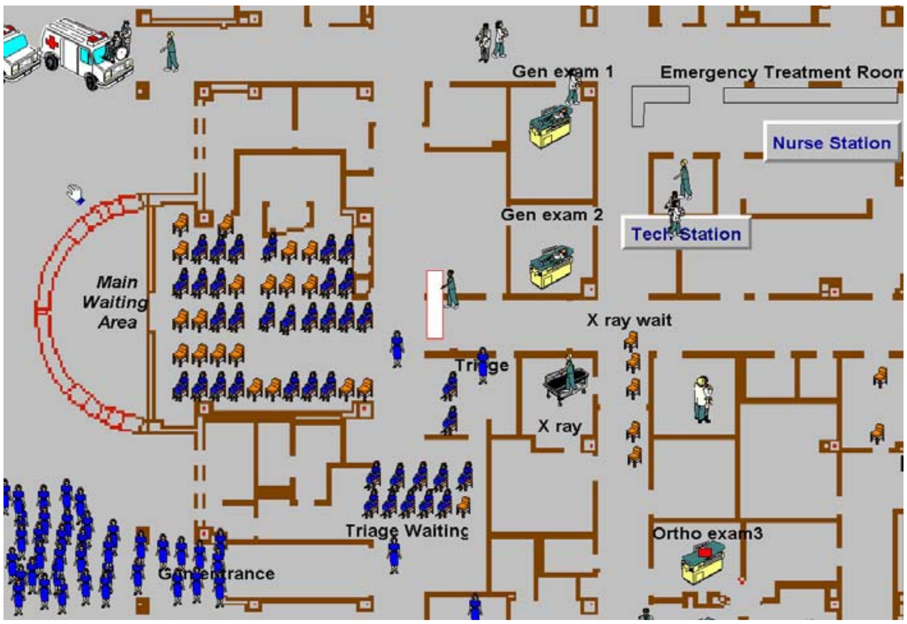

Figure 4 General entrance and waiting areas

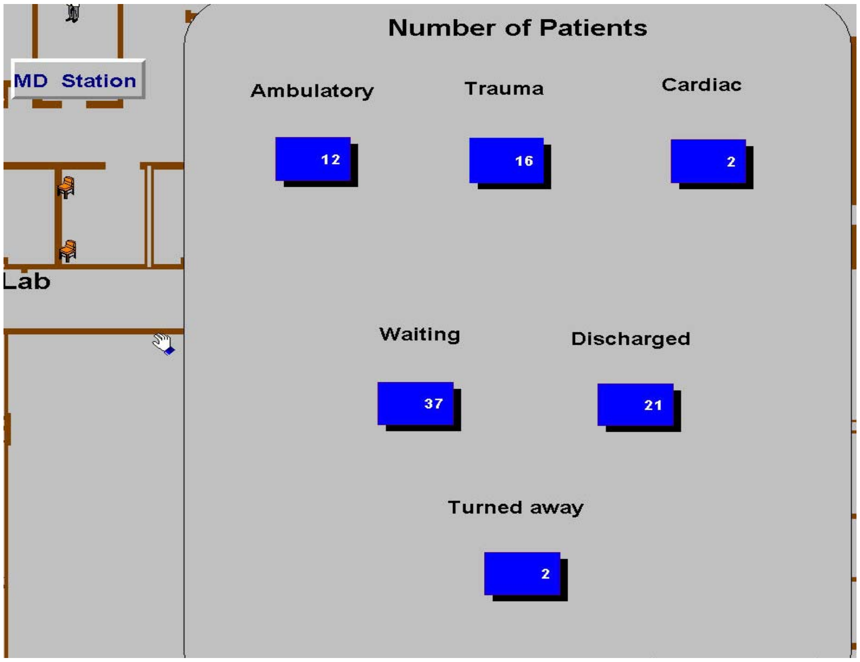

Figure 5 Data Display

6 ISSUES AND STANDARDS NEEDS

The interoperability between incident management Modeling and Simulation (M&S) applications is currently extremely limited and the cost of transferring data is often very high. The development of simulation models often requires significant expertise and special skills. The process is often very time-consuming. Much effort is also needed to verify and validate the simulation models that are developed. The analysis of the simulation output data is also a complicated process. Incident management organizations often lack the resources for simulation model development. Standard interfaces, good reference models, validated scenarios, or scenario data in standards formats, interoperable tools to allow rapid integration, and reusable data sets could help reduce the costs associated with simulation model construction and data exchange. This could make the technology more affordable and accessible to a wide range of potential incident management organizations.

The major challenge for the realization of the scenarios according to the architecture is the development of mechanisms for communications and time synchronization between and among simulation modules and game modules. Major issues associated with distributed multi-player games are how and when players receive information on fellow player's actions. Time lags may occur between when a player initiates an action and when other players see the action. This latency causes problems in the execution of distributed games. The High Level Architecture (HLA) has been used for integrating distributed simulation models in the manufacturing domain. A neutral reference architecture was developed for integrating distributed manufacturing simulation systems with each other, with other manufacturing software applications, and with manufacturing data repositories (McLean, Leong and Riddick 2000). The need for standardization of interfaces was highlighted. The HLA Run Time Infrastructure (RTI) technology does not require the use of servers for centralized management of game data but uses time synchronization mechanisms that may be unacceptable in a game environment. In the HLA RTI world, simulators publish and subscribe to data objects to communicate. Simulations may be time regulating or time-constrained, i.e. control the advancement of time or have their time advancement controlled by other simulations progress.

An associated challenge is managing the training of people at different levels of the incident management hierarchy. The best mode for training the first responders using a game client is to execute in real-time (i.e., time progress in a game environment is the same as wall clock time). The best mode for training the incident management managers and other personnel operating in Emergency Operation Centers (EOCs) may be segments of real-time execution interspersed with accelerated time (i.e., time progresses in the simulation and gaming environment faster than wall clock time) and fast forwards (i.e., simulated time jumping to a few hours or a day later). This mode will allow the EOC team to train in decision making over few simulated days of an unfolding emergency event while spending only a day in wall clock time. Combined training of first responders and EOC teams would require careful orchestration of time segments and fast-forwards.

Distributed simulation architectures have come a long way. HLA is currently a standard architecture for integrating distributed simulations. However, HLA has grown from the background of war games executed in real-time. While HLA has been used for accelerated time execution to some extent, it may be a challenge to achieve speedups of 10 times or more with the large number of modules envisaged for full scenario training.

The MMOG architectures are still evolving. There is no standardization in this field as each game provider uses its own proprietary architecture. An open MMOG architecture will need to be developed that would allow plug compatibility of different gaming modules. The architecture should also allow plug compatibility of components of the core game engine.

Software licenses for game development systems and game distribution are often quite expensive. Pervasive use of this technology will require that many incident management organizations get access to licenses to develop training applications. Perhaps hundreds of thousands of game-based training applications will ultimately be distributed. Game engine developers often collect royalties on each game sold. If commercial game engine software is used, the traditional business models of these software vendors may need to change.

7 FUTURE WORK

Incident management must deal with many different scenarios with multiple, interacting objectives:

- Assist the victims
- Prevent further casualties
- Preserve law and order
- Mitigate further damage to infrastructure and private property
- Preserve forensic evidence.

The solution is an integrated suite of software applications that enable simulation-based, training, mission planning, and operational support that is:

- Based upon commercially-developed and supported software
- Affordable to acquire and maintain
- Configurable to meet regional needs
- Easy to integrate with independently developed modules
- Based on standard data formats that enable access to local, state, and federal data sources
- Evolvable to support technological changes over time

Simulation-based training systems and exercises will need to integrate modules and data sources from different developers and user organizations. The proposed framework, system concept definition, and architecture are steps towards addressing the challenge. A coordinated effort is required to achieve the vision of an interoperable simulation-based training system; standards are needed to enable the integration. NIST has the expertise and experience to provide the technical support to accelerate the standards development process. More effort needs to be put into the following aspects:

- Use simulation technology to provide technically correct models, behaviors, and data for various phenomena that affect training, mission planning, and operational support.

- Use gaming technology to provide an immersive, engaging graphical, audio, and haptic (force feedback) environment that offers high quality realistic experiences.
- Enable time synchronization, data sharing, check-pointing, time warp, rollback, replay, and logging functions between various simulation and gaming applications.
- Allow for centralized distribution and management of updates to software and data sets.
- Provide security features that prevent unauthorized access to, or modification of, computer systems, software, and data.

8 CONCLUSION

First responders and incident management personnel need better training resources to prepare for future disasters. Live training exercises while valuable are often very expensive to organize and conduct. Training using modeling, simulation, and gaming technologies could help to prepare for a more diverse range of scenarios than live exercises, as well as support individual, team, or multi-organizational training needs at lower cost. Effective, technically sound, and commercially available standards-based solutions are needed. A concept demonstration has been developed at NIST to facilitate the identification, development, and deployment of standards that enable the integrated use of modeling, simulation, and gaming technology for incident management training, mission planning, and operational support. ProModel was used to model the hospital emergency room for the concept demonstration. The concept demonstration of a dirty bomb explosion was used to identify use case scenarios, integration requirements, interoperability issues, standards needs, and available solutions.

DISCLAIMER

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