ABSTRACT

DEVELOPING A VIRTUAL CITY FOR
EMERGENCY PREPAREDNESS PLANNING AND TRAINING

By
Jon K. Morgan

Existing techniques for emergency preparedness planning and training fail or lack the ability to convey training on a broad scale and timely fashion. Skill sets that are required for planning, mitigation, response and recovery issues are lost through information overload or failure to identify other channels in which to convey the information. In order to resolve some of the issues with currently existing methods such as tabletop training exercises (TTX), instructional video learning and full-scale exercises we can turn to virtual environments.

In a virtual environment teams can interact with their surroundings from the comfort of the office without having to incur the costs associated with traveling to various exercises. Additionally, a virtual city could allow for teams to develop a shared awareness, attempt to utilize and reinforce skill sets, while at the same time providing a safe, realistic, and adaptive gaming environment.

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APPROVAL PAGE

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EMERGENCY PREPAREDNESS PLANNING AND TRAINING

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Whose woods these are I think I know.
His house is in the village though;
He will not see me stopping here
To watch his woods fill up with snow.

My little horse must think it queer
To stop without a farmhouse near
Between the woods and frozen lake
The darkest evening of the year.

He gives his harness bells a shake
To ask if there is some mistake.
The only other sound's the sweep
Of easy wind and downy flake.

The woods are lovely, dark and deep.
But I have promises to keep,
And miles to go before I sleep,
And miles to go before I sleep.

-Robert Frost

To my family and friends,
My fiancée, Amber

ACKNOWLEDGMENT

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CHAPTER 1

INTRODUCTION

A variety of training tools and methodologies exist today for the preparation of both public and private organizations in emergency situations. Examples of such methodologies are tabletop training exercises (TTX), instructional video learning, full scale exercises, and modeling and simulation programs. While these methods and tools present a well rounded approach to emergency preparedness and response, they do not address the overall emergency response when used individually. Additionally, the argument that the methods must be used in conjunction with each other cannot be made due to geographical restrictions, time restrictions, material cost, and opportunity cost. The solution is to provide participants with the capability to remotely simulate emergency events through a computer terminal or allow individuals to take part in person.

1.1 Problem Statement

Simulation tools currently available for standalone use only address a very small portion of the overall emergency situation. The simulation tools are designed to simulate a contamination plume, a physical crash, or other similar single events. The simulation tools are not designed to simulate the entire emergency, but instead just one or two aspects of a much larger issue. Jain and Mclean (2003) express this same view in the examination of available simulation tools:

> The available simulation tools are mostly meant for standalone use and do not attempt to address the overall emergency incident response. In the case of the plume simulation example, once the emergency response personnel have understood how the plume will spread, they need to plan the

movement of first responder units, prepare evacuation plans, prepare plans
for handling casualties, etc. (p.1068).

It has therefore become necessary to find an all inclusive approach to simulating emergency events. If only a portion of the entire emergency is portrayed to participants then the value of that information exchange is questionable. Per the example above, the direction of a contamination or chemical plume is now known, but the other opportunities associated with the emergency remain in question. These opportunities range from potential fatalities, the extent to which contamination will travel in the ground water, and the long term impacts on the surrounding area.

The simulation software could be combined with a TTX in order to provide an understanding of the contamination plume, first responder movements, and planning. Other opportunities regarding emergency response also become apparent. The simulation now portrays where the plume is and can visualize how it is moving. It can also be noted that the emergency responders know who must be evacuated and the best direction to evacuate based on wind speed and direction. The question then becomes, what steps should be taken in regard to evacuees and how can this plume be remediated? Will the plume dissipate over the course of a week or will it stay in the ground water, eliminating drinking water for a long time?

The correct information is currently being shared and proper questions addressed, but to a very small audience which is representative of a small portion of responder groups in attendance at meetings. Typically in a tabletop training environment, companies and public sector authorities will often only send three or four personnel to a training exercise at a time. The intent is for these groups to then return to their operations

point and share the lessons learned and conveyed at the exercise. When the groups in attendance later return to their organizations and attempt to convey the lessons learned to fellow members of the organization, information is inevitably lost, due to an overload of information in a short time period. Human beings need ample time to process information and extensive reinforcement of lessons learned so that new knowledge moves from short term memory to long term memory. Once lessons become committed to long term memory, those individuals can further benefit others by providing them with insight and sharing the training experience. Achieving this, however, requires a repetitive and dynamic environment that allows individuals to take part in the exercises on a regular basis.

Existing tabletop training environments (TTX), instructional video, and full scale exercises tend to have specific areas in which they benefit different learning styles. Learning styles are ways in which people remember the information and subject material presented to them. Woeste and Barham (2007) state that, "learners of all ages have different characteristic strengths and preferences in processing information." (p. 63) These different characteristic strengths and preferences in processing information can be placed in four basic areas. The four main categories used in this discussion of learning styles are auditory, visual, read/write and kinesthetic. These categories are known as the VARK (Visual, Audio, Read/Write, Kinesthetic) learning styles inventory and was developed in 1987 by Neil Fleming. These styles imply that some individuals tend to learn more quickly by watching or visual aid, others prefer to listen and learn better from an audio source. In contrast, kinesthetic learners touch and perform the job at hand in order to remember and mimic that knowledge. The reason VARK was chosen over the

original three categories of visual, audio, and kinesthetic as developed by Stirling; was because Fleming and Mills (1999) found, "the categories appeared to be insufficient to account for more detailed differences we noted among students. Even though our eyes are used in taking in all visual information, the information itself differs." (p. 138). These differences lead to Fleming and Mills (1999) to define visual as a preference for graphical and symbolic ways of representing data versus read/write which is information printed in words. Existing environments for emergency preparedness training foster each of these learning styles in a different manner. Failure to take individual learning styles into account in these various environments could lead to a participant that becomes disengaged from the tabletop or simulation due to a lack of stimulation directed towards their learning style preference. Woeste and Barham (2007) further support this by stating, "Developing an environment directly connected to individual learning styles is important. According to Lawrence (1994), engaged learners absorb more in a classroom situation." (p. 63) The environment provided in the training exercise can have a significant impact on the ability of the participants to retain the knowledge being provided.

The TTX style training environments that use presentations and document handouts favor audio and read/write learning styles since the information is presented as printed words. There may be some kinesthetic and visual learning depending on graphical representations and group interaction but it is limited in nature. It should be noted that some traditional tabletop exercises do include information in kinesthetic form which would allow the individual to interact physically with the exercise. Video-based training methods favor both auditory and visual but again lack the reinforcement of physical interaction with the information being presented. In addition, the majority of the

information is now being presented as a graphical representation of information, thereby placing the read/write learning style at a disadvantage. Finally, full scale exercises can bring all of these various learning styles together in a simulation. This is because full scale exercises provide a multisensory approach to the delivery of information. The participants are receiving the training information through all of the VARK learning styles. The main restraint of a full scale exercises is the cost, geographic location, time and sheer magnitude of individuals requiring training. Agrait et al. (2004) argue that the demand for domestic preparedness training and exercising far exceeds current capacities.

1.2 Research Overview

This research presents a virtual environment framework where the various opportunities associated with existing methodologies for emergency preparedness training can be addressed. In a virtual environment the four categories of the VARK learning styles can be addressed by allowing individuals to interact with the environment as they would in real life. The sounds of the simulation and communications would stimulate auditory learning and the three-dimensional graphics would stimulate visual learning by showing how the emergency unfolds. The read/write learning style would be addressed through the various forms of communications and the kinesthetic learner would be able to interact with the system in a hands-on approach through either the command and control interface or full immersion into the virtual city. This provides many of the same features of a full scale exercise without the financial and time constraints imposed by a full scale exercise. The full scale exercise requires the participants to be at the physical location which could potentially be on the opposite side of the country. On top of the geographical

opportunities, individuals must take time off from work to attend. Finally, the virtual system can visualize and simulate events that cannot be done in a full scale exercise such as earthquakes, hurricanes and other events.

Another problem with the delivery of all of these various instruction and training methods is the difficulty in reaching all of the required audience. It can be very difficult for large groups to make the same meeting as would be required by a full scale exercise. In order to take part in an exercise that is geographically restrictive they must take time off from family and work and afford the costs of possible travel and participation. Typically, the instruction for training and exercising takes part in a classroom setting where an instructor acts as a mediator and director of the exercise. Although it provides hands on experience, unfortunately this method does not come close to meeting today's needs. Agrait et al. (2004) estimate that, "3.2 million first responders need domestic preparedness training and exercising, not to mention the additional four to five million medical workers and countless private sector participants." (p. ES-1)

There is a requirement for an online environment which can reach the large groups of individuals who need to participate in emergency preparedness training. It would be extremely cost, time and resource prohibitive to attempt to train all of these individuals in full scale exercises. Additionally, other factors contribute to issues with existing training methods. Agrait et al. (2004) argue that existing training methods are constrained by a number of factors, including the following:

> 1) A preference in the emergency response community for hands-on, face-to-face training and exercising delivered by recognized subject matter experts (i.e., a mind-set that it's hard to learn how to rescue victims in a burning building from a book—hence, skepticism of new media and training techniques).

2) The response community has been relatively slow in adopting alternative training media (like models, games and simulations) due to lack of awareness or familiarity. Trainers are relatively inexperienced at selecting training objectives and designing training and exercising.

3) Training and exercising events (particularly those requiring multi-organizational involvement) are limited in time and location due to scheduling/availability and funding constraints.

4) Resource limitations—money, staffing, and equipment. There appears to be no strategic approach to coordinating and prioritizing procurement of equipment and training and exercising regionally, leading to potential duplication of resources and potential shortfalls.

5) Inadequate participant preparation is often a factor that limits the overall effectiveness of exercises. Participants are sometimes chosen to attend training and exercising events at the last minute and do not have sufficient domain expertise or understanding of the training and exercising format to contribute effectively. (p. 10)

These five points by Agrait et al. (2004) represent some of the main obstacles in delivering effective training to individuals today. However, a virtual system could place many of these obstacles aside by providing a way for individuals to connect to simulations in a virtual environment whenever they find the time to take part. This eliminates many of the problems with resource limitations since individuals could take part from their desk or any location with a capable internet connection. The use of asynchronous communications can also encourage team formation and development of trust. One of the primary issues with current methods is that there is a feeling that only face-to-face interaction can build virtual teams with intrinsic trust. However, when using computer based medium and regularly interacting with the same individuals in a virtual environment, participants can create a similar form of trust. The individual learns that the

co-participants repeatedly carry out the correct courses of actions in the given emergency allowing them to form a bond in a virtual environment that can carry over to actual applications in response to emergencies. Also, having the ability to observe the virtual environment prior to participation allows the individuals to come adequately prepared for the training and exercises with an understanding of how they can interact with the virtual environment or observe others in the same capacity.

1.3 Thesis Outline

This thesis includes eight chapters. Chapter 1 introduces the thesis and provides an overview of the research conducted. Chapter 2 provides a literature review of existing methodologies used in emergency preparedness training. Chapter 3 provides a brief background in Information Theory which further supports the need for additional communication channels during training. Chapter 4 presents the outline of the virtual city and the basic guidelines the virtual environment must follow to alleviate some of the existing issues with other training methodologies. Chapter 5 provides background information on programming languages and existing graphics frameworks that can be applied to achieve the desired realism. Chapter 6 examines the requirements and stakeholders involved in the development of the virtual city. Chapter 7 briefly discusses the possibilities for expansion once the framework has been established. Chapter 8 concludes the thesis and provides contributions and limitations of the existing framework and research.

CHAPTER 2

LITERATURE REVIEW

This chapter provides the review on literature related to tabletop training exercises and other various emergency preparedness training techniques. Based upon the literature review the limitations of existing approaches are discussed and the main research topics are identified.

2.1 Overview of Tabletop Training Exercises

This overview includes how tabletop training exercises (TTX) are used in training participants regarding emergency preparedness.

2.1.1 What is a Tabletop Training Exercise?

Tabletop training exercises (TTX) typically consist of documentation, power point slides, video recordings of an event, and interactive discussion. A TTX usually develops into a dynamic group environment in which ideas are exchanged in an orderly fashion with an individual that acts as a mediator/facilitator. On certain occasions tabletop training exercises also consist of scenarios laid out in model form. The model is a small scale mockup of a local city showing the buildings, rivers, and local roadways. The participants can move certain components, such as a fire truck, into a planned position for a response to an emergency. The United States Department of Education released an article through the Emergency Response and Crisis Management (ERCM) Technical Assistance Center (2006) that defines tabletop exercises as:

Tabletop exercises analyze an emergency event in an informal, stress-free environment. They provide participants with an emergency scenario to analyze and increase their awareness of the roles and responsibilities of individuals who need to respond, stabilize, terminate and help others recover from emergencies. They are designed to prompt a constructive discussion about existing emergency response plans as participants identify, investigate and resolve issues. (p. 1)

Tabletop exercises focus on a theoretical event or a past event that has or may occur. They demonstrate how that event will unfold while having an interactive discussion with current participants. The general idea is to facilitate a discussion that will benefit all the involved parties if the given situation were to become a reality and increase awareness.

2.1.2 The Tabletop Training Exercise Process

The tabletop training exercise process can be broken into three critical stages, Preparedness, Mitigation/Prevention, Response and Recovery. The Preparedness stage consists of the planning for an endless list of possible events. New Jersey Business Force (2006) defines the preparation phase in the 2006 New Jersey Emergency Preparedness conference as the opportunity for both public and private sectors to address critical matters and controversial decisions regarding continued operation of the business or sector and providing security to workers. The tabletop encourages both public and private sectors to ask questions in regards to the plans that should already exist. What are the plans that the group has in place? Are there backup generators available? Have Points of Distribution (PODs) been established in case of a bio-terror event? These are just a few of the many questions addressed in the Preparedness stage of the tabletop exercise. It is basically asking the group what vulnerability analysis and management steps they have reviewed. The idea behind the TTX is to allow the group to investigate the nature of risk

in any multi-criteria decision problem the entire group or portions of the group may be faced with. The tabletop facilitator asks the members of the group how they can work together to minimize the overall risk for the group based on the actions of the individuals. It additionally asks how they can minimize the risks for themselves upfront by aiding a member nearby who is in need before the situation escalates.

Vulnerability analysis and management can be beneficial in this stage since it allows the members of the tabletop to take part in identification of vulnerabilities, potential threats, and how they may be addressed. A vulnerability risk or threat to a group or organization as defined by Broder (2006) is; "an indication of impending danger or harm. It is a forthcoming, upcoming, possible happening event or activity; from a security standpoint, anything that can adversely affect the assets of an enterprise or organization." (p. xiii). There are many terms in the business which are regularly used interchangeably in regards to risk. The words still follow the same basic outlines of risk analysis and management. For example, Arthur T. Nielsen, P.E. of Erdman, Anthony, Associates, Inc., defines catastrophic loss as, "an uncontrolled flow of incomplete and inaccurate information, a rapid and continuous change of the accident scene, the presence of third party personnel and investigators, and an immediate need for the design professional to assist the owner in abating any continuing danger." (p. 1).

In comparing the two definitions of threat or risk with catastrophic loss; parallels between the two definitions can be identified. Risk management does not just stop at the planning and threat response stage, but continues forward throughout the course of the event itself. There are inherent risks at every stage of an emergency that can often be identified in the mitigation/prevention phases of the exercise. For example, a computer

system becomes compromised and poses an immediate risk to an organization. The computer according to company protocols is then immediately taken offline, the virus removed and a managerial decision must be made. Does the organization place the machine back online without a format due to the high financial cost, or is the machine formatted to ensure that any possible virus or any other complications are removed? Clearly there are two variations of risk here, in one variation organization is pretty sure the virus is removed and the risk has been marginalized, whereas, in the other variation the organization knows for a fact the virus is removed, the risk has been eliminated but at a higher cost. Risk analysis requires input from all levels of the organization. In the above example, the organization's management may insist the computer system is returned to online status because ninety-eight percent is an acceptable risk in exchange for the money that will be saved. Broder (2006) describes this process of identifying possible risks as Hazard identification:

> Unless your processes are very complex, hazard identification in a corporate environment looks outside the organization as well as internally at hazards and risks to processes, materials and equipment. (p. 104)

The Information Technology department may tell the management that the ninety-eight percent is an unacceptable risk/hazard when dealing with a mission critical system and it would be better to spend the money and be sure.

In order to properly address a risk by performing a risk analysis, it is necessary to accumulate an organizational memory which is rarely done in table top exercises. A technique as described by Turoff et al. (2008) called "muddling through" offers the current complications with identifying risk and opportunities during an emergency situation. Turoff et al. (2008) state that "effective management of a large-scale extreme

event requires a system that can quickly adapt to changing needs of the users. There is a critical need for fast decision-making within the time constraints of an ongoing emergency." This implies that while the participants attempt to identify the risks and solutions during the emergency they must first pass through the large quantities of available information in order to make fast decisions and adapt to a quickly changing environment. In other words, the muddling through process makes sense of the information being presented and the identification of problems so that the emergency can be properly addressed. The participants need to be concerned with correcting mistakes and potential errors as they respond to the emergency to combat or prevent that emergency.

The lack of this data collection leaves the participants open to unexpected results and seriously degrades the quality of the information exchanged in mitigating the risk. On the contrary, in a virtual environment that does not have set rules and exchanges of information, it can help foster creativity and reflection by groups taking part in the exercise since the system would generate a database of information to approach later. In addition, as the individuals proceed through the exercise, comments can be added in regards to what the group should review later or where something occurred that stirred interest. This in turn helps create the organizational memory that is lost in current tabletop exercises.

Risk management in the face of a threat is a tool that can be used by management to help reduce the dangers and impact. Broder (2006) argues that risk management can be further divided into three common categories; Personal, Property and Liability. During the Mitigation and Preparedness stage some groups will realize that they have not

been able to cover all bases, though this is not uncommon nor is it a surprise since no organization can prepare for every eventuality. A development that occurs at this stage is mutual agreements that may form on how to benefit one another with a known threat on the horizon. For example, one company may have extra laptops available and may be able to lend them out to the local law enforcement agency during a crisis if it occurs. Another company, such as a transportation company, may be able to provide buses or a helicopter during the crisis. An interesting aspect of the tabletops is that they have expanded to include both the public and the private sectors. In the case above, the private corporations have realized they have assets they could lend to the local law enforcement agency during a crisis that may not otherwise have been available.

2.1.3 Review of a Tabletop Training Exercise

The presentation and tabletop exercise performed by the New Jersey Business Force (2006) lists a Homeland Security Presidential Decision Directive five that addresses the role of private organizations in addressing potential risks and disasters:

> The Federal Government recognizes the role that the private and nongovernmental sectors play in preventing, preparing for, responding to, and recovering from terrorist attacks, major disasters, and other emergencies. The Secretary (Secretary of Homeland Security) will coordinate with the private and nongovernmental sectors to ensure adequate planning, equipment, training, and exercise activities and to promote partnerships to address incident management capabilities. (p. 1)

The directive is clear in highlighting the need for both the public and the private sector to work together to find solutions to emergencies that may be faced. The federal government has implied through the presidential directive that the private sector can

contribute required resources during an event and that they should not expect government aide in all situations due to the particular nature of the crisis.

The tabletop exercise used in discussion of tabletop exercises for this paper is, "New Jersey Business Force, Business Executives for National Security, 2006 New Jersey Emergency Preparedness Conference, Private Sector Tabletop Exercise Report, November 3, 2006". The tabletop addresses the occurrence of a Bio-Terror event occurring in the mass-transit system of New Jersey. The eight primary objectives of the New Jersey Business Force (2006) tabletop are listed as:

- Comprehend the challenges presented by catastrophic bio-terrorism or natural occurring pandemic events.

- Clarify and delineate the possible roles the Private Sector may be called upon to perform during bio-terror or natural occurring pandemic events.

- Identify the prerequisites for forming new and constructive partnerships between Public and Private Sectors.

- Propose ways to eliminate obstacles to viable, fully functioning Public-Private Sector partnerships.

- Devise strategies to facilitate information sharing and access to Private Sector capabilities.

- Explore Private Sector decision making processes employed during emergencies and the internal and external pathways used to communicate time sensitive decisions.

- Assess measures the Private Sector can adopt to improve homeland security preparedness.

- Demonstrate why the Private Sector is integral to the nation's homeland security efforts.

The idea is to portray a situation in which sectors both private and public can view how each group should respond to such an event. It should be determined how the public and private sectors can work together to help each other as well as achieve common goals. The interactive discussion generated by the various stages of the scenario help facilitate these goals. The scenario is often presented after the Preparedness phase in order to demonstrate just how unprepared many groups are for a catastrophic event. It is not that they are trying to dash the hopes of participants, but instead present them with the reality that although the participants can prepare for an event, there is no way to prepare for all eventualities. Instead, the existing emergency preparedness plan must be adapted and altered to match each situation.

This is where the Response phase begins during the tabletop exercise; the plans that had been prepared no longer adequately address the situation presented. Immediate issues are addressed in the crisis situation in order to reach the recovery phase of the scenario. How can the company then adapt the plan and work with other private sector groups and public sector groups to remedy the situation? These are the questions and answers that are developed during the response discussion. For example, employees are abandoning posts because the corporation or public sector agency failed to move the employees' families to safe locations. How then can the public or private sector adapt and bring the employees back to their jobs so that operation can continue? There is a distinct need for the participants to be creative in their potential solutions for the current emergency being presented. An example could be a bulldozer that happens to be located

next to a collapsed building. Though not originally an intended resource it could be used to greatly aid in response to the emergency. Ideas such as this and others need to be fostered with the participants. In a virtual city the objects could be placed in plain site as a way for participants to utilize nearby resources in ways they had not previously considered.

The recovery phase is referred to as the "time it takes to return to normalcy", if it is even possible in the post-event environment. Now that the situation is over, how does the organization adapt to the new conditions it must exist within. An emergency situation can sometimes drastically change the operating environment for an organization. The goal is to get both the private sector and the public sector to discuss how things have changed and what the best approaches to returning to normalcy are in the given situation. These are often difficult questions to address but are an important aspect of post-event situations. An emergency is not officially over until all repercussions of that emergency are dealt with and the chain reactions caused by that emergency come to an end.

The groups involved in the tabletop exercises then stop to reflect on all the stages of the scenario in a summary of the events that have occurred. This is crucial to the exchange of information as it provides a hindsight look into where they could have improved the outcome of the situation. In retrospect, the groups involved in the tabletop exercise are also being trained in the summary to stop and ask, "How did this situation occur", and "why did the plan fail and how can the plan be adapted to future situations?" These questions are an important part of the scenario in that they improve group contingency plans in the event of a real emergency.

2.1.4 Issues With Tabletop Training Exercises

Every emergency deals with uncertainties in regards to vulnerability detection, communications, and decision making These uncertainties can greatly affect the outcome of various stages of an emergency. In understanding the way in which the role of communication affects the process of preparing and responding to an emergency a basis for a virtual system can be identified.

Marco Biocca (2004) of the Regional Agency for Health and Healthcare of Emilia-Romagna states in regards to the role of communication in the evaluation and management of environmental risk for health that there are five uncertainties that should be taken into account:

General Situational Uncertainty – it characterizes a specific circumstance and should be faced at the moment. It results from different aspects, in particular from informative inadequacy on decisions that have to be taken, and can have a variable intensity.

Legal-Moral Uncertainty – it is connected with the possible consequences of the decision that will or will not be taken. The possibility to be prosecuted for a particular action, or anyway to face one's own sense of guilt in case of negative evolution influences decisions and often leads to defensive and dilatory attitudes to a handicapped spreading of information.

Social Uncertainty – it is caused by the degree of cohesion, or vice versa of conflict, in a community and by the level of integration with institutions.

Institutional Uncertainty – it results from a scarce ability to communicate, comprehend, collaborate among the different organisms, especially public institutions, that have to manage a problem, and it is enhanced by traditional jealousy, competition, and secrecy typical of some bureaucracies.

Uncertainties Determined by Rights / Interests of Property and Privacy – they are the consequence of regulations that control the possibility to divulgate or hide information, and concern citizens, professionals, enterprises, organizations and institutions. (p. 198)

These uncertainties break down communication and the ability to effectively respond in the event of an emergency situation. Uncertainty causes hesitation and the desire to avoid direct confrontation. A participant taking part in a given tabletop situation that experiences uncertainties may fear that ideas will not be accepted, appear foolish or generally be chastised as a poor decision. In a face-to-face environment, these uncertainties are stronger due to the nature of proximity and the lack of anonymity. Additionally, it is very difficult to simulate realistic communications in a face-to-face environment due to the proximity to other participants. Instead, in a virtual environment where anonymity can be guaranteed, may be more conducive to the fostering of ideas that might not otherwise be shared by reluctant participants. This open exchange could lead to unique approaches to emergency situations which have not been considered before. At the same time, if the idea is openly accepted in the virtual community as a good response, the individual will gain confidence in his/her ability to share and communicate ideas with other agencies during a real emergency.

One of the major dilemmas with a major emergency is that it impacts both public and private sectors. Therefore, in gaming emergencies both parties are brought to the table to encourage internetworking between groups. The private sector has resources that could be made available to the public sector during a crisis that would greatly improve the response situation. One of the additional complications in current communication is that experts in public response have codes and language specific to their respective field

that is not shared by the other sectors. Biocca (2004) further states that experts share languages and codes. Experts create a language that is unique for their respective purpose. They have their own techniques and opportunities that facilitate communication among themselves, which often results in a loss of information when presented to other outside groups. Experts are a community united by technical assessment of risk, even when holding different opinions. These groups form a unique culture in which acronyms and specific methods are acceptable standards. The other groups, typically non experts and interested population groups are a community united by a perceived risk. These groups can consist of private institutions that wish to provide resources to help prevent or mitigate this perceived risk. The perceived risk group has a different structure and method of communicating the same information as the technical group. This results in complications when attempting to unite the two different groups in order to achieve a common goal.

The technical assessment of risk brings in the minimization of risk and best responses to a given situation. This could be best defined as risk management firms and public sectors, or first responders. The perceived risk is better suited in this argument for the private sectors or local companies that may be impacted by an emergency. One of the key problems at tabletop exercises is that the two groups do not see things in the same manner; they spar back and forth looking for a middle ground that is often hard to achieve. However, much of the dilemma that is behind the argument is the visualization of the actual emergency. There are two distinct entities with very different perspectives of what the emergency may look like and the best way to respond.

As Biocca (2004) points out, the mass media does not solve these discrepancies and can often worsen a situation if it is the only reliable information made available during an emergency due to inaccuracies in reporting. Biocca (2004) additionally says that, "asymmetries are widespread and the mass media does not necessarily solve them because this is not their function." (p. 200). If the two different groups, the technical assessment of risk and the perceived risk, were placed in a virtual simulation where visualization of the emergency can occur in real-time, a joint perspective may be formed. The well formed asymmetries will start to break down due to the nature of the situation. Instead of just one feedback loop of which both groups are accustomed, there are now two feedback loops, thereby improving the flow of information. Additionally, the absence of important stakeholders such as the press or a community leader results in a lack of realism in tabletop exercises. Misinformation is part of every emergency and the press plays an important role in providing both accurate and inaccurate information that may be used to make crucial decisions in emergency situations.

Additionally, it should be noted that computers are being used more frequently to improve cooperative work environments and eliminate problems such as evaluation apprehension or production blocking. There are many different human factors that affect cooperative work environments. Prante et al. (2002) argue that evaluation apprehension and production blocking can prevent the full realization of the group's capabilities in developing ideas.

Evaluation apprehension is the reward or punishment that is received based on a response in a group environment. If the statement made at an event is received openly and accepted, the individual considers it as a reward and will be more likely to make

another statement later in the meeting. However, if the statement is not received well, it will be viewed more as a punishment and disapproval. Therefore the individual will be less likely to state his/her ideas to the group again. Production Blocking is when one individual in a group takes control of the group and starts discussing his/her idea while blocking the others from sharing their ideas. The other group members may not get the chance to share their ideas or may forget an idea entirely during the course of the discussion. Production blocking and evaluation apprehension are two of the main problems with face-to-face tabletop groups that could be reconciled through the use of computer mediums and virtual environments. Additional work supporting this idea by Prante et al. (2002) state:

> To overcome the limitations of traditional creative group work, computer-supported cooperative work (CSCW) benefits from the use of information technology. For instance, by anonymizing the individual input of participants in an area finding session, the conforming effect of evaluation apprehension can be prevented. Or by entering text simultaneously, i.e., parallel instead of uttering oral statements sequentially, production blocking can be reduced. (p. 106)

Computer supported environments such as the virtual gaming environment allow users to be anonymous which as stated by Prante et al. (2002), aides in the prevention of evaluation apprehension. Additionally, computer environments such as the virtual gaming environment which is designed with distributed networking in mind, allows users from all over the world to link into the system and take part in the emergency gaming simulation. Due to its distributed nature, information can be captured in parallel instead of finding time for each member to speak at a traditional tabletop exercise. By capturing this data that could have otherwise been lost, new paths can be identified in solving emergency situations.

Further research by Prante et al. (2002) point out that face-to-face meetings and turn taking do in fact hinder the brainstorming processes regardless of tools used in attempting to capture the data that is being lost:

> In accordance with other findings in the body of literature regarding traditional face-to-face meetings, the mean quantitative output of the groups was hampered by turn-taking work mode, no matter if the mind-mapping tool or the SMART notebook was used. This clearly shows the negative effect of production blocking, especially since the quality of ideas did not change significantly with different tools. (p. 108)

The research points to the need for a virtual and anonymous environment where idea sharing can proceed unhindered by production blocking. These two issues with face-to-face brainstorming only represent the very base of the problems that can occur if production blocking and evaluation apprehension are allowed to occur. For example, in most threat situations, an individual that may have encountered a threat situation similar to the one being presented may institute production blocking immediately as observed by Staw, Sandelands, and Dutton (1981):

> When placed in a threat situation, an individuals most well-learned or dominant response may be emitted (Zajonc, 1966), but this response may be grossly inappropriate if the task or learning environment has changed. Similarly, decision-making groups may reduce their flexibility under a stress situation, sealing off new information and controlling deviant response (Janis, 1972). (p. 502)

As Staw, Sandelands and Dutton (1981) state, the response being emitted by the individual who has the floor may be "grossly inappropriate" for the situation at hand. Given this situation there is now not only production blocking happening but the individual has proposed an idea that is inappropriate or dangerous, and possibly eliminated other solutions to the emergency being portrayed in the virtual environment.

If this idea then gains momentum based on the individual's past experience in a similar situation, evaluation apprehension will develop in the face-to-face meeting. Staw, Sandelands, and Dutton (1981) further explain the pressure the need for uniformity can exert on a group and its members:

> Pressures for uniformity can lead to exclusion of deviants from vital functions. In a cross-cultural study, Schachter et al. (1954) also showed that pressures for uniformity increase as a group goal is threatened and that such pressures increase the magnitude of threat or value of the goal increases. (p. 510)

In this combination of research from both Prante et al. (2002) and Staw, Sandelands, and Dutton (1981) an argument can be developed that the traditional face-to-face methods have challenges that can affect the identification of new paths in emergency gaming simulations. While some decent ideas may be shared and some paths identified, the potential to identify wrong paths and block new ideas is very high. This is especially true when the group is being threatened by an outside force, in this case the tabletop moderator by placing the participants in a position where they will be forced to respond quickly and adequately or face evaluation apprehension from the group. This is the same dynamic which occurs in the actual response to catastrophic events. This in turn will lead to only the dominant personalities or experts wanting to share their opinions with the group due to the nature of the pressures being placed on the other individuals. Once the dominant personalities have established their presence and knowledge with the rest of the group, the production blocking will begin to occur and the situation will again be taken in a direction that was not intended.

A problem that exists with dominant personalities is that the personalities tend to control and lead the rest of the group. A dominant personality can exert pressures for

uniformity in the group's decisions. During the 2006 New Jersey Emergency Preparedness Conference in New York City, a few dominant personalities lead the discussion on the scenario presented during the exercise. While these individuals were well versed in their individual group's preparedness plans, their domination over the others in the room lead to minimization of a collective response through generation of evaluation apprehension and production blocking. Staw, Sandelands, and Dutton (1981) associate these dominant personalities with the constriction of control and leading to faulty group decisions:

> Consensus seeking also involves a constriction of control, such that the opinions of the dominant members may prevail and their influence may become more centralized. Such changes in information and control processes may, of course lead to faulty group decision making. (p. 511)

This problem of group domination and idea blocking is often mitigated by a facilitator who attempts to ensure each member of the tabletop receives an equal time to discuss the situation. However, it should be noted that when people feel as if they are under pressure to conform they will be less likely to suggest methods that may not be accepted by the overall group. The only way to alleviate this problem is through the asynchronous methods suggested above that allow for a level anonymity.

This highlights another flaw in tabletop exercises; while they may be successful in establishing steps in planning, they lack the realism of a true simulation. The lack of realism in a given tabletop exercise makes it easier to jump to conclusions than in a simulation. For example, utilizing the tabletop scenario from the 2006 New Jersey Emergency Preparedness Conference, pneumonic plague is released into a train station during the rush hour commute. The participants at the conference were quick to state that

they will tell their non-critical employees to stay at home until after the peak of the event. In actuality, the outbreak in the scenario presented will not even begin to peak until six days after the initial infection, allowing both their critical and non-critical employees to possibly become infected. The facilitator at the conference then demonstrated that when the event is actually detected it will establish mass panic throughout the vicinity of the corporation's operations. The point that is difficult to make with traditional methods is that the spread will be silent and hard to detect in its initial stages. This is the type of information that has the potential to be lost during the course of the tabletop or misinterpreted by participants. In an emergency, there is the potential for information overload due to the large amount of real-time information that is arriving to those trying to respond to the emergency. The fact that the participants are not subject to this in some tabletop exercises removes another level of realism from the tabletop. A simulation on the other hand, could accurately portray the course of infection on a computer screen in front of the participants, allowing them to truly see just how dangerous and unpredictable the situation could become.

2.2 Overview of Instructional Video Learning

Instructional video learning or case study is similar to how sports teams record their progress during a game and then later analyze it to improve performance. The idea is that in reviewing the events that have come to pass they can then learn from mistakes or choose to do things differently. Nagarajan (2006) states that, "video provides a dynamic medium to present authentic cases of teacher instruction, student learning and classroom interactions." (p. 495)

2.2.1 Issues With Instructional Video Learning

The problem with this type of study is that it allows for retrospective knowledge. This problem can be countered by offering active participation and facilitator engagement with the content being displayed in the video. However, as Nagarajan (2006) notes, "Passively watching video cases without a particular driving question may not facilitate learning." (p. 501).

Passive interaction is not the only problem that can occur in instructional video environments. Retrospective knowledge can also lead to undesired results when attempting to respond to an emergency. Retrospective knowledge is when an individual looks to their past experiences, draws a comparison to the current event being portrayed, and arrives at the decision that the same solution will apply to the event being presented. In other words, the participants already attempt to demonstrate that they know exactly how the event occurred and may not take the same paths they would have the first time.

Kielman (2006) in reference to the knowledge required for understanding terrorism and consequences of disasters, argues that, "Retrospective analysis, and even knowledge discovery, is less useful under these conditions than prospective, real-time synthesis of information for multiple users." (p. 3) The problem with using retrospective knowledge in an instructional video learning environment is that the event is not occurring real-time so it appears as if the previous solution can be applied again. In a real-time environment with constantly changing conditions, plans must be adaptable since the same plan will not work in all instances. Instructional video learning draws conclusions of which the scenario cannot react. While instructional video learning does provide some benefits in the field, the command and control unit miles away will not be

viewing the same image and will have a completely different view of the emergency. It again represents a small portion of the overall dilemma in emergency preparedness training.

For example, an earthquake damages a major city by causing gas leaks, ruptured water mains and other forms of damage. However, the majority of the buildings have remained intact and the roads relatively clear. This allows police and fire command to mobilize to places they need to be since many of the city roadways are clear and passable. There is a breakdown in the synchronous interaction between the participants and the scenario. The participants will look at the video and mobilize their units in much the same manner as was done when the event originally happened. If the same initial event was utilized with a larger quantity of buildings collapsing into the major roadways and transportation arteries, the same response would no longer apply to the situation at hand. Granted this is the eventual goal to refine and correct possible paths, it could lead to a bias in regards to which path works and which one does not. The participant now has 'retrospective knowledge'. They know what worked once and make dangerous assumptions that it will work again in the same manner. While experience accounts for a lot of how a situation is handled, no two emergencies are exactly the same. An assumption of how an event "will unfold" can lead to catastrophe and actually greatly worsen a situation. While retrospective knowledge provides a foundation in experience, it does not provide an exact knowledge of how to respond to all emergency situations. It should be realized that it does not always apply to the given situation and therefore still leaves the emergency response personnel unprepared for the event. A feedback loop

from the scenario that responds to choices is missing since the event has already occurred.

Instructional video learning can be compared to watching a movie unfold. The events can be seen happening and the participants can be told what response to take in that given event based on the outcomes. However, there is a distinct lack of reinforcement of this knowledge. The participants in the video learning environment are being told how to do things, not allowing them to actually apply what they have learned. Additionally, if the emergency preparedness personnel feel confident in their response to certain events given their training in an instructional video learning environment, they may make fatal mistakes by making the assumption or parallel that the two cases are exactly the same.

For example, in a hostage situation, the use of force after the failure of negotiations leads to the neutralizing of the attacker and the rescue of the hostages. In a different situation, after the failure of negotiations with the hostage taker, the same method is applied. The difference is in this proposed case, the attacker instead takes action that results in the killing of the hostages and possibly even the emergency personnel. This is just a generic example of how not every situation is always the same.

Past experience can still prove very valuable when dealing with an unpredictable situation. The goal is to demonstrate to the emergency personnel that while experience can be applied in a given situation, it is not always the method that results in the minimization of negative consequences. A situation that occurred where the negative effects were minimized is a desired outcome for responders, however, the question that needs to be asked: is how to increase situational awareness to provide even better

solutions than the ones that were chosen? Instructional video learning reviews focus on an event that already occurred and the course of action that was taken. The facilitator then asks the participants to improve upon that course of action. The next question that needs to be asked is: what if the participants were allowed to actually replay the event again from the beginning in a virtual environment but take a different course of action? Would the outcome still be the same or would a different path identify errors that might have been made given a slightly different set of circumstances?

In repetitively reviewing the same scenario errors will be identified and solutions can be laid out to resolve these errors again in the future. However, in using this method there is only one course of action that has occurred that can be analyzed repeatedly. In contrast, using a virtual environment the course of action that could have possibly been explored is not limited. The goal is to provide organizations the tools to develop a high reliability organization (HRO) as defined by Weick and Sutcliffe (2001), "organizations that operate under very trying conditions all the time and yet manage to have fewer than their fair share of accidents." (p. 3) In reviewing more and more possibilities in an attempt to identify possible errors and omissions in existing plans, a high reliability organization can be developed with participants to better prepare them for the unknown.

2.3 Benefits of Three-Dimensional Interactive Environments

Three-dimensional interactive environments have many unique properties that set them aside from traditional methods of gaming. One such aspect of three-dimensional environments is that they allow users to be fully immersed into a hostile virtual environment or to visualize it from a bystander point of view. The bystander point of

view could be just a viewing window into the simulation or it could be as complex as allowing the individual to play a character in the simulation environment. The perspective would be based on the type of training or participant observation that is required for the individual.

Figure 2.1 A Rendered Virtual City.
(Parish, Yoav, 2001)

Three-dimensional worlds have come a tremendous distance in the last ten years, developing from basic box graphics into full renditions of actual cities that are completely navigable in a virtual environment. The figure presented above by Parish and Yoav (Figure 2.1) is a full three-dimensional rendition of lower Manhattan. Many distributed virtual environments exist today that would support emergency preparedness gaming. One such example is the online system, Second Life, where individuals can navigate virtual worlds, create buildings and stores, and interact with other players in a real-time environment. Another example would be Eve-Online, a massive multi-player role playing game based in the future. The game has over 5,000 solar systems and supports over 30,000 players on a daily basis. The market in Eve, the politics, the construction of ships, and the collection of resources is all handled by the players within

the system. This includes deploying security patrols, allocating assets, locating potential threats, and taking action. A parallel can be drawn from this gaming environment to emergency preparedness training as responding to an emergency requires identification of the threat, allocation of resources, and communication.

If a scenario for emergency preparedness was developed in this virtual environment it would gain a depth of perception that is lost in exercises previously discussed. Unlike the previously discussed methods of emergency preparedness the virtual environment reacts and interacts with the users based on the inputs provided. The unique aspect of the effect of these inputs on the overall output of the system is that one minor change in the course of the same exercise could have a drastically different outcome based on the variables changing over time. A benefit of this in the virtual environment is that that minor change which completely altered the outcome of the scenario can be recorded and later reviewed.
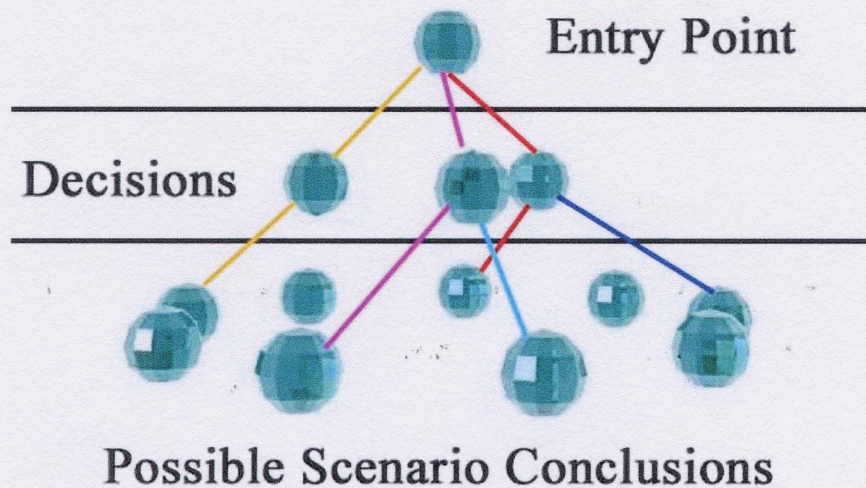
Figure 2.2 Three-Dimensional Scenario Decision Tree.

A virtual system has the capability to provide an exponential decision tree which is difficult to quantify with measuring systems due to the complexity involved with each decision the participant makes. The example above demonstrates the decision tree in its most simple form. Each one of the green spheres represents a decision and an outcome based on interaction with the system. In this example, each choice provides an additional three choices. Every decision has three possible outcomes but are not limited to just those three as the system allows back tracking on previous decisions, or in simpler terms the ability for participants to recognize and correct mistakes. This means that any of the possible conclusions to the scenario can be reached regardless of the intermediate decision trees providing an extensive list of variations in the virtual scenario. If the virtual system is developed using this methodology then the same scenario could be gamed with the same group of individuals with differing results. For example, the yellow line in figure 2.2 indicates a direct pathway from beginning to conclusion. However, the magenta and cyan lines originate from the same decision but reach different conclusions based on the inputs at that decision point, or by back tracking to that previous decision and changing an input variable.

This decision tree portrayed in figure 2.2 is especially important due to the ability to have participants in first person within the game. A first person environment is one where the participant actually controls a character or unit within the game and role plays their part within the scenario. This means that due to the first person nature the individual can affect the outcome of the scenario just by the decisions they make. An example of first person environments would be "Grand Theft Auto - San Andreas" by Rockstar Games. In this game the user plays a character in first person and walks through cities

and even specific buildings, while performing a variety of missions and other items within the game. While the games graphic and violent nature should be noted, it should also be noted that the game is filled with artificially intelligent pedestrians that walk down the city streets and interact with characters around them and other stimuli.

Figure 2.3 Grand Theft Auto IV Interactive Environment.
(RockStar Games)

If one were inclined to point a gun at a pedestrian in this game, the pedestrian would freeze and put there hands up, run the other way, or possibly start shooting at the person who originally threatened the virtual pedestrian. These reactions in turn trigger a police response, ambulance and fire response as well as possible escalation to swat and military response. It is also worthwhile to note that as these events occur, media coverage within the game increases, leading to helicopters monitoring the situation and pedestrians generally being attracted to areas of conflict. This could represent a form of intelligence for a command and control unit located further away by collecting information from individuals that saw the event or from the media covering the event. If the artificially intelligent entities were replaced with real players that can interact and

control there actions, it would then be possible to view the simulation from first person and interact with the surrounding environment. In a first person environment a hostile member or a participant whose goal is to create an emergency could technically walk past those trying to protect the city without them even recognizing the threat as the individual would look like the other pedestrians in the game unless their identity were revealed.

2.3.1 Existing Simulation Systems and Virtual Environments

Existing simulation systems can be examined to see current applications of virtual environments. These environments can be compared to demonstrate the benefits a three-dimensional virtual environment would provide in emergency preparedness settings. An example of the use of video game technology to produce three-dimensional environments is a system developed by BreakAway Games to be run on a Microsoft Xbox game system. Agrait et al. (2004) describe the idea of the game as a method to familiarize soldiers with urban areas prior to mobilizing them on the ground in that area:

> BreakAway Games, a game developer, has created a video game based on the streets of Iraq. The game was made for the Microsoft Xbox game system and was developed for the Army Research Institute, with the prime objective being to familiarize soldiers with an urban setting in a foreign country. (p. 8).

The game, however, has gone far beyond just familiarizing the soldiers with foreign urban areas. The game can also be updated quickly and transmitted via satellite to reflect changes to the existing environment. Agrait et al. (2004) further expand on their research of the game developed by BreakAway Games to include updating the game with recent satellite data and other information to improve the realism for future simulations:

> Suppose orders are given to go into an area of conflict. What we are able to do is download satellite data for that area of conflict and put it into the game at real time. The objectives of the game stay the same, just the environment changes. Say, for instance, you are en route to an area that was bombed. You just get new data and burn a new disk, and the bombed area would be reflected in the game. (p. 8)

When universal adversaries decide to attack a target they lay out their plans and choose the best course of action to achieve their goals in the most sensational way possible to attract attention. Unfortunately, even if public authorities intercept or gain intelligence on these plans, there is nothing to prevent the adversaries from immediately switching targets and proceeding to a less defended entity. In providing a red hostile or offensive team, a group of participants' intent on causing an event within the virtual system, with the ability to view the city in first person, a new dynamic is added to the simulation. The red team could walk down the street, notice increased security and turn and strike another target or choose to abort the mission. This is important in the sense that these are how events unfold in reality.

Additionally, from the perspective of the blue defensive team, the group of participants attempting to prevent or mitigate the incident, have the needle in the haystack problem. The blue team knows an attack is imminent and may have taken the appropriate steps to avert it. They may have roadblocks deployed searching for the individual, reported pictures to the media, or taken other steps. However, in a city setting they have one person, or a group of individuals mixed in with thousands, if not millions of other people moving about the city on a daily basis. In simulations studied thus far, the blue team did not have to sift through a real setting in searching for individuals. The steps were always laid out on how to proceed. In the virtual environment the individuals they

are searching for blend into the environment, making it difficult to locate them before they carry out their strike against assets.

An additional view that is important to gaming in a virtual environment is the command and control interface that provides real time operations, units available, resources available, and intelligence resources information. An example of a game that utilizes a basic command and control interface would be the Command and Conquer series of games developed by Westwood Studios. A user in this game chooses a side similar to the red or blue teams and then controls a selection of units, the funds to operate those units, and where to place the units and assign them there orders. The resources and units in the game are not unlimited, therefore the user must choose where to deploy the resources he/she has in an attempt to minimize losses or avert an incident.

These two different views are very important in that they both portray two separate aspects that must be taken into account when handling an emergency situation. The view at the scene of the emergency may be far different than the scene portrayed to the command and control unit possibly miles away that is directly in contact with those units already in the emergency area. It is this combination of views that allows for a shared situational awareness. The idea of the three-dimensional virtual system is to provide those on site and those in command and control a shared situational awareness through gaming on the virtual system. Rhyne (2002) states that the U.S. Department of Defense began to utilize the resources of entertainment and game developers in 1999 through the Institute of Creative Technologies to further improve decision-making skills in complex environments:

> The institute of Creative Technologies, a program begun in 1999 by the
> U.S. Department of Defense (U.S. Army Simulation, Training, and

Instrumentation Command) to tap the resources and talents of the entertainment and game development industries, jointly operated with the University of Southern California, is developing combat video games to enhance the strategic, combat, and decision-making skills of next-generation military field commanders. (p. 41)

The use of video games and similar virtual environments for simulation of combat, flying or disaster modeling is not a new concept in response and training. However, even though it is not a new concept, the applications for the field still seem to be in their infant stages. A three-dimensional virtual environment unfolds in a similar manner to the tabletop training exercises. The primary difference is that the participants develop the scenario as it progresses through interaction with the system. A tabletop training exercise in contract usually has a pre-determined course of action planned in advance.

Examples of three-dimensional simulators can be found in many different aspects of today's society. The military uses three-dimensional simulators to train soldiers how to interact with groups of individuals in hostile situations. An example of such training was utilized for the NATO force currently deployed in Kosovo. Three-dimensional flight simulators are used to train jet pilots in the appropriate manner of flying before they are placed behind the controls of an airplane. The pentagon has been using virtual environment simulators in war games for years now in an attempt to visualize enemy battlefields and possible future conflicts around the world. These environments use real world data such as geographical information systems to model entire cities for realistic planning.

A more recent application based on visualization and gaming technology for emergency preparedness is SIMNET or National Exercise Simulation Network.

Nicholson (2007) describes SIMNET as a network based real-time simulation for Homeland Security preparedness which can be accessed by emergency response personnel from the same computers they would use in the event of an actual situation:

> ...a mix of live, virtual, and constructive simulations to; Prepare elected officials, emergency managers, emergency response providers, and emergency support providers at all levels of government to operate cohesively; provide a learning environment for the homeland security of all federal agencies; assist in the development of operational procedures and exercises, particularly those based on catastrophic incidents; and allow incident commanders to exercise decision making in a simulation environment; and uses modeling and simulation for training, exercises, and command and control functions at the operational level. (p. 2)

One of the primary goals of SIMNET is to make the simulation and training available to all members of government that have contact with the management of emergency situations. Three-dimensional virtual gaming simulations share some characteristics with the SIMNET structure. For example, the events in both simulations would be unscripted and based on the participant's decisions. Secondly, both systems would run in real-time, utilizing actual communication media to respond and interact with the simulation. Finally, the systems would use real world information such as geographic features, contamination plumes and other items to provide a realistic environment. Nicholson (2007) notes that an environment such as SIMNET would be more prone to revealing inconsistencies / incompatibilities and allow for playback of events which facilitates collaborative review of decisions.

SIMNET seeks to provide a distributed solution for participants that cannot attend federally funded training due to previously mentioned constraints. Similarly, the virtual environment allows users to login from their own work stations and take part in events. The system runs in real-time and is decision based like the tree discussed in the virtual

environment. One of the primary problems with SIMNET is that its use is somewhat restrictive due to the sensitive nature of some federal command and control structures. While SIMNET appears to address the federal and public authority side of emergencies, it seems to come up short when private sector operations are taken into account.

The Close Combat Tactical Trainer (CCTT) at Fort Carson, Colorado provides a real-time environment for gaming opposing forces which are participant controlled, as well as, semi-autonomous forces. The idea of CCTT is to provide a realistic simulated battlefield environment. After the simulation has taken place the participants are allowed to watch the recorded session on monitors in a classroom environment, thereby utilizing not only the full-scale simulation but also reinforcing it with instructional video learning and a mediated discussion.

Another example of using virtual systems in training is the IVR small arms training system developed by VirTra systems for the U.S. Army. The environment allows for participant customization depending on what the individual needs to train. Haag (2008) describes the technology as, "This user-friendly technology offers more pertinent training, allowing customization of scenarios to each customer's particular environment and agency guidelines, and at a sizeable savings compared to custom-produced filmed scenarios." (p. 1)

The idea behind the system is to provide participants with a custom multi-sensory simulation that can aid them when deployed in a true emergency or combat situation. However, the CCTT and VirTra systems have a downfall in that the training is only offered at specified locations and times. These are highly advanced full immersion virtual reality systems that require extremely powerful computers and virtual reality gear

that the participant must wear, such as goggles and haptic devices. The virtual environment proposed in this paper does not take that extra step and while participants can immerse themselves as a character in the game they are not physically inserted into the world unlike these simulators. However, it should be noted that the virtual environment does support features like this if it were desired that it should be added at a later date.

2.4 Comparison of the Three Methods

The three methods discussed in this paper, tabletop training exercises, instructional video learning, and simulation systems, each have their own unique properties which make them appropriate for preparing for a variety of given situations. It can be derived from the technologies and training methods examined thus far that virtual environments have advantages over tabletop training exercise that are difficult to replicate in a TTX environment. Tabletop training exercises come in a variety of forms, some with just text based notes which provide an outline of the event. Additionally, tabletop training exercises sometimes provide mocked up city models. The scenarios can then be varied by the facilitator so that each time the scenario is played it has a unique training value.

In contrast, a virtual environment can have its possibilities randomly adjusted to provide a realistic simulation environment. For example, putting out a small fire in a city at night is a relatively easy task given proper conditions. The computer could unexpectedly change the weather conditions by bringing a snowstorm into the equation if the event were happening during the winter. The easy fire fighting task has just become an astronomically more difficult task to accomplish.

Instructional Video Learning probably presents the weakest methodology in actual preparation for emergency situations. It should instead be used as a way of reviewing how participants responded to the event and how the participants can take corrective action to streamline their response. An instructional video can tell participants how others reacted and what the results were but there is little reinforcement of specific actions given the portrayed scenario. This method of preparedness training is often best used with other methods of training such as TTX environments.

Virtual simulation systems also have other significant benefits over TTX, full scale simulations, and instructional video learning. In examining information theory and various learning styles it can be determined how the multi-sensory approach of a virtual environment can greatly improve the lessons learned in emergency preparedness training.

CHAPTER 3

INFORMATION THEORY

In order to maximize the information received, processed and retained by participants it is necessary to examine the rate at which humans can process information. The reason for the importance of examining information theory and human processing rates to prevent an effect known as information overload. Information overload occurs when too much information is presented, the brain retains portions of the information exchange but large chunks of information are discarded. It is important to deliver multi-sensory information in a way in which it maximizes the storing of information without overloading or under stimulating the human mind. Overloading leads to the discarding of information and under stimulation results in boredom and the information receptors begin to ignore information being sent to them and result in habituation. Habituation is an example of non-associative learning due to repetitive applications of stimuli. Over time the individuals being presented with the same information start to discard the information since it is not rewarding, nor is it harmful. The end result is the loss of attention, and the closing of the communication channel.

Shannon (1948) first developed the idea of information theory in his paper, "A Mathematical Theory of Communication". Shannon created the schematic diagram of a general communication system which demonstrates how information is converted into a form that can be transmitted through a channel over a medium and then received and recoded so that the destination can again see the intended message. Weaver (1949) further expanded on these ideas bringing the logarithmic equations in regards to capacity of information that can be transmitted:

In a more general case, one has to take account of the varying lengths of various symbols. Thus, the general expression for capacity of a channel involves the logarithm of the numbers of symbols of certain time duration (which introduces, of course, the idea of information and corresponds to the factor 8 in the simple case of the preceding paragraph); and also involves the number of such symbols handled (which corresponds to the factor n of the preceding paragraph). Thus in the general case, capacity measures no the number of symbols transmitted per second, but rather the amount of information transmitted per second, using bits per second as its unit. (p. 9)

In terms of emergency preparedness and training, individuals are having data encoded and transmitted to them through audio and visual channels. A facilitator that is speaking to a room of participants is taking his expertise and conveying it in the form of speech to the participants who then must process that information and store it for future reference. In addition to the ability to encode and transmit information, there is also a limitation on how much information can be conveyed at a given moment. Gregory (2004) states that: "Typing is limited to about 15 bits per second. Speech can be as high as 26 bits per second, though around 18 is normal. It has been estimated that silent reading can be as high as 44 bits per second." (p.105). The information captured during a tabletop training exercise can be derived from these values to be in the area of twenty six to forty four bits per second given the equal nature of reading and interactive discussion that occurs. Information capacity from visual input, however, has been calculated to 6×10^5 bits per second.

"Ditchburn and Drysdale (1973) calculated the information capacity from measurements of the variation of contrast sensitivity with number of lines per degree of visual angle for targets which were sinusoidal gratings. This calculation also yields a value of 5×10^5 bits per second, thought their method includes capacity in terms of targets with different shades of gray. Neither of these estimates includes color information, but it is likely that the additional information due to color is more than about 20 per cent, making 6×10^5 bits per second in all." (Gregory, 2004, p. 464)

Additionally, Gregory (2004) states that further research confirmed that the entire visual system has about five hundred to six hundred times the capacity of the aural system: "Thus the central region of the retina has about 50 times the capacity of the ear and the whole visual system has about 500 or 600 times the aural capacity" (p. 464). It would then make sense that the visual system should be stimulated with information as well as the aural system when attempting to train participants. However, it should be noted that while stimulating visual information to participants care should be taken to avoid information overload. If information overload occurs the participants will begin to disregard information that may be of vital importance to the exercise.

Aural Information Input:

> "A group of emergency helicopters is attempting to make a landing in foggy conditions somewhere inside the United States to provide resources to the first responders."

Visual Information Input:

Figure 3.1 Visual Information Input.

The visual aid Figure 3.1 serves as an example of how the exact same information conveyed in the aural input information can be conveyed in the visual information. However, the visual information input contains more data and allows for a shared point

of view on the landing conditions for the helicopters. The words "Foggy conditions" can be interpreted by the receiver of the information since the conditions are not well defined and are left open for interpretation. In the visual input, however, the exact conditions are portrayed. If the two communications mediums are used in conjunction with each other, then the participants will have a greater chance of improved stimulation from the data instead of habituation.

CHAPTER 4

OUTLINE FOR THE VIRTUAL CITY

4.1 Establishing the Outline for the City

In order to construct the virtual city it is necessary to develop the framework and tools for the system. Therefore an interface should be provided to each participant or participant group taking part in the exercise. The idea is to provide the participants with the set of tools they require to coordinate plans to improve response capabilities. Jain and McLean (2003) argue that, "A set of tools that can help develop and evaluate coordination among these multiple plans can significantly improve the response capabilities. These tools need to be integrated together to reduce the time and effort for their use." (p. 1068). It can be derived that in order to provide the set of tools that can help develop and evaluate coordination, the tools should be provided through one system.

The integration of the tools is vital in reducing the opportunity and time costs associated with existing methods of training and simulation. A system that can be developed to support these capabilities of bringing together multiple tools, while providing various outputs for different learning styles and personal engagement, are immersive simulation systems. An immersive simulation system is a system that can provide training and simulation of actual events for groups ranging from the command and control groups to the first responder groups. Currently simulation tools focus on different stages of these various views of looking at emergency response but not in an inconclusive environment. Jain and McLean (2003) discuss a variety of simulation tools currently available for emergency response:

> Simulation tools for emergency response training mimic and present situations created by occurrence of a disaster event to human training subjects with the intent to improve their capabilities for emergency response. These tools extend from those targeted at decision makers to those targeted at first responders. Sandia National Labs has developed a program called the Weapons of Mass Destruction Decision Analysis Center as a way to simulate a war-room environment in the event of a terrorist attack (San Francisco Chronicle 2002). It is aimed at training public officials' response to a bio-terror attack. A development targeted at first responders is BioSimMER, a Virtual Reality (VR) application that immerses subjects in a computer-simulated setting (a small airport in which a biological warfare agent has been dispersed following a terrorist bombing) (SNL 2002). (p. 1068)

The Weapons of Mass Destruction Decision Analysis Center is focusing on war-room command and control environments while the BioSimMER virtual reality environment is focusing on first responders. The two simulation environments are responding to similar events but in two different styles. Instead, the groups taking part in the Weapons of Mass Destruction Decision Analysis Center should be providing command information and instructions to the groups taking part in the BioSimMER environment. This would then provide a mimicked environment of how the actual response would occur. There are a series of issues associated with these technologies that are available.

One of the primary disadvantages of simulation software available today is that it is proprietary. This means there is a cost associated with the acquisition and use of the software. Also, the software being developed is often focused on federal and public authorities while its use is being restricted from the private sector. The list of current issues associated with existing systems can be addressed by establishing an outline or framework for the virtual city environment. The following items must be kept in mind

while designing the system to ensure that the previously discussed issues with existing

methodologies of emergency preparedness training are avoided.

- **Geographically Independent** - The system should be accessible from any geographical location world wide through network technologies. Any computer that is able to access the Internet should be able to access the simulation given it has the appropriate access rights.

- **Time Zone Independent**– The system must be available on almost a twenty-four hour basis. This would allow groups from other countries to participate with the system during off hours in other countries. Additionally, by making the system time zone independent, a more diversified interaction occurs with the system. The system should run in real-time, allowing changes to occur if an individual takes a break from the scenario.

- **Open Source Technologies** – The system should be developed utilizing open source technologies to both minimize costs as well as improve the ability of others to contribute to the system. Proprietary technologies should be avoided as these will only increase both the material and opportunity costs of the system. The system should also be platform independent, meaning the system can be interacted with on Windows, Unix, Linux, and Apple computers.

- **Participant Anonymity** – The participants of the simulation should be provided with a level of anonymity. Data collection must still be permitted on the individual basis but the actual name of the individual would be withheld. This is to aid in the prevention of evaluation apprehension and production blocking. This implies that pen names or aliases would be assigned to individuals taking part in the exercise.

- **Participant Roles** - Participants must be able to choose roles they either usually fulfill in emergency situations or roles that they are not accustomed too. This allows for the participants to develop a shared situational awareness by understanding the position of command and control, as well as the first responder perceptive. The chosen roles should be selectable by the participant before entering the simulation. There should also be an option to allow the facilitator to assign roles as necessary.

- **Modular in Design** – The individual objects in the system should be modular in nature, such as buildings, parks, cars and over interactive objects. This allows modules to be removed, added or customized without requiring the virtual cities governing program to be altered.

- **Shared Situational Awareness** – The system should allow participants to view a scenario from as many perspectives as possible and attempt to provide a shared situational awareness between fully immersed groups of individuals and those watching from the command interface during a scenario.

- **Plug and Play Functionality** – The system should allow plug and play functionality through utilizing global positioning coordinate systems and geographical information system templates. The coordinate system should allow real buildings and other points of interest to be inserted into the virtual city and have the objects align automatically to their true positions in State Plane or similar coordinate systems. This in turn will allow existing technologies to possibly be tested and used in conjunction with the virtual city environment.

- **Multimodal Environment** - The system allows users to interact with the system far behind the standard keyboard and mouse environments by placing them within the system and providing a visual and aural environment, allowing ideas and commands to be shared over voice communications and other forms of communication when gaming in the system.

- **Realistic Environment** – The system should be a reflection of reality in terms of buildings and other objects as well as interaction with these systems. Weather effects, lighting effects an other phenomena that can diversely affect an emergency situation should be taken into account to provide training as close to full scale simulations as possible.

- **Unscripted and Decision Based** – The system should change the variables and outcomes of various scenarios based on a combination of random variable generators and decision based trees created by the participants.

Each one of these eleven guidelines attempts to resolve a potential issue with existing methods of training for emergency preparedness. The ten steps attempt to provide a reusable and adaptable environment that would be available to both public and private participants on a world scale accessible through existing network technologies.

4.2 Addressing Multi-Phase Training

A virtual city allows an almost unlimited approach to stimulate ideas about a situation and serious planning. Traditional tabletop exercises are usually restricted in the ways that they can address multiple phases of training. An example would be attempting to use a traditional tabletop exercise which is scripted for serious planning and response. The variables for the exercise are already scripted and play out the same way each time the participants approach the problem. However, in the virtual city the variables can be changed to examine different aspects and variations of an emergency.

The planning phase could be incorporated into the virtual city in a variety of ways. The city could be flooded to show potential results of a one hundred year flood on the city and then during the same exercise the flooding could then be increased to five hundred years or higher. This leads to flexible planning and adaptation in the planning stage of the scenario; as conditions change the plan must change. Another example of how the virtual city provides advantages over tabletop exercises is the ability to immerse a red team into the gaming environment that can actively change its courses of action against the defending team or participants.

The ability to easily change and adapt the system can provide benefits in training, detection, mitigation and preparation. One of the main opportunities with training is in

providing a well rounded approach to a possible emergency. Unfortunately, no two emergencies are truly identical even though they may share many similarities. In providing a system that can be altered while performing the training in different situations and possibilities can be explored without placing the participants in harms way. Additionally, the use of a red team or other immersed group carrying out certain actions can act as a tool for training individuals in detection of threats and the best way to respond to those threats. This can include the placement of units and resources in an attempt to minimize the potential threat posed by these individuals; basically, planning for an emergency which has yet to occur. This similar strategy of preparation and placement of resources can be used in terms of predicted weather events or other naturally occurring disasters. Examples of predictable weather events include hurricanes, heavy rain resulting in flooding, snow storms, and tornado related events. All of these different weather events have specific responses that can be taken in regards to them, but a variation in the event could lead to unexpected outcomes. Therefore the virtual city not only addresses the preparation for the event in these cases but also response and recovery based on the event.

The unique aspect of having a virtual city in terms of response and recovery is that on top of the preparation, supply lines and resources can be simulated. In preparing for a simulation certain supply lines and locations of resources as well as their alternative locations will be mapped prior to the event given enough time in advance. These locations and resources can change quickly with little advance warning after an event has occurred. For example, supply trucks make be cut off from the city due to heavy flooding thereby requiring the supplies to be airlifted into the residents. The next

problem in a flood emergency is identifying a field in which the airlifted supplies can be dropped which is not subject to flooding. This, in turn, could lead to using the system to identify and simulate potential future dangers of areas that seem like a good place to setup a supply or evacuation center. However, if the city increases the simulation from a one hundred year flood to a five hundred year flood the results could differ drastically.

As hurricane Katrina demonstrated in 2005, the dangers of improper communication, poor coordination, and failures of command and control during the response and recovery phase following the hurricane. These are things that could have been previously gamed and simulated using the virtual city environment. Hurricane Katrina actually side swiped the city of New Orleans. Had it been a direct hit, the damage to the city would have been extreme in comparison to the damage that did occur. A simulation could have been developed and modeled after New Orleans in an environment much like the virtual city. It could then be used to simulate a direct hit or nearby miss of the city allowing participants to vary certain aspects of the city and storm to see the various outcomes. For example, they could alter the wind speeds of the approaching storm or increase rainfall amounts. Additionally, in one scenario the levee could hold and in the other break in three places.

These all represent preparation for potential disaster situations; however, there is no reason why the city cannot be flooded in exactly the same manner and used for the response planning. The flooded city can then be used to identify locations where casualties and injuries can be handled and addressed. It can be used to locate places where food, water and shelter can be provided to survivors of the disaster and help mitigate the potential dangers of disease and further loss of life. This can lead to possible

detection of problems in the supply line and logistics of actually delivering aid and relocating displaced individuals.

In allowing the participants to simulate actually providing aid, they can be broken up into different groups. The first responders can orchestrate getting the materials to the various sites in the emergency area while the other individuals can look at their available resources and what they can contribute. By using a seeding method, various resources that are not part of the 'response' plan could be seeded all over the city providing that the location of these assets is identified by the first responders on the ground in the simulation. An example would be a truck of fuel that could be utilized to provide energy to generators to keep victims warm, provide cooking fuel, and light for emergency operations.

Another attribute of the system that would help participants with the multiphase training is the ability to stop in the middle of an incident or go backwards to undo a step that may have led to undesired results. In the Katrina example this could be conveyed in that the original scenario occurs exactly as it did in real life, but then they back up and return to a point where they can issue mandatory evacuations another day in advance. It allows the participants to explore how a slight variation of the original chain of events could have a significant impact on the overall emergency situation. As the emergency is approached time and time again from different perspectives and variations, a wealth of knowledge can be created and stored in a database system. This could lead to the identification of possible patterns or paths that could be taken in emergency situations to greatly reduce the impact of the emergency. This would generate a comprehensive database of lessons from which a collaborative knowledge will build. Additionally, it

would be able to identify potential short falls in existing training methodologies by recognizing where responders fail to adequately address an issue within the emergency. These short falls can then be conveyed as lessons learned to other individuals in an attempt to construct a combined knowledge with which to measure future trainees.

4.3 Incorporating Realistic Communications

Communications provide a vital role in emergency preparedness and response through a complicated network of voice, text based communications, and video conferencing. These communications allow for first responders to properly move units into place prior to an event, as well as, provide communication during the response and recovery from an event. In contrast, while attempting to foster various communications mediums in a training environment, the same communications should also be interrupted to mimic real situations when certain important contacts or groups cannot be reached.

There are times during many major emergencies when communications equipment fails to reach the intended party or that party is busy attending to the needs of the situation and is unable to answer the communication. There is no guarantee that wireless networks, cellular phones or satellite phones will work in an emergency given the possibilities for interference and changing conditions. The traditional land lines may work, but again, there is no guarantee that the lines were not severed or submerged during the emergency. First responders and command and control individuals need to be prepared for contact between parties to be severed. This implies that first responders, as well as command and control should have set protocols of how to operate in the field without contact. These protocols of communication could be simulated in the system in

order to test their efficiency by allowing participants to communicate in a manner similar to how they would in a given emergency.

In addition to actually determining if communication structures will succeed or fail in different given emergencies, the system could also support intelligence options that are reflective of real events. A new media could be simulated within the game to report on certain happenings given the variables are such that it automatically triggers the event. If an explosion would occur in the virtual city, the simulated reporter would perform a news broadcast in the game stating an explosion had occurred on 22nd West Street and 3rd Avenue, that there were reported casualties but no word yet on the cause of the event. This is intelligence that participants can use to improve their response to an emergency or actually worsen their response.

The key part of this argument is that the media can sometimes provide misinformation or inaccurate information. If this information is then used in emergency response it can have serious consequences. Therefore in utilizing a similar system, participants would need to, as suggest by Turoff et al. (2008) "muddle through" the various intelligence and news reports to try and identify the next logical step. Turoff et al. (2008) suggest, "a collective intelligence where the group result is better than any one member would have reached working alone and where decision making can occur as quickly as a single individual seeking to collect and consider carefully all the available information that might influence the process." In this case a group of experts or experienced professionals would each muddle through the enormous amounts of information and reach a collective decision versus one person attempting to come to the same decision. This could be fostered among the participants by having them make

decisions as a group in a limited period of time based on the disclosed information within the simulation.

4.4 A Geographical Information System and Global Positioning Capable System

Geographical information systems (GIS) and global positioning systems (GPS) have recently become more mainstream and used on a daily basis. Today, car navigation systems, cell phones, civil and environmental engineering companies, and even state government departments utilize these systems to generate maps that contain data that can be queried. In the 2006 Strong Angel full-scale exercise (Mikawa, 2006), a group of GIS vendors worked together to establish a joint interoperable database of geo-referenced data. GIS can provide important imagery, maps, and three-dimensional projections. The GIS systems can be coupled with GPS tracking equipment so that individuals, teams, and resources can be actively tracked in the GIS database. GIS databases are inclusive of flood plains, roads, terrain maps and even potential toxic plume paths. GIS datasets can be used to visualize information and potential threats that are not visible to the naked eye such as radiation or contaminated water. Pyush et al. (2002) argue that geospatial information is critical to effective, collaborative decision making during emergency management situations. GIS can also be used to forecast these potential dangers and others before they occur.

An example of such a GIS map would be the Federal Emergency Management Agency's flood maps. The digital flood maps are in state plane coordinate systems so that they can be inserted directly into a system enabled with the state plane coordinates and snap to their existing locations in a reflection of the actual flood maps. The flood zone

lines can then be queried through an SQL database and reflect if the area in question lies within a flood zone or outside of a flood zone, as well as which type of flood zone. This data could then be used to simulate a real flood within the virtual city. The city could randomly generate a one hundred year storm thereby flooding all areas that lie within the one hundred year flood zones. If desired that same storm could be altered to generate a five hundred year flood again utilizing the flood zone lines to determine where the water would approach based on the geographic information. The participants of the simulation would be shown how differing amounts of rainfall would inundate certain areas with water. This allows for the identification of safe locations where resources can be placed out of harm's way before the storm even arrives.

In another example, surface contours that depict elevation data are now becoming available. This information could be used to generate complex variables that cannot be simulated at a tabletop training exercise and can only be found in full-scale exercises. Accurate surface data can be used to predict the movements of water, contamination plumes, aerosolized plumes from chemical spills, and other hazards affected by the layout of the landscape. Additionally, landscapes themselves can pose natural hazards such as avalanches and mudslides or natural obstructions to reaching areas affected by a disaster. The other important feature of GIS systems and buildings that have GPS coordinates is the ability to import an object and its attributes into a three-dimensional space and have it 'snap' or conform to its original coordinates in the real world. Global positioning systems are what define the coordinates for use in a geographical information system. Designing the system around this approach allows for collaborative data from different sources to be entered into the system and allow for that information to be easily updated.

This allows for different aspects of the city or overlay modules to be created by other institutions or groups and then inserted into the virtual city for immediate use.

Geographical information systems consist of data that has either been digitized or identified utilizing global positioning systems. GIS data usually consists of object lines, data points and layer sets. The object lines depict the boundary lines of the data or other important information. The data points are usually either GPS points to the corresponding actual line or the digitized points that have been aligned with a State Plane Coordinate system. The layers represent the actual data which can be toggled on and off as required. GIS systems and databases provide large knowledge bases for a variety of information. The data is unique in that it can be imported as a GIS entity into the virtual city and it would snap to the appropriate coordinates given the coordinate systems match. Snap is a term implied to GIS entities in that the data contains the information regarding its real location, therefore when it is brought into a coordinate system the points automatically align in the virtual system to the corresponding data points or 'snap' to its location.

In addition to providing accurate coordinates for structures, global positioning systems also provide real time navigational benefits for both military and civilian applications. GPS allows a user to either track movements or determine the locations of vehicles, individuals and other assets. The Strong Angel (2006) full scale exercise used GPS location tracking on Sprint Nextel mobile push-to-talk phones, which had a location tracking capability based on cell-tower triangulation. (Mikawa, 2006) This in turn was linked to the GIS solutions. This means that the GPS can be directly integrated so that units can be tracked real time on state plane coordinate grids for accurate response and resource deployment.

A State Plane Coordinate system is a grid overlay of a state that is in a coordinate system of either feet or meters. The grid could also be in geographical coordinates; however, the larger the grid, the higher the inaccuracy becomes of the items actual location. For purposes of this paper the focus will be on the state plane coordinate system for New Jersey, NAD 83, U.S. Foot. The inaccuracy of the grid for field located items can be up to approximately three feet depending on satellite locations when the global positioning system is utilized to identify a location or set a point. A point is a set of coordinates, a northing and an easting in feet. These coordinates correspond to an intersecting point somewhere within the New Jersey State Plane coordinate grid. Therefore it is possible to locate objects using a GPS system and later plot them into a computer system, or in this case, the virtual city.
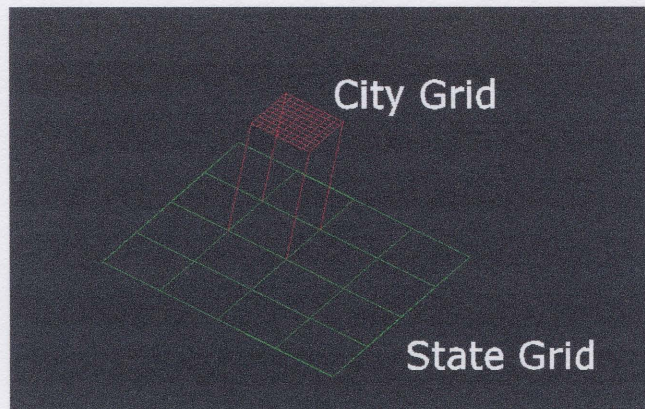
Figure 4.1 Geographic Information System Grid Overlays.

If a building had been designed for the virtual city and placed in the city grid as shown above, the building would snap into the city coordinates when inserted along with its related SQL DB describing the attributes of the building. These attributes could range from number of floors, services present, owner of the building, and a large variety of other values. The point of this would be to allow groups to develop independent modules

or buildings and then provide them to the host of the city for implementation. The modules allow for expansion of the city while maintaining the integrity of the existing system. Like building blocks, the system can be added to just by inserting the next city block.

A GPS unit is not limited to just building corners and can be used to locate manholes, pipe lines, and many other features to a degree of accuracy that is unmatched by the traditional digitizing of maps. If a three-dimensional virtual model of the New Jersey Institute of Technology Campus Center was developed and then the GPS points were recorded at the building corners, the model could then be accurately placed in the virtual city according to the coordinate system. In fact, if so desired every building that is digitized virtually in three dimensions regardless of location can be inserted into the virtual world according to the points provided. A virtual world would be the next step beyond developing a virtual city, the reason the world is noted in this paper is to demonstrate that once the coordinate systems are developed in the virtual city the ability to expand the system is always present.

Additional grids can also be developed such as the Newark City grid, where the system only loads the city that the emergency simulation will take place. This would limit the amount of required bandwidth, memory, and processing power required to load the city for the simulation. Later, if the simulation moves to another city, the city grid of Trenton, New Jersey could be loaded and The Newark City grid could be disabled. By placing the virtual city into the grid system the ability to introduce new items to the environment with plug play compatibility has been included. For instance, deployed units such as police, fire or military can now be tracked using the city coordinates. This would

provide a dynamic command and control advantage similar to the ones that are under development currently. If so desired the tracking could be increased to individual units, such as a swat team moving through a building, or the tracking of fire fighters on multiple floors of a building fighting a fire.
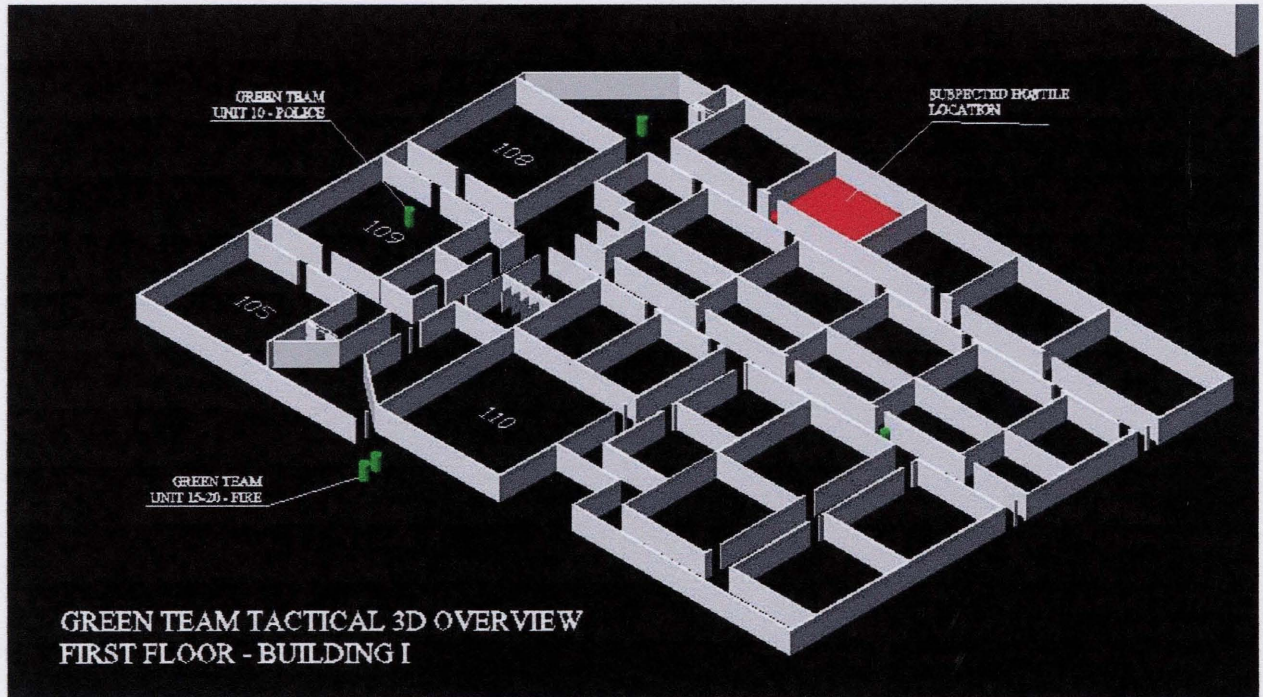
Figure 4.2 Tactical Three-Dimensional Building Overlay Utilizing Global Positioning Tracking Techniques.

The global positioning system could provide a significant amount of benefits to the expansion of the virtual city if implemented appropriately. Additionally, it can help foster awareness and benefits of its use among emergency response personnel that may be lacking in the training and use of such equipment. The benefits the global positioning system would provide to the tracking of equipment and the information it details make it a necessity for the virtual city.

An example of an application of this technology can be seen using the New Jersey Department of Environmental Protection's I-Map. I-Map allows the user to select a

region of the state and zoom in while activating various GIS layers to view combinations of information in a two dimensional view.   It then allows the user to print the combination of the layers, or download the layers for use in other applications. In the picture depicted below the image is portraying the 2002 Aerial Photographs of the New Jersey Institute of Technology, as well as the road names and local ground water contamination plumes as highlighted in magenta.   The combinations of information that can be formed and displayed are extensive and highly valuable in nature. The example demonstrated below is used only to demonstrate a simplified example of GIS in use.

Figure 4.3 High Resolution New Jersey Orthophotography Showing a Contamination Plume.
 (NJDEP I-MAP, 2002 High Resolution Orthophotography)

The idea is that models for the city could be built using a loosely fitted standards guide that would then allow models of buildings, trucks, or other features to easily be imported into the virtual city. This would provide a foundation for entire cities to be created digitally and imported into the three-dimensional gaming environment to not only improve realism but provide accurate replicas for emergency preparedness training exercises. The other optional data consists of GIS layer sets that have already been created that overlay the city and can be utilized by participants that choose to view the situation from the command and control perspective. These layers in combination with the virtual city that allows for full immersion represent aspects of emergency preparedness simulations only found during full-scale exercises.

4.5 Incorporating Roles

One of the key aspects of every emergency situation is the assignment and fulfillment of roles related to responding and recovering from an emergency. These roles can vary by level of management as well as by area of management. One of the key points of the virtual city is to allow participants to change roles, or have new roles assigned while the scenario is unfolding inside the system. This provides the system with the ability to defer to expertise and provide an improved situational awareness experience for the participants. There would be three possible ways to assign or change roles within the system. One would be the initial acceptance of a role before taking part in the simulation. When the individual logs into the system he/she can pre-determine what type of role to fulfill in the system and receive the necessary attributes to fulfill that role. If the individual wishes to be a firefighter then he/she will be able to interact with the

equipment in that field since the system will make the assumption that this individual has a basic level of firefighter training. It should be noted that the system still provides a limited guidance of interaction, meaning that if the individual is not sure what step to take next the system should be able to offer potential options in order to prevent stagnation within the system.

Individuals can be assigned roles or receive field promotions or demotions depending on their current level of activity within the virtual city. These promotions could either be automatically generated depending on performance or they could be generated by individuals with command levels assigning a higher or lower level of responsibility. If a field commander becomes incapacitated during a response to an emergency, then someone must be selected to fulfill that role. This allows for a dynamic role based environment which mimics real life situations in which the original command structure must change as the emergency unfolds due to a variety of reasons.

It should also be noted that there are roles beyond those assigned in the game itself. This is because individuals will be able to view the simulation in progress but not take part. The idea is to allow individuals to watch an event unfold and comment on the response process but not actually interact with the simulation. The role may either be automatically assigned by the system when an individual chooses to view a simulation in progress or it could be assigned by a facilitator.

Finally, the remaining way to assign roles would be through the facilitator or administrative functions in which the facilitator wants specific roles to be assigned to specific individuals. This allows for pre-planned simulations in which groups of individuals could perform their real life roles and functions inside the virtual system.

This also allows the facilitator to place individuals whom have shown a lack of preparedness in certain roles with the training they require in order to correctly perform the required duties in this position later. As Turoff et al. (2008) argue in the ISCRAM conference paper, decision making cannot be statically in the hands of a few centrally located individuals. As the situation changes, delegation of decision making should adapt to allow for those experts best suited to have authority to make decisions. A dynamic role based system provides the best solution since it allows deference to expertise with the click of a button in the virtual city. Additionally, individuals do not require the title to make decisions if their communications are severed with command. Instead, the virtual city can assign field promotions based on certain actions that produce positive results.

4.6 Using Virtual Models for Interaction and Realism

The virtual city as proposed thus far would require virtual three-dimensional models to improve interaction and realism. These models include not only vehicles and tools but also people and animals. Three-dimensional models can be developed by private organizations, universities or other organizations using a variety of currently available software. These models can then be animated and inserted into the system so that participants can interact with the models in the virtual city. This allows for point and click customization of simulations given advanced notice.

A few of the current software applications available for the development of these models include Maya, 3DStudio Max, Carrera, Vue, Poser and Bryce. These programs represent the forefront of current animation and video game development and can be

acquired for five thousand dollars or less making the software easily attainable by most organizations. In addition to these applications, Autocad by Autodesk could also be used to model terrain and buildings in three dimensions, then exported using state plane coordinate systems as discussed previously. This allows real models of buildings to be inserted at their actual location in the virtual world. By allowing this functionality in conjunction with the modules of cars and individuals a virtual replica of existing cities could be created with accurate GIS information overlays.

A layer and data standard can be established to ensure that all contributed three-dimensional models will be compliant with the proposed virtual city. These models could range from something as simple as a street lamp to something as complex as a skyscraper building or university campus. The goal is to provide the models with specific attributes that define it within the virtual environment. These attributes can be customized to include a variety of important items in an emergency situation. The attributes can define if the building has water, power, and gas lines, and answer the questions; how many floors does the building have, can it be entered, is there fire on any floor, and how many hit points does the building have before structural collapse?

Hit points are defined as a mathematical value that represents the survivability of the building or object within the simulation. As the building or object sustains damage, for example by fire, hit points will be continuously subtracted until the damage to the structure ceases. If the damage does not cease before the value of damage is equal to the survivability of the building, the building will collapse and damage the surrounding structures. This damage is referred to as 'splash' damage and it occurs when an explosion or other non-proximity event occurs. All objects within the pre-determined

splash range receive damage to their hit points, potentially rendering them immobile or a casualty of the emergency. If the fire trucks are parked too close to a building that collapses, they will be rendered immobile due to the splash damage effect.

Additionally, a building can be built floor by floor so that it utilizes a grid system that be used to identify utilities and access points for potential first responders. This internal grid system would be activated upon entering the building, and this in turn would trigger the loading of the graphics and information associated with the active floor. The goal is to improve realism while still minimizing the loads on the hardware that will be utilized in the system. This would allow participants to enter and interact with buildings that are included in the emergency without activating every building in the game.

Virtual people represent another object and module that would be present in the game. These virtual people would have preset reactions to certain kinds of emergencies and responses similar to those seen in Rock Star games Grand Theft Auto series. If an emergency occurs, individuals are attracted to watch these emergencies. As the emergency grows it attracts the media and other organizations. If these virtual people have their lives put into jeopardy then they flee the scene of the accident in a sense of panic. These virtual people can either be generic civilians in the system, or they can function as blue or red team members.

If the virtual people are blue team members they could fulfill roles such as police, fire, rescue, swat, and other necessary roles depending on the emergency situation. They can function as a substitute for real individuals and act as resources for individuals practicing command and control. However, in direct contrast, the blue team could accidently force the red team to change targets or abort their missions entirely by

preventing a too formidable defense. The red team, like the blue team, could be either human participants or virtual members. If the red team was presented as a virtual universal adversary, they could be given an anxiety meter in which the anxiety increases when too much security is provided, leading to the red team switching targets in the middle of the game. The unique aspect of this switch is that the red team members blend in with the other virtual people in the game, making them hard to detect. This is similar to the problems cities face when they are looking for one individual in the middle of ten million others.

4.7 Randomizing the Virtual Environment

Aspects of the virtual city would need to be randomized for a variety of purposes leading to an improved simulation environment. It should be noted that the administrator or facilitator of the simulation would be able to alter the environment as necessary. The weather systems and time of the emergencies could be set on a random generator. This implies that while the participants may take part in a flood evacuation in June during the day in one simulation, the same flood evacuation the next time could occur in February at night. It should be noted that the difference in months can lead to a significant response and outcome change in the simulation, even though the participants are still taking part in a flood evacuation.

The clock in the virtual environment runs on real time unless time is paused or accelerated by the administrator. Therefore, if the emergency starts at 5:00pm, participants should expect darkness to set in shortly after, possibly complicating their search efforts. If the emergency is a hurricane strike on the city, the facilitator could

increase the pass of time temporarily to demonstrate the damage that occurs to the city regardless of the precautions that were taken. The ability to move forward or even backward in time greatly improves the understanding of how an emergency or event occurred and permits individuals the opportunity to raise comments or questions.

In addition to the weather and time being randomized, items within the virtual city that individuals are permitted to interact with would be randomly seeded into the city. Again the quantity of these available tools could be increased or decreased by the administrator or facilitator depending on the desired results. However, this implies that just because there was a bulldozer down the street at a construction site does not mean it will be there the second time the participants take part in the emergency. This requires the participants to actively search out potential resources in order to mitigate the emergency.

4.8 Administrative - Facilitator Functions

The administrative and facilitator functions provide high level access to all aspects of the virtual city. The words administrator and facilitator can be used interchangeably when referring to the settings for the virtual city. The facilitator of the simulation system has the ability to control all aspects of the city including but not limited to; the seeding of objects, the weather, time, and even the personality of potential red team members.

In reviewing the weather, the administrator has the option to institute a variety of natural disasters. These disasters can range from flooding in which the administrator can choose the quantity and location of the amount of rain, as well as the simulation of lava flows towards the virtual city. The administrator has the ability to determine the categorical strength of hurricanes, as well as their flooding potentials, quantity of

tornados and other features. On a basic level, if chosen by the administrator, just the default level of the hurricane could be selected and the rest randomized by the computer based on a preset range of possibilities. This implies that during an emergency response, the administrator could trigger a snow storm or thunderstorm to complicate existing response efforts.

The administrator would have full control over the time in the game. The administrator has the ability to increase, decrease or pause time entirely so that the various stages of the emergency can be reviewed by the participants. The administrator also has the choice of allowing the system to choose the time of an emergency, or take a predetermined path and assign the times for when the emergency will occur.

The administrator also controls the random seeding values, allowing him to determine how many existing resources will be available in the game. These resources can include emergency units, supplies, hospital beds and random objects within the game such as seeded construction equipment. The administrator can also choose where to place these objects in a manually created simulation intended to reflect a real life simulation that has previously occurred. This is reflective of games such as SimCity and Civilization, where scenarios can be created or real life situations mimicked.

In addition to the above areas, the administrator will be able to have an affect on the virtual media in the game. The administrator can queue when intelligence leaks will be reported to either team. This allows the administrator to dynamically affect and change the simulations dependent on the participants' performance within the virtual city. It also allows the administrator to activate or deactivate various aspects of the game at any point in the simulation.

4.9 Data Collection and Analysis

One of the key aspects of the virtual city is the collection of decision paths and other related data as a scenario progresses. It can identify times and key turning points in which the participants either correctly or incorrectly altered the scenario. These key turning points presents decisions that then branch out into other areas, thereby altering the outcome of the scenario. It allows for identification of positive or negative skill sets and attributes exhibited by participants in the simulation and associates these with the virtual penname that was assigned.

The identification of areas that are excelling in response to an emergency, as well as the areas that are failing to appropriately respond, leads to possible solutions and review points for the participants in the scenario. The constant collection of data can be used to identify paths in which the individuals continuously follow and thereby generate statistics for analysis on why certain paths may be better than others in a given emergency situation. These paths can then be examined so that the participants receive the required skill sets and form a shared situation awareness of the emergency.

Aside from the key turning points in the emergency, other short falls could be potentially identified. For example, failures to communicate with units, improper usage and application of resources, and failure to plan appropriately given advanced warning can easily be identified in a virtual city environment. Comments could be made and collected as the scenario unfolds, and placed in the database identifying points that need to be returned to and reviewed again at the conclusion of the scenario. It allows the participants to stop and return to the point of the comment and perhaps approach the

same problem with a different view or defer to expertise on the situation and watch the outcome drastically change.

The key point with the data collection is that once the system is generated with buildings, objects and other aspects, these objects are reusable. As the data collection grows, it establishes a baseline from which a comparative analysis can be done based on existing groups versus the current groups performance. If the current group of participants scores higher, the former baseline and decision path data can be used to determine why this even occurred. It can be used to identify what factor, or variation in the simulation lead to such a drastically different outcome. This, in turn, can possibly produce an operational plan basis from the data collected through the virtual city.

CHAPTER 5

BUILDING THE VIRTUAL CITY FOR EMERGENCY PREPAREDNESS GAMING

5.1 The Programming Language – Java versus C++

In designing a virtual city of this magnitude, care must be taken in establishing what programming language will be utilized to develop the system. The language should clearly be object-oriented due to the modular nature of the system. Object-oriented languages would allow sections of module code to be re-used for a variety of objects within the virtual world.

The two object oriented languages that were chosen are Java and C++. For years C++ was arguably faster for game development before Java received much needed attention and upgrades. Today, Java and C++ both present competitive object-oriented languages that are capable of fulfilling the role of building a virtual world. Andrew Davison, author of Killer Game Programming in Java addresses some of the misconceptions of Java such as; Java is too slow for game programming, has memory leaks, and is too high-level. Other misconceptions are that Java application installation is a nightmare, Java is not supported on game consoles, that no one uses java to write real games, and that Sun Microsystems is not interested in supporting Java gaming. Davidson (2005) states,

> It's worth saying that I think almost all of these objections are substantially wrong. Java is roughly the same speed as C++, Memory leaks can be avoided with good programming techniques like profiling. Yes, Java is high-level, but it offers more direct access to graphics hardware and external devices. Installation isn't a nightmare if you use decent installation software. There's a growing number of excellent fun Java games, and an enormous amount of support available from Sun and Sun sponsored Sites. (pp. 394-401).

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C++ also has a wide base of support for use in gaming systems. The language has been utilized for years in a variety of areas. C++ follows the same three principles of object-programming as defined by Frank Carrano (2005), "Encapsulation: objects combine data and operations; Inheritance: classes can inherit properties from other classes; Polymorphism: objects can determine appropriate operations at execution time." Aside from processing speed and the traditional wide spread use of C++ in application development, the differences between Java and C++ in terms of the virtual system are negligible. Therefore, there is no defining reason why one language should be chosen over the other when examining the development of a virtual system unless speed and skill sets of the developers become a factor.

In this case, Java will be chosen as the language that will be utilized in the development of the virtual world. Java is continuously being developed, upgraded and deployed into new environments and areas. The language is flexible and support is easy to obtain. Additionally, there are many modules that have already been written for Java that may be used to support the development of the virtual world. Java 3D provides the developers with the ability to modify high-level constructs such as rendering, three-dimensional graphics, materials, lights, and sounds. All of these items form key components of the virtual world by improving the realism of the environment.

Additionally, Java 3D was developed in two variants, one that supports OpenGL and one that Supports DirectX. These variants are extremely important in that they represent the two mainstream platforms for three-dimensional game development. The variant that will be chosen for the virtual system will be Java 3D for OpenGL. The reason for choosing this variant over the other is that OpenGL supports a variety of operating

environments versus DirectX which only supports Windows environments. These differences will be further discussed in the next section of this document.

Java3D also has the advantage that the applet technology was designed specifically for internet applications. Salisbury (1999) argues that Java3D has the potential to revolutionize elements of web-base visualization through applets that act as visualizers.

> The coupling of Java3D and applet technologies has the potential to revolutionize web-based simulation visualization. Applets can enable the dynamic and distributed instantiation and elimination of viewers that until now was not possible. A visualizer based on these technologies is under development at the Air Force Research Laboratory's Information Directorate. Unlike existing visualizers that must be running at the simulations start time, this tool allows users to come and go as they please – effectively allowing one to peer into the state of a simulation at a place, perspective, and time that is of interest to them. (p. 1425)

The visualizer technology points to another one of the main reasons why Java was chosen for this project. The ability to peer into an emergency simulation in the virtual environment has many positive aspects. This would allow non-members in the simulation to view the simulation remotely from anywhere in the world, just by viewing the applet made available on a server system. In turn, while participants take part in the simulation and learn from their choices and interaction from the system the participants will also be receiving an outside perspective input on the actions taken within the simulation. In utilizing this technology the participants are now provided a second feedback loop for information as viewed from a different perspective. Additionally, Java allows for viewable objects as derived from any data source or simulation.

"JView allows one to create Java Beans that interface with the main viewing window. These small pieces of code enable JView to display objects from any data source (i.e. simulation). A list of viewable objects would include not only aircraft, tanks, and ships, but also radar coverage, sound, thermal coverage and other non-visible phenomena." (Salisbury 1999).

In reviewing the work researched by Salisbury (1999), it can be derived that if the list of viewable objects includes not only vehicles but also physics information and non-visible phenomena, then the JView window can be used to display emergency communication lines, utilities, and police and fire deployments, as well as unit locations within a building utilizing a global positioning grid. This information can be stored as data layers within a database that could be turned on and applied in the JView window to communicate information to the participants or outside viewers regarding the status of the simulation and the appropriate next step.

5.2 Three-Dimensional Development Platform – Graphics

The OpenGL development platform is one of the most widely supported graphics development platforms available today. The OpenGL platform can be used to implement realistic graphics displays throughout a variety of system platforms and architectures because it is platform independent. This is an important attribute for the proposed virtual system since this implies the system can be developed to include the myriad of possible operating systems that might be utilized to access the virtual city. Additionally, OpenGL is easy to implement through already developed programming libraries. Kuehue (2005) describes that using OpenGL as an application developer brings simplicity to the development of the system by providing the developer with existing libraries. Kuehue

(2005) further states that the libraries allow even a novice developer to quickly develop applications capable of rendering complex images containing lighting effects, texture mapping, atmospheric effects, and anti-aliasing, among other techniques.

The other available development platform is developed by Microsoft and is known as DirectX 10. DirectX 10 comes standard with all new Windows systems, but unfortunately it is not directly compatible with different operating systems, which makes its portability and usability limited. The DirectX platform provides shading and modeling techniques similar to the OpenGL environment. Unfortunately, Direct3D, a primary component of DirectX is a proprietary API which is a downfall in attempting to provide the virtual system to as many parties as possible. OpenGL, on the other hand is an open standard which means the support across multiple operating systems is far greater. While Microsoft did implement the DirectX standard in their various operating systems, they have also provided a map function that allows OpenGL requests to be transmitted directly to the Direct3D engine thereby providing OpenGL compatibility on Microsoft systems. Due to the similar performance of both API standards but also the diverse areas in which OpenGL can be implemented versus DirectX, it was determined that OpenGL should be selected for the virtual system.

The intent of utilizing OpenGL in the virtual city is to simulate real world effects in a visual manner on monitors that will be observed by participants. For example, snow, rain or haze can be used to obstruct lines of site that participants might have thought would remain unobstructed. In another example, the effects of contamination spreading into the water supply could be simulated. This again can be rendered and displayed with ease utilizing the OpenGL routines.
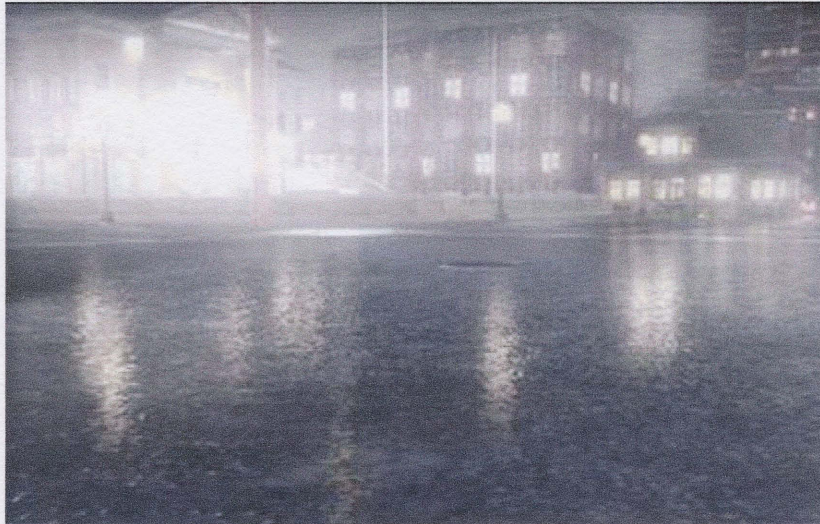
Figure 5.1 Misty Glow in the ToyShop Environment.
(Tatarchuk, 2006)

Additionally, bitmap images of real materials can be applied to buildings. Therefore, when a member chooses to walk down a city street, the roads, buildings, and even the trees appear almost real. Every item in the view will have its own unique set of attributes that can be modified, or a group of items, such as the trees, having the same attributes that can be adjusted globally in order to increase performance. Research has also led to the development of real-time volume graphics. This has led to the accurate and realistic modeling of smoke, fire and atmospheric conditions. "Volume data is ideal to describe fuzzy objects, such as fluids, gases and natural phenomena like clouds, fog and fire." (Engle, 2004, p. 2). The difference between a volumetric object and a normal rendering object is that the volumetric object contains data, where as a normally rendered object consists of a frame developed by vertexes that have bitmap overlays, for example, a brick wall. In the image of a brick wall there is no need normally to include the internal data of that wall unless the wall will be breached and the individual bricks would need to be shown and not another image depicting the opening. "The OpenGL architecture

addresses the task of efficiently converting vertex and pixel based data representations into images." (Kilgard, 1997, p. 46).

Figure 5.2 Example of Shadow Mapping Technology Used to Render Dynamic Shadows on Varied Surfaces in the ToyShop Demonstration.
(Tatarchuk, 2006)

Engle (2004) refers to a survey paper developed by Nelson Max which captures a summary of the most important optical models for direct volume rendering. These optical models are:

> **Absorption Only**: The volume is assumed to consist of cold, perfectly black particles that absorb all light that impinges on them. They do not emit, or scatter light.

> **Emission Only**: The volume is assumed to consist of particles that only emit light, but do not absorb any, since the absorption is negligible.

> **Absorption Plus Emission**: This optical model is the most common one in direct volume rendering. Particles emit light, and occlude, i.e., absorb incoming light. However, there is no scattering or indirect illumination.

Scattering and Shading / Shadowing: This model includes scattering of illumination that is external to a voxel. Light that is scattered can either be assumed to impinge unimpeded from a distant light source, or it can be shadowed by particles between the light and the voxel under consideration.

Multiple Scattering: This sophisticated model includes support for incident light that has already been scattered by multiple particles. (p. 5-6)

The reason these various techniques for volumetric objects are important is because they can lead to a realistic limiting of the line of sight. For example, if the participants are responding to a collapsed building, the area will be filled with clouds of dust. These clouds absorb light particles which greatly reduces the distances the participants would be able to see clearly. This is also true if a view were to be incorporated from a news helicopter at the scene of an emergency. If large plumes of dust and smoke are in the area, the view of the scene may be greatly restricted thereby leading to a lack of accurate intelligence information being delivered to the command and control center, thereby requiring confirmation by units present on scene. Additionally, volume graphics can be used to develop realistic interactive entities that can be viewed inside the virtual city. A few examples of volumetric models presented in the paper by Engle are:
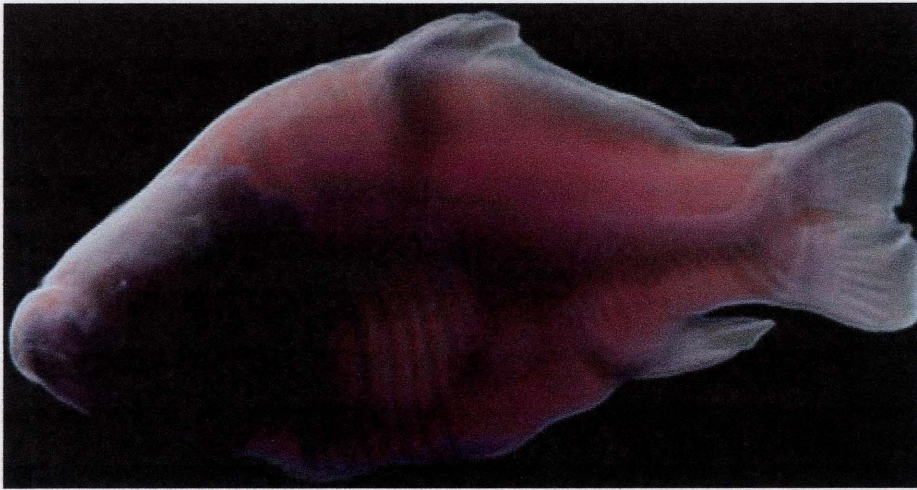
Figure 5.3 Carp CT Scan.
(Engle, 2004)

Figure 5.4 Stanford Bunny.
(Engle, 2004)

Figure 5.3 and Figure 5.4 were generated and rendered from pre-existing datasets, much like how the buildings in the virtual city would be generated and rendered. There is a time and cost associated with the development of these models for the virtual system, however, Roger D. Smith (1999) probably states it best with his comments regarding models;

> Models have been constructed for almost every system imaginable, to include factories, communications and computer networks, integrated circuits, highway systems, flight dynamics, national economies, social interactions, and imaginary worlds. In each of these environments, a model of the system has proved to be more cost effective, less dangerous, faster, or otherwise more practical than experimenting with the real system. (p. 3)

In review of Smith's statement, it is apparent that preparation is necessary for possible extreme emergency situations. In the example of a category five hurricane striking New York City, it is not possible to have a hurricane strike the city to test if our emergency plan will work in real life, but same goal can be accomplished utilizing a virtual system. Other items that cannot be simulated for obvious reasons would be dangers from nuclear and biological weapons. These are all items that can be simulated in a virtual environment for minimal costs with no danger to civilians or assets. The simulation can also be run multiple times to see if the results of the scenario are similar in nature each time, or if flaws in the original response plan can be detected and remedied.

The graphics models can be used to portray real working environments for first responders and simulate what the response may look like, drawing a connection between both the scenario guidelines and the visualization of the scenario. Natalya Tatarchuk (2006) of ATI Research provides excellent information regarding the rendering of weather in city environments in the paper, "Artist-Directable Real-Time Rain Rendering in City Environments." The paper focuses on the constraints of developing large immersive worlds in real-time and provides considerations for lighting environments, rain specific events in city environments, and scene rendering.

> Our goal was to create a moment in a dark city, downtown, during a rainy night. Fortunately, we had many opportunities for research, having started on the concept for the demo in the middle of October in Boston. As a

comparison, in Figure 5.4 we see a snapshot of the theater district in Boston downtown compared with the final rendering in the ToyShop demo. (Tatarchuk, 2006).

(a) Rainy night in downtown Boston   *(b) Rainy night in the ToyShop town*

Figure 5.5 Comparison of a Photograph from Downtown Boston During a Rainy Night Versus a Synthetic Rendering of the ToyShop Town Demonstration. (Tatarchuk, 2006)

As these two images in figure 5.5 above demonstrate, computer rendering capabilities have almost reached the point where it is becoming difficult to discern between the real world image and a snapshot from a simulated world. While rain is just one facet of the overall simulated world, it represents another step towards portraying a realistic gaming environment for emergency preparedness training. The next question is how real must the virtual city be in order to accurately simulate the virtual environment? Figure 5.6 shown below is a rendering of a taxi cab window in the ToyShop demonstration by Natalya Tatarchuk. The simulation has the ability to portray water drops on the windshield of the cab as well as the paths that have been cleared by the car's windshield wipers.

Figure 5.6 Taxi Windshield Rendering with Animated Windshield Wipers. (Tatarchuk, 2006)

Computer Graphics capabilities in both modeling and simulation have made leaps and bounds since the simulations of the 1990's that had box like graphics and unrealistic environments. The virtual interactive environments today can be created with an unmatched realism that can sometimes even make the participant feel as if they are really in that environment watching the event unfold. These virtual environments can only continue to improve as time passes with the release of new graphics cards capable of supporting more complex and much more realistic environments every year. These improvements and virtual effects are extremely important because they allow things that cannot be seen by the naked eye to be visualized in the virtual city.

CHAPTER 6

REQUIREMENTS ENGINEERING

6.1 Stakeholder Identification

There is a large group of stakeholders identified for this project and more will be identified once the project is underway. During the requirements elicitation process stakeholders are identified and noted. A stakeholder can be identified as, "…any person or group who will be affected by the system, directly or indirectly." (Somerville, 2004) Stakeholders can either be users of the system, or in the case of this project, the general public. The reason for the general public being listed as stakeholders in the project is because the system will be used to train first responders and emergency personnel. The different stakeholder structures can be identified and broken down into different groups. In an initial view of the different stakeholders involved, the groups can be broken down into private, public, academic and federal areas.

Private stakeholders such as private corporations have an interest in aiding the public during an emergency in an attempt to return to normalcy. While an emergency situation remains, public utilities, roads and lives could remain disrupted. This, in turn, could and often will result in disruption of operations for the business. Many businesses that close their doors due to a disruption fail to reopen them if the emergency is not resolved quickly enough. Therefore, private organizations have a desire to take an interest in emergency response and wish to offer help which in turn makes them a stakeholder in this project. A few examples of private organizations that may have an interest in the development of the system would be public utilities, pharmaceutical companies, information technology companies, global positioning and

telecommunications companies, and even construction companies that may be able to offer their equipment during an emergency.

Public stakeholders can range from the general public to public institutions. Examples of public institutions that are stakeholders in the development of the proposed system would be the Department of Public Health, the local emergency response units including first aid, police, fire departments, and hospitals, as well as, the Department of Transportation, Port Authority and other public or state guided organizations. An important role that falls under the public stakeholder category is the role of the Press. The Press represents a stakeholder in that it provides first responders with initial intelligence reports in regards to the situation and emergency. Additionally, if public sector authorities decide to start an evacuation, the Press would play an important role in directing citizens in regards to where they should go and how to best prepare for the unfolding emergency. These groups are important stakeholders because they represent what is considered to be the first responders. The public group is one of the primary focuses of this system in training individuals in how to properly respond in a given scenario.

An additional stakeholder is the academic group, which includes public and private universities. Universities and colleges have an important role in the development of the system. Since the system is intended to be modular in nature, universities could contribute components or new modules to the system. This allows them to test out their models in relation to emergency preparedness while providing valuable experience to students and strong support of local agencies in the field of emergency preparedness. The original university that agrees to support the development of the virtual system will have

the greatest stake in the project as they will be responsible for ensuring access to the system as well as choosing which modules get added and developed into the system.

A final stakeholder is the federal government, federal emergency management agencies and Homeland Security. The virtual system will let them plan for potential disasters in urban environments while adjusting variables for a variety of possible results. For example, FEMA could utilize the virtual city by having a local river reach its five hundred year flood level. This, in turn, would flood the city and a response plan could be developed to evacuate remaining citizens from the rising waters. Additionally, it could mimic the damage to structures on the waterfront of the city or randomly simulate structural collapses within the city which causes the plans to be adjusted and further developed for unexpected events. In addition, Homeland Security could use the exact same scenario to mimic a bomber in the city or a hostage situation in which appropriate steps must be taken to minimize the collateral damage within a city environment. The system can be used to develop a combined situational awareness between those that see the actual scene of the emergency with those that are directing the response effort.

6.2 System Requirements

This section provides an overview of the various system requirements the virtual city would require during development.

6.2.1 Feasibility Requirements

The systems feasibility depends on a group of different factors. Based on current Massive Multiplayer Online Role Playing Games (MMORPG), the development of the

system should be designed in accordance with these types of systems. The systems are typically accessed through a client remotely on a computer terminal. The actual system is stored on a network server at a central location that accepts multiple connections. As the system is intended to be of modular design, it does not require all components to be active in order to provide a gaming environment. The other modules, or in this case, nodes, can be activated as the simulation proceeds.

The initial city could consist of one node or multiple nodes where one node supports a section of the city. For example, the city of Newark, New Jersey can be divided up into other groups, such as the Ironbound section, the University Heights section or the Industry section. These nodes could be located on either a single server or multiple servers, allowing users to move seamlessly between the servers depending on their location within the virtual city. This results in prevention of what gamers refer to as 'lag'. Lag is when the server struggles to support the current user load in a portion of the city resulting in poor game performance or even a server crash or node crash.

The computer and server hardware required for the graphics acceleration to support three-dimensional environments has been around for some time now and continually improves on a monthly basis. Currently, virtual environments using the Shader 3.0 technology can support realistic environments in which simulations can be played. Additionally, physics cards now allow for realistic additions of simulation environments, bringing weather, gravity, and other standard physics principals into account when gaming.

Another argument that could be made is the use of network bandwidth. Due to the increasing bandwidth on personal computers, high speed gaming should no longer be

an issue given that the user is running on a high speed connection such as a cable modem or DSL connection. The server itself would have to be running on a high speed connection as well in order to support the massive bandwidth required to support a few hundred users at a time. However, if the graphics for the city are kept locally and utilized by the gaming client, the overall bandwidth required for the game to function can be greatly reduced. This results in a large graphics package having to be installed locally on the client computer. The benefit of this, however, is that updates can be sent out from the server on a specific basis so that all clients are required to be up-to-date before they can log into the gaming system. This ensures all users of the gaming system are always using the most up-to-date package available.

6.2.2 Usability Requirements

The system usability requirements are the more complicated part of the system. The system must be designed to not only be user friendly to the novice computer user but also customizable so that it is also user friendly to the expert computer user. Additionally, the system must be both usable from the first responder's viewpoint to the individual in charge of the emergency operations viewpoint. In other words, the system usability must be able to foster shared situational awareness. In order to achieve shared situational awareness in terms of system usability, the actual controls of the system must be scalable. The experts must be able to customize the interface to allow them to streamline the processes associated with their job while the novice users still need access to the help systems so that they can function in the virtual city.

The various skill levels and shared awareness are just two of the factors regarding usability requirements for the system. The system must also support fast, split second decision making due to the nature of the system. This requirement for speed borders on a reliability requirement but also is part of the usability requirement in that level that it requires immediate action. In emergency preparedness response scenarios, a delay of a few seconds could cost lives. The idea is to provide as much usability as possible up front for the end-users but leave room to customize and expand through interaction with future participants. The defining of the usability requirements for the virtual city will be an ongoing opportunity.

6.2.3 Reliability Requirements

The virtual city's reliability will be of very high importance due to the distributed nature of the system. The system will function in one location but have multiple groups from possibly other locations in the world, logging in to take part in the exercises. This means the network connection to the system must be able to handle the bandwidth of real time gaming over networks. Additionally, the software must be fault tolerant so that any minor issues in the gaming experience do not interrupt the entire simulation. For example, a client computer may receive an error but that should not cause the server to restart. The idea is to minimize the possible risks to the main server through programming exception handlers on the client side. If possible, the best solution would be to try and minimize errors all together as errors during game play could potentially affect the outcome of a scenario. This is an unintentional danger associated with the mapping of pathways and decision trees inside the system.

The primary reliability of the system should be focused on the interactive clients and servers supporting the virtual environment. The secondary levels should focus on clients monitoring the scenario but not taking part in the scenario. The reason for this is that the non-participant clients exert a resource pull on the system but should be determined as a lower priority for resources since they are not directly affecting or interacting with the exercise being gamed.

6.2.4 Functional Requirements

Functional requirements are the key requirements of the system in regards to how the system reacts to specific inputs or other internal responses. For example, a functional requirement would be how the system would respond to a team issuing orders for road blocks in specific sections of the virtual city. Sommerville (2004) defines functional requirements as,

> These are statements of services the system should provide, how the system should react to particular inputs and how the system should behave in particular situations. In some cases, the functional requirements may also explicitly state what the system should not do (p.119).

The functional requirements for the virtual system are significant in that the system must interact with every input supplied to it by the teams utilizing the system. The system, however, is intended to be open-source. This implies that the functional requirements may change significantly with each new revision of the system or its interactive entities. If one of the system modules undergoes a revision, it may be necessary to revise the functional requirements that guide interaction with that module. The level at which the functional requirements are to be developed or modified can be

determined at the first iteration of a system revision during the ongoing cyclic development process.

One example of a functional requirement in the virtual system is the ability of both teams to be immersed into the virtual environment. When the teams are immersed into the virtual environment, the system should respond by realizing the scenario has begun and to begin the standard operations of the city. These automated operations can include the weather, simulated traffic which consists of both automobile and human, as well as, establishing the values for buildings and other resources in the game.

A second example of a functional requirement for the system is the red team proceeding to commit a hostile action as defined by the computer system, basically one of any number of pre-determined actions. Once this action occurs, the system will have to begin the simulation as if the action happened in a real environment. The system would need to adjust nearby values accordingly for damage or infection, roadways may become impassable and buildings may collapse as a result of the action. Additionally, this would begin a chain of events such as reporting and intelligence reports being provided to the blue team.

A final example of functional requirements is how the system accepts incoming connections, such as, people who want to view the scenario from abroad but not take part in the scenario. There is the exchange over the network before allowing the user to begin viewing the scenario.

6.2.5 Non-Functional Requirements

Non-functional requirements include the requirements associated with system performance, external requirements, privacy, implementation requirements, and other similar requirements. Somerville (2004) defines non-functional requirements as;

> ...requirements that are not directly concerned with specific functions delivered by the system. They may relate to emergent system properties such as reliability, response time and storage capacity. Alternatively, they may define constraints on the system such as the capabilities of I/O devices and the data representations used in system interfaces. (p. 119).

The non-functional requirements of the virtual system are fairly far stretching with significant implications depending on the system's role. For example, the product requirements are extremely important given the nature of scenarios and who must take part when the scenario is being gamed. The system must be usable, the average computer user who is only familiar with Microsoft Office must be able to sit down at the scenario and be able to interact with the scenario in some capacity. The system must meet its performance requirements as well as be reliable and portable. The system must be designed in such a way that it can support upwards of a few thousand users at any given moment. These users do not necessarily have to be interacting with the system, but they must be able to view what is occurring. Additionally, users could be interacting from a console on the system or from a remote console in Europe. This means the system needs to be reliable; the user in Europe must be provided with an equivalent experience of the user located at a console in the building which holds / contains the system. Additionally, the system must be portable. Therefore, it needs to work on different operating systems such as Windows, Apple or UNIX based systems. This ensures that the system can reach as many people as possible and does not exclude certain groups. Many smaller countries

have turned to Linux as an alternative operating system platform to Windows as a way to lower their costs. Because of this, the system should be designed in such a way that they can still interact with the scenario in the virtual city.

In other non-functional requirements, organizational and privacy requirements will have an affect on the development of the virtual city. Organizations have different operating perimeters, and while this serves as a reason for a unified scale that allows all the organizations to work together, there will still be subtle differences between them. Since these are differences beyond the control of the virtual city, the system should allow for customization depending on the agency taking part in the exercise. Clearly the extent of customization needs to be limited; however, some items can be adjusted accordingly through a settings tab to better fit that organization.

The matter of privacy is a major issue in the non-functional requirements of the system. The system is designed with privacy in mind for the end-users. The end-users can select a user name that is not associated with his/her real name, thereby eliminating the personal identification associated with ones actions. In an additional sense, certain organizations that may take part in the scenario may request that there identities be kept anonymous as well. This may also include certain aspects of the business's course of action in certain events. The need for privacy as a non-functional requirement is intrinsic to the success of the virtual city.

6.3 Requirements Gathering Techniques

This section details the various techniques that should be utilized in the development of the virtual environment to gather and elicit requirements for the system.

6.3.1 Prototyping Technique

The prototyping technique is a combination of both a prototype virtual city software interface and the preliminary paper prototypes used to convey to potential participants how they would interact with the system and gather feedback. When a button is pressed on the pseudo-control interface on the paper prototype, the appropriate paper identifying the next screen is shown. It should be noted that paper prototyping will be limited in some respects as the system allows interaction with the virtual city in a first person role. Therefore, the paper prototyping is best suited for logging in and out, accessing maps and the control interface, and the control of units. "Paper Prototyping is a variation of usability testing where representative users perform realistic tasks by interacting with a paper version of the interface that is manipulated by a person "playing computer," who doesn't explain how the interface is intended to work" (Snyder, 2003).

Paper prototyping is important as it will aid in determining the differences between an expert system user and a novice user. It will also allow for improved usability of the virtual city as it undergoes development by allowing participants to try or test variations of the same interface to see which one better fits the needs of participants. A framework of system capabilities should be established prior to the semi-structured interviews. The system has a strong focus on visualization and it is difficult to convey in words and questions to an interviewee the full capabilities of the system. However, it should be noted that unlike a web interface the majority of the features in the system will be more game-like in nature, requiring a different level of participation. Therefore, while paper prototyping may be sufficient for the command and control interfaces and remote

viewing and access, it will not be sufficient in determining the effects and usability of the actual simulation.

6.3.2 Interviewing Technique

The interviewing technique can provide professional insight into the functions the system currently is capable of filling and those that are lacking. The intent is to identify various groups of users and interview members of each group in order to gather a full picture of the users that will be taking part in the simulations. The four main categories of users are: public service users, private businesses, government users and academics. These four main categories have a level of expertise in both computers and their respective fields in handling emergencies. The goal is to determine the acceptance among the various groups of utilizing simulation and visualization software in training.

The interviewees can be selected at random from tabletop exercises or meetings of individuals that work in emergency preparedness such as ISCRAM. The reason for choosing these two areas is that the interviewees will represent the group for which the system is being developed. The interviewees will be experienced and highly knowledgeable in various aspects of emergency preparedness. Rubin (2005) defines experienced individuals as having relevant, first-hand experience. It can be derived that the individuals attending the emergency preparedness tabletops would have experience and a knowledgeable background in the topic.

Rubin (2005) further notes that the credibility of the findings will be enhanced when interviews are conducted that reflect a variety of perspectives. Due to the diversified nature of tabletop exercises which include both public and private parties, the

overall variety of opinions and views can greatly improve the credibility of the findings. In order to structure the interview properly, two separate aspects must be addressed in regards to current opinions of tabletop exercises and full-scale exercises. A baseline for the research must be established prior to presentation of the new system through a short survey. This will provide area of expertise, educational background, age, and other demographics.

The next step is to present a mockup of the system. The best way to present it would be through a video that demonstrates features of the system including the command and control aspect, as well as the first person views. The primary advantage of the system is the ability for the individual to interact directly with the simulation with full visualization of the scenario. After showing the demonstration video, a series of semi-structured questions can be asked of participants to gather an understanding of how they feel the system may help facilitate emergency preparedness training or possible issues regarding it.

Probing techniques can be used to further elicit concerns or other potential requirements that can provide a more rounded base for the system. Responses must be recorded for further analysis and coding techniques. The coded data can then be used to develop follow-up interview questions about all areas of the system or areas of potential concern which need to be addressed. It is expected that the initial interviews will need to be followed up with additional, more specific interviews due to the breadth of the information to be examined.

6.3.3 Case Study and Focus Group Technique

Case study and focus groups can contribute to the identification of system issues and further the development of the project in the later stages, after a prototype system is functioning. The ideal condition would be to have each member of the focus group perform an initial protocol analysis of the system and then take part in the actual group analysis in which ideas can be conveyed and shared. Kruger (2000) defines focus groups as a "special type of group in terms of purpose, size, composition, and procedures." The idea is to select participants that have certain characteristics in common with each other, such as individuals associated with emergency preparedness.

In providing focus group discussions with potential future clients, the requirements of the system can be defined in a way to make it compatible with the views of the individuals that will be taking part in the simulation. The goal is to identify and understand different perspectives that may be occurring in dynamic group environments such as emergency training. For example, the group can be divided up into public authorities, private businesses, government officials and academics. Each one of these groups has a set of protocols or rules they follow when taking part in a simulation or exercise; all of which differ from one another. These groups can be brought together into a focus group to pilot test the virtual city to determine acceptance and acquire qualitative data.

The focus group should be arranged to minimize bias by providing a random selection of participants from an emergency preparedness seminar or event. An incentive could be provided such as a gift card that can be used at a store or restaurant located at the emergency preparedness event. This way the participants feel as if they are being

rewarded for taking the time to participate in the study. The study should be videotaped as the system is presented to gather responses that may otherwise be lost during the course of the focus study. After the study and the collection of the data, an analysis and report is generated to further improve the virtual city and develop its features. One of the key focuses of the group study will be to determine the group interaction with the system.

CHAPTER 7

THE BENEFITS OF THE SYSTEM AND POSSIBLE EXPANSION

The benefits of the system are not limited to just training aspects. The system can indeed be used for local planning in terms of floods or other events. The virtual city's ability to simulate storms and flood waters over time allows townships and cities to plan in advance. A city could take its current response plans and test out a variety of situations in the virtual city to determine potential outcomes.

While this paper primarily focuses on a virtual city, it should be noted that it is a scalable solution. There is no reason why the city cannot be scaled down to a small town, or scaled up as large as a state. The primary limitation of using virtual environments is currently limited to the power of the servers that can be obtained. The development of massive multiplayer online games which can consist of thousands of lands or solar systems demonstrates the opportunity for problems large scale virtual environments to be solved by establishing nodes. Each node represents an independent server, yet they all function as if they were a single virtual environment. This allows the systems to process only the information that is immediately relevant to the existing emergencies, thereby improving efficiency.

In addition to the scalability of the system by making it acceptable to existing GIS state plane coordinate systems, it allows the GIS information to be updated on the fly. This means that as new GIS layers become available, they can be implemented into the system for use by participants. This includes buildings and new GIS layers, such as a potential fallout layer from a nuclear power plant that was recently built. This implies the

system can be easily upgraded to include new information that is highly important and relevant to the simulation of emergencies.

Finally, the system is based on open source graphics and software; meaning that new additions and modules can be built onto the system to increase its capabilities and improve realism. The new Shader 2.0 technology released with today's video cards already begins to cross the lines of realism, making the box-like animations of the past archaic in comparison. Modules can be created by universities or private organizations and then directly inserted into the system to improve the interaction with the gaming environment. The potential upgrades that can be made to the system are long term and significant.

CHAPTER 8

SUMMARY AND CONCLUSIONS

8.1 Conclusion

The virtual city has the potential to revolutionize emergency preparedness training and planning on a scale that currently does not exist. It allows users regardless of location or available time to login from their home computers at their convenience and take part in a simulation with other participants or remotely view a simulation in progress. In addition, the virtual city provides a realistic environment subject to real-time emergency operations.

The system influences participants to consider new paths and options they may not have considered previously while actively challenging their existing plans and notions through a variety of interactive methods. These new paths can be identified as possible successful solutions in mitigation and response to emergencies as they occur. This allows them to establish the required skill sets and core competencies they need as an organization so that in emergency situations they can function as a high reliability organization. The goal is to identify problems as they occur and ask why they occurred prior to them magnifying into a serious emergency.

8.2 Contributions to Emergency Preparedness Gaming

The virtual city is a complete solution to the problems associated with existing emergency preparedness gaming methods. It not only provides a realistic gaming environment that is interactive but also provides this environment in a geographically and

time independent method. It combines the tactile, kinesthetic, auditory and visual learning experiences into a dynamic gaming environment in which participants from all over the world can simulate and take part in virtual emergencies. The collective data from all the participants can then be used to identify skills sets and core competencies that can be used to improve existing training methods and help put effective plans into operation.

8.3 Limitations

It should be noted that the initial development of the virtual system will be time consuming and will require an iterative process that must include emergency preparedness participants. There may be several iterations of user interaction interfaces before one is considered appropriate given the scenario. In addition, there may be some initial opposition towards using the virtual system due to the belief that face-to-face instruction is better or more conductive of learning. As with all new ways of performing a new task there is also some reluctance before the system becomes an accepted method.

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