Modeling and Simulation of Catastrophic Events Affecting Critical Infrastructure Systems

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Abstract: Critical infrastructure systems are very important to the socioeconomic stability of any nation and the overall well-being of humans. However, those infrastructure systems are vulnerable to the distractive forces of natural and anthropogenic episodic events. In response to security and safety concerns related to the infrastructure new applied computing methodologies have been developed for training of law enforcement and security personnel, improving assessment tools for first responders, detailing mitigation and evacuation planning, and providing realistic analysis of various emergency scenarios. Those methodologies involve development of simulation, animation and visualization computer applications for disaster prevention, response and mitigation. These applications can also assist in incident analysis, and planning of massive emergency evacuation and transportation. The applications involve an integrated combination of a variety of software packages. This study describes some infrastructure safety and security projects that utilized a combination of different software such as AutoCad, Adobe Photoshop, Global Mapper, ArcGIS (ESRI), Di-Guy (Boston Dynamics), Presagis (MultiGen-Paradigm), and AIMSUN.

Key-Words: Animation, Emergency evacuation, Episodic events, Flooding, Infrastructure, Safety, Security, Simulation, Visualization

1 Introduction
Both the social stability and economic prosperity of a nation depend strongly on its critical infrastructure system (CIS). The CIS includes different important components such as power plants, water and wastewater utilities, airports, seaports and waterways, bridges, highways, railroads and other transportation facilities, hospitals, government buildings, etc. Disruption of any component of the CIS can have a very negative impact to the rest of the infrastructure and to the ability of a nation to function effectively and efficiently.

In spite of the major efforts placed to safeguard the critical infrastructure there are always natural and/or anthropogenic incidents that can jeopardize its operability. Hurricanes, earthquakes, tsunamis, floods, volcanic eruptions, fires as well as human errors, acts of wars and terrorist acts can damage the built infrastructure and disrupt its operations. Some of the events provide some warning period (e.g. hurricanes, tsunamis) while others occur without any warning (e.g. earthquakes, terrorist acts).

The safety and security of the critical infrastructure involve major issues that require coordination and planning of federal, state and local agencies as well as the private sector. One of the tools available to analyze different scenarios of potential threats to the infrastructure is applied computer simulation, visualization and animation. Those computer tools are very useful in preparing plans for protection, response and mitigation of any infrastructure system under a variety of hypothetical emergency conditions.

Through funding by the U.S. Federal Transit Administration (US-FTA), U.S. Federal Highway Administration (US-FHWA), U.S. Department of Homeland Security (US-DHS), South Florida Waster Management District (SFWMD) and other sources, the Center for Intermodal Transportation Safety and Security (CITSS) at Florida Atlantic...
University developed a number of simulation and visualization applications for site-specific security training, emergency response, and mitigation planning. Some of those major applications included the Washington Metropolitan Area Transit Authority (WMATA), the Port of Everglades, the City of Baltimore and the south region of the South Florida Water Management District service area.

Those application involved an integrated combination of software packages i.e. AutoCad, Adobe Photoshop, Global Mapping, ArcGIS, Digeuy, Presagis (MultiGen), Vega Prime and Aimsun. This paper discusses in detail the development of training tools and emergency evacuation analysis conducted for the WMATA project. That included visualization of different suspicious activities, incident analysis and a massive emergency evacuation using transit buses. Additional information in less detail is provided for the studies of the Port of Everglades, the City of Baltimore, and the South Florida regional area.

2 WMATA Project Description
The project objectives were to develop various visualization scenarios of suspicious activities and security breaches so that law enforcement and security personnel were trained to identify those activities by using an interactive animation tool. The animation package was able to realistically create different physical environments i.e., low visibility due to power failure, smoke from explosion and/or fire, etc. In addition the results were summarized and printed for general public awareness. The project is further involved in developing an emergency evacuation plan by using the available public bus transportation system with particular emphasis on the evacuation of persons with special needs.

2.1 WMATA System
WMATA is the 2nd largest transit rail system and the operator of the 5th largest transit bus network in the U.S. In 2004 this system served 190 million rail passengers and 146 million bus passengers.

The Washington Metro’s fleet consists of 904 rail cars. The subway system consists of 47 stations utilizing 50 miles of track. The ground system has 47 stations and utilizes 46 miles of track and the aerial system consists of 6 stations and utilizes nearly 10 miles of track.

The security of WMATA is under the Metro Transit Police and employs 400 sworn officers, 106 special police officers and 30 civilian personnel. The Metro Transit Police Officers have jurisdiction and arrest powers throughout the 1,500 mile transit zone that includes the District of Columbia, and the States of Maryland and Virginia.

2.2 Project Development
The project was conducted in a sequence of tasks as follows: (1) collection of on-site and other existing data, (2) creation of the simulated environment, (3) development of training scenarios, (4) production of distributable media, and (5) simulation and planning for emergency evacuation.

2.2.1 Data Collection
The Union Station, near the Capitol was selected as a prototype site for this study. Then a detailed on-site survey of the Union Station area was conducted. During the survey, images of the Union Station-WMATA platform, upstairs shops, ticket booths, stairs, etc. as well as the exterior features of the building were recorded using an eight megapixel digital camera. These images were used both for reference to ensure accuracy of the station platform model as well as for creating texture maps. Texture maps are orthographic images created from the photos, which are applied to the three dimensional wall surfaces of the simulation model to create a more realistic simulated representation of the true environment. Figure 1 shows an example of the texture reference image of the station ceiling. After completion of the station survey, the investigating team visited the Landover Rail Yard to obtain images of a rail car, and the Landover Training Facility to take images of a damaged rail car. Both of those cars were used as references for construction of vehicle simulation models (Fig. 2).

Other reference data were collected from the WMATA’s GIS department including scanned
blueprints of the original architectural drawings of the station, an aerial image of Union Station, and GIS data of the track lines which could be used for a further expansion of this project.

Fig. 1 Ceiling texture reference image.

Fig. 2 Train simulation model.

Measurements were also taken to determine the proper location of other interior features of the station (e.g., benches, phone booths, trash bins, etc) which could not be identified on the available drawings, in order to add further detailed representation of the simulated environment.

2.2.2 Development of simulated environment
Due to the lack of Computer Aided Design (CAD) drawings, the dimensions of the terminal were determined from a digitized set of engineering blueprint drawings dating back to 1969. To ensure accuracy, the spacing of the interior arrangements of the station was physically measured to account for any potential changes over the years due to upgrades, and refurbishments within the station’s interior.

While normally CAD data would be used to ensure accuracy of the dimensions, due to its unavailability, parts of the engineering drawing representing the top, front and side views of the station were cropped and saved to texture map images. These images were then projected on to three dimensional planes called “faces” (MultiGen Creator). Each face was reconstructed to the size shown in the measurements on the engineering blueprints creating a 3-D version of the drawings, which could then be rotated and be accurate to the real-world specifications (Fig. 3).

Fig. 3 Recreation of 3-D drawing of the station.

The subway tube structure was produced by creating a curvilinear face which matched the profile of the tunnel. That tube face was then extruded to the length of the station and rotated to match its pitch to the side profile that was previously created (Fig. 4).

Next the upstairs and downstairs platforms were traced-off from the engineering blueprints into a 3-D drawing, thus creating a base to build the remainder of the main station elements. The distances between the points which make up these elements were then checked and compared for accuracy to the original design drawings supplied by WMATA. Finally, the platforms were extruded and built based on dimensions taken from the construction drawings. Thus the resulting base model was ready for texture mapping (Fig. 5).
With the deployment of furniture this would create a photo-realistic environment, on which the training scenarios would be developed.

![Fig. 4 Creation of the tube tunnel.](image)

At this phase texture maps were applied to the station to add another level of realism in the simulated environment. Textures were created from photographs and manipulated in Adobe Photoshop. Through picture manipulation perspective was removed from photographs and created a texture that could be replicated in a sequence without any noticeable seams. This process called “tiling” was employed to enhance performance of the model in the final run-time processing, while keeping visually believable representation of the simulated environment. Once the texture maps were completed, they were applied to the walls of the model in a way similar to wall-papering. Three points were picked representing the x, y, and z coordinates on which the texture was placed on the wall polygon faces (Fig. 6).

![Fig. 6 Wall texture application.](image)

Once all of the polygons have been textured, the model of the structure itself was completed. However the details which would bring it to life were not yet in place. Those details known as “Streetscaping Materials,” included light fixtures, sitting benches, trash bins, wall signs, etc. In addition, the project required train cars as well as people to inhabit the station and mimic the everyday activities which bring the scenario to life. The streetscape materials were created from reference photos and field measurements recorded taken during the site survey. The higher resolution models contained up to three levels of detail (LOD) which could be swapped in as the user moved further away from the object. The LOD’s allow the user to see a distance object at a lower detailed version of the original close-up. As the distance increases the substitution is not noticed, and that allows more computer system resource allocation for other objects which are closer to the observer at its present location. Using LOD’s increases the performance of the system in which the simulation scenarios are conducted. These streetscape materials were placed throughout the station based on the actual positions and measurements (Fig. 7).

The train was created from pictures taken during the survey, in conjunction to measurements supplied by WMATA and further reference materials taken from the train manufacturer’s website. Each car is 75 feet in length and 10 feet in width. Both the interior and exterior of the car was constructed along with three levels of detail (LOD) to aid in performance during runtime. Upon completion of the train in operating conditions, a second version was produced representing damage to the front or rear areas of
the car which could be used to simulate an incident event (Fig. 8).

**Fig. 7** Station with Streetscaping materials.

**Fig. 8** Train in damaged condition.

After this final step, all of the 3-D OpenFlight files were configured to run in VegaPrime through its configuration tool LynXPrime [1]. Any anomalies such as flickering faces, and textures that incorrectly showed up in the runtime application were then repaired in MultiGen-Creator before proceeding to create the scenarios and adding any special effects in VegaPrime.

### 2.2.3 Development of training scenarios

Upon the selection of the security training scenarios, the area of the platform was populated with a crowd of simulated people going about their daily routine by using DI-Guy’s Scenario Editor [2]. The first group of characters, that were placed, primarily consisted of those who were standing alone, or standing and interacting with another character while waiting to board the train. For this task the “People Blitzer” tool was used so as to allow a user to select a character type and a behavior, and place them along the station platform [2].

Once the first group of characters was placed, a second set of characters actually moved around within the scene that was created. This second set consisted of people randomly walking around, boarding as well as debarking, and a train which had arrived into the station. The addition of this second set of characters created the appearance of a busy platform, in which people were going about their normal life. These additional people were set not only to walk and run about the station, but to move in a way which they are aware of others around them and they did not accidentally run onto one another (Fig. 9).

**Fig. 9** Human characters occupying the platform.

Finally, a suspect was introduced into the scene. With authorization from Boston Dynamics [3], access to the DI-Guy character models was allowed and permission was given to modify and change them. With this control, a 3-D backpack image was created (Fig. 10) and attached to a suspect character (Fig. 11).

In the following, different security scenarios were created around the activities of the suspect character. The emphasis was for the security personnel to be able to identify the suspects and the associated safety threats.

### 2.2.4 Creation of distributable media

The training scenarios were distributed to WMATA personnel in the form of video clips on both DVD, as well as computer .avi formatted...
video files. PowerPoint slides were created in which the video files were embedded to be used in final distributable security training demonstrations. Direct access to the software package allowed for a user-interactive animation and visualization of the scenarios developed.

Mesoscopic models prove to be efficient because they model flow more efficiently for larger networks while microscopic platforms can capture more details of vehicle and driver behavior. For this reason the microscopic simulation platform is applied for the metropolitan part of the city where a hypothetical incident occurred at the WMATA Union Station. A mesoscopic point of view is being analyzed for the surrounding areas of Washington D.C. in order to assess how the evacuation traffic will affect the adjacent traffic of the metropolitan area. Currently there is a total of thirty-two transportation analyses zones (TAZ) and a network composed of 129 miles of road and 785 intersections. A Transportation Analysis Zone (TAZ) is an area delineated by local and/or governmental transportation officials for use in tabulating traffic-related data [5]. This delineated area consisting of census blocks, is utilized as inventory of data relating to journey-to-work and place-of-work statistics. For the purposes of an emergency evacuation this data is useful for configuring an origin-destination (O/D) matrix based on the specific exit node closest to them. Four destination safe-zones were chosen for mass departure away from the area of the hypothetical disaster event at the Union Station. These zones are used to create staged evacuations (Fig. 12).

The study is using an origin-destination matrix for each of the four zones which produce a continuous vehicular traffic to compensate for evacuation of individual populations. The study applies a hybrid evacuation plan comprised of staged evacuation and contraflow methodologies.
Staged evacuation is a common methodology where the city is divided into certain zones. These zones are then grouped together according to the level of proximity to the incident area. People residing in zones that are in most danger (closest proximity) are evacuated first. All zones in contact with the closest-proximity are evacuated second. All other zones that are not directly adjacent to the zones in immediate danger are evacuated first as well. This type of strategy considers staggered evacuation and schedules into a series of evacuations between origin nodes and safety destinations. A dynamic network assignment is imposed so as not to overload the network at any one time [5].

Lane Reversal or (Contraflow) provides an increase of roadway capacity by employing opposing lanes in addition to the existing paths. Contraflow takes into account all lanes of a road and makes them all flow in one direction. Contraflow has the ability to nearly double the capacity of a particular direction. Additionally, contraflow has been used in incident situations by emergency personnel vehicles to allow expedient movement around a network. Considering that the metropolitan population of Washington D.C. is so dependent on the public transportation system people will be urged to walk to the appropriate bus stops to have buses evacuated them to safe zones. In this study we are assuming that the metro rail system is closed for safety purposes.

3 Port Everglades Project

The project objectives were to develop various simulation/visualization scenarios addressing safety and security issues related to potential natural and anthropogenic disastrous events (i.e., ship accidents, port flooding, terrorist acts, etc.) Due to the interactive capabilities of the simulated environment developed, the software application can be used to assess a variety of alternative scenarios and to observe the surroundings using any desirable vista point.

3.1 Port Everglades

The Port Everglades is one of the finest examples of complete intermodal transportation in America. The Port is serviced by a transit bus system for cruise passengers, a rail system carrying cargo in and out of the Port, and is located next to the Fort Lauderdale International Airport. The study was focused on how to sustain a continuous operation of this major port, while maintaining appropriate security of its multi-modal environment.

3.1.1 Port Everglades Model Development

The virtual environment has been created in terms of the port’s operations, safety and security. The project utilized digital pictures and CAD drawings for the exteriors of all Port Everglades facilities. GIS mapping was incorporated for accuracy of terrain, bathymetry and structure location. The entire exterior of Port Everglades was created displaying the complete infrastructure of roadway connections entering and exiting the complex either from cargo or cruise stations (Fig. 13).

![Port of Everglades model.](image)

The Port simulated environment could be viewed in a day or night mode, in rain or fog, and have sea-state representing that of smooth or hurricane like conditions (Fig. 14). Vehicles and ships could be activated to be in motion at any predetermined speed during the launch of the Port Everglades model. Furthermore the application extended to the vendor environment of Port Everglades including detailed modeling of private industry warehouses, fuel fields, and shopping complexes. Cruise terminal security barriers and fencing have been incorporated, showing new revisions that meet and exceed U.S. Coast guard standards. The project analyzed recommended
physical changes to improve safety and security of passengers and provided effective physical deterrents compliant with Homeland Security standards of cross modal relevance.

Fig. 14 The Port of Everglades under flooding.

4 City of Baltimore Project
This project was done under the aegis of the National Center for the Study of Preparedness and Catastrophic Event Response (PACER) at John Hopkins University. The two study scenarios selected were: (a) an Urban Chemical Disaster (UCD) involving the explosive rapture of two railcars [6] and (b) a Bioterrorism Crisis Management (BCM) involving the release of smallpox in aerosol form from an air handling facility during a music concert attended by 13,000 fans [7]. Both of the incidents were supposedly occurred near the downtown metropolitan Baltimore City area. The Florida Atlantic University research team is involved in the development of emergency evacuation plans during those incidents.

4.1 Project Objectives
The project objectives for the City of Baltimore studies were: (a) to simulate the spread of the contaminant (chlorine gas or smallpox), (b) to simulate a realistic flow of the moving population affected by the contaminant, (c) to simulate the command and control, and risk communications to be undertaken by the first responders once the nature and scale of the event was recognized, (d) to simulate hospital surge operations, and (e) to simulate the traffic flow under emergency evacuation and patient movement conditions.

4.2 Emergency Evacuation
The transportation infrastructure is often just as important as the availability of medical supplies and treatment centers. With the ability to simulate real-time, dynamic traffic assignment scenarios, one can effectively locate traffic congestion points, and that could assist in avoiding/preventing congestion in order to improve efficiency of the emergency evacuation. With the use of a hybrid simulation technique, two levels of simulation, mesoscopic and microscopic, were meshed for enhanced analysis. The hybrid allowed for simulation of small networks or areas (microscopic) while simulating the surrounding area through mesoscopic simulation. With the hybrid model, one can study the effects of signal controls, network origin-destination (O/D) travel routes/times and the traffic redistribution effects. This network and simulation were performed using the Traffic Simulation System Aimsun 6.0. The basis of this model involves travelers moving from one point to another through an O/D matrix. This model is run under what is known as the User Equilibrium Model. This model suggests that travelers will try to minimize their travel time. This is achieved through travelers choosing routes that they feel are the shortest under current traffic conditions. Routing and re-routing throughout the network is performed based on this concept. The model uses per-link cost-based functions to determine the paths or links based on the traffic demand. Therefore, dynamic traffic assignment (DTA) enables the description of traffic flow pattern evolution throughout the network.

The traffic loading into the network for the simulation is based on a normal distribution. A normal distribution was chosen because during the peak-hour of home-to-work and home-to-school trips, the highest volume of traffic would be during the middle of the time period while tapering off at the beginning and at the end that period. The origin/destination matrix is composed of Transportation Analysis Zones (TAZs) through Baltimore City and parts of Baltimore and Anne Arundel Counties. The trip data for the entire day was provided by the Baltimore Metropolitan...
Council (BMC) and was converted to peak hour trips. With the matrices provided by BMC (Fig. 15), the trip generation model involving 300,000 vehicles was applied.

Once replications of the simulation were complete, then a good understanding and insight of the traffic conditions was available. Path assignments and path statistics were obtained, and details of the probabilities when a vehicle enters the network were established. Path assignments and costs associated with using those paths were also available (Fig. 16).

The microscopic simulation process becomes important once the incident management command and control system model establishes the hospital/emergency center locations. Discretion was used to attempt to balance the amount of trips that could arrive at each desirable destination under the worst-case scenario. These two levels were intertwined at the interface of arterial roads (microscopic level) leading to the hospitals from the main interstate highway infrastructure that runs throughout the city (mesoscopic). This routing alters the home-to-school and home-to-work matrices, because some of the trips are now being diverted to the hospitals based on the need for treatment. This give-and-take relationship regarding trips between the two models exhibits a response situation (microscopic) while normal daily operations are continuing to operate around the city (mesoscopic).

5 South Florida Hurricane Flooding

Acquisition of hydraulic and hydro-meteorological data, and modeling and simulation of extreme hydrologic events are key components of disaster and emergency preparedness planning due to potential catastrophic flooding events. Water control and emergency management agencies are responsible for the collection, validation, and archiving of the hydrologic data, modeling of extreme hydrologic scenarios and supporting state and federal agencies to prepare and plan for such events. Thus, there is a constant need for development of modeling environments/animation schemes that are capable of visualizing these extreme events. That helps to enhance the understanding of possible damages to the built infrastructure and to plan for public safety and emergency preparedness due to any natural disaster.

Accurate assessment of damages to infrastructure can be done effectively if extreme flooding events can be visualized in space to evaluate the nature and extent of damage to specific infrastructure objects of interest. In the current context, there is a need to evaluate the possible depth of flood waters in specific urban or rural/agricultural areas located within the South
Florida regional area. That would determine inundation of hydraulic structures operated by water management officials, flooding of the highway network and damage or inoperability of other infrastructure components. In addition, information would be obtained for emergency evacuation planning that is a priority to officials from different state and federal agencies, who are interested in assessing the extent of flooding in a region and identifying safe and reliable transportation routes. Visualization and animation schemes that combine exhaustive details of the terrain, infrastructure and flooding extent, and also provide an easy way of identifying optimal emergency management alternatives are invaluable working tools.

5.1 Project Objectives
The objectives of this project were to develop a virtual reality environment scheme for a catastrophic flood event in the South Florida regional area. The goal was to use computer simulation and animation tools to create “fly-bys” to evaluate the extent of flooding caused by an extreme hurricane event. Detailed representation of the area of interest using spatial data sets, a hydrologic simulation model output (or flood depth estimates), satellite images and animation software were used to develop the animation scheme. The scheme enables the water resources management and disaster management personnel to assess the extent of damage to infrastructure and also identify evacuation plans.

5.2 Spatial and Hydrologic Data
For successful application of hydrologic simulation models, spatial and hydrologic data are essential. The spatial data mainly comprises of the terrain, aerial imagery, digital elevation model and infrastructure data. The hydrologic data for this study was mainly the water levels (e.g., stages) obtained from a hydrologic simulation model (or other approximate methods) considering extreme hydro-meteorological inputs (i.e., category 5 wet-hurricane). The spatial data is generally available from state and federal agencies (e.g., USGS, SFWMD). At first, the area to be studied was developed by using a mosaic of Digital Ortho Quarter Quadrangles (DOQQ) with a maximum resolution of each tile at a fixed 2048 x 2048 pixels. The mosaic was then converted into a Geotiff. The geo-referencing of aerial images was carried using the Global Mapper software. The digital elevation model (DEM) and flooding depth layer, corresponding to the extreme hurricane event were converted into a format appropriate for the animation software. The proprietary software used for this study provided three modeling tools that help to edit vector and raster data and terrain processing capabilities. Terrain creation involved a terrain grid created by using Polymesh Tessellation (Fig. 17).

![Fig. 17 Polymesh Tessellation of the study region.](image1)

![Fig. 18 Aerial extent of flooding.](image2)
In addition to the terrain, infrastructure components (roads, office buildings, houses, etc.) were developed using available information about their location and structural details. Those features were created as objects within the modeling environment and were overlaid on aerial imagery layer. The extent of the infrastructure details was limited to the features that the study was interested about.

After the extent of the severe flooding event was established (Fig. 18) then the 3-D “fly-by” animation was completed by using the MultiGen software (Fig. 19). The animation involved different scenarios with variable meteorological parameters such as wind speed, daylight conditions and others.

Fig. 19 “Fly-by” animation of flooded structures.

6 Software Tools
The software packages involved in this study were: AutoCad, ArcGIS, Global Mapper, MultiGen-Paradigm (Presagis), Boston Dynamics/Di-Guy and Aimsun. The AutoCad, Global Mapper and ArcGIS packages were used as supporting platforms for the animation, emergency evacuation and flooding applications.

6.1 MultiGen-Paradigm (Presagis)
MultiGen-Paradigm is one of the industry’s leading real-time 3-D modeling software programs, giving users the power to create application-ready 3-D simulation content fast and with a high degree of realism and fidelity. MultiGen-CreatorPro is an extensible and multi-purpose polygon-based authoring system designed for real-time 3-D content creation of optimized model objects, high fidelity terrain and realistic synthetic environments. CreatorPro brings unsurpassed efficiency and productivity to modeling with a unique blend of polygon and vector modeling tools in one package. The CreatorPro modeling system is ideal for creating and assembling ground vehicles, buildings, and specific areas of high interest such as airfields, ports, city centers and industrial complexes.

Users can efficiently model local high interest areas from vector data by importing Computer Aided Design (CAD) or Geographic Information Systems (GIS) data into CreatorPro to aid in the creation of 3-D assets. In addition, CreatorPro can automatically places fully textured, and colored 3-D models on the terrain surface using GIS feature data. One can greatly reduce development time by leveraging vector data processing capabilities created in CreatorPro to re-generate similar scenes for multiple rendering engines.

CreatorPro displays the scene being modeled in an OpenGL render window creating a true 3-D “What You See Is What You Get” (WYSIWYG) environment for creating content which will look the same in both the editor as well as the final run-time environment. Offering the ability to build from multiple points of view, helps streamline and simplify the modeling process, increasing user productivity. The “drag and drop” hierarchical view in CreatorPro allows for control of the underlying structure of the 3-D model being worked upon, and how it’s controls the rendering process. Features such as Level of Detail (LOD), culling, priority ordering, logical switching, and degree of freedom (DOF) articulation and other non-visual nodes required by rendering software can be controlled within this viewport.

MultiGen-VegaPrime is a toolkit designed for real-time 3-D application development and deployment. VegaPrime is based on VSG (Vega Scene Graph), an advanced cross platform scene graph API, and includes both an advanced abstraction API for ease of use and productivity as well as the LynXPrime GUI configuration. In addition, Vega Prime includes environment effects, motion models, coordinate systems, virtual texture, simple audio, overlays, statistics, lighting systems, collision detection, planar shadows, diurnal effects, and path/navigator tools.
6.2 Boston Dynamics/DI-Guy
DI-Guy, is a Commercial Off The Shelf (COTS) software tool developed by Boston Dynamics, and is capable of being integrated into MultiGen-Paradigm's Vega Prime toolkit. DI-Guy allows the introduction of life-like, animated human characters into a simulated environment. Each DI-Guy character moves realistically, responds to simple commands, and travels about the environment as directed. DI-Guy was chosen for this project because the software is capable of achieving outstanding real-time performance through optimizations such as motion caching, variable motion interpolation, level-of detail switching, motion level-of-detail switching, and task-level control [2].

The DI-Guy contains one hundred human figures, including civilian, first responder, and soldier characters. DI-Guy uses industry standard OpenFlight models, so to allow the addition of new models as well as the modification of existing characters to the library included with the package. DI-Guy’s library contains over 2,000 human behaviors, motions, and transitions in its library.

The software package has two separate components, DI-Guy Scenario, and DI-Guy Motion Editor. The primary component used for this project has been DI-Guy Scenario which is a tool for creating interactive 3-D training scenarios with lifelike human characters. Its graphical user interface allows users to work directly in the 3-D scenario to create, place, and control realistic people and vehicles. Once a scenario has been created, it can then be run directly within DI-Guy Scenario for an immediate preview. A second integrated component of DI-Guy is the Motion Editor, a tool that allows users to modify existing DI-Guy motions and create new ones from scratch. It has a powerful graphical user interface that supports inverse kinematics, forward kinematics, and key-frame animation, all on a multi-track user configurable timeline.

There are also optional features for importing motion capture data and animations created with 3rd party products using industry standard Biovision Hierarchical motion capture (.bvh) and motion analysis Hierarchical Translation- Rotation (.htr) data formats.

6.3 Aimsun
Aimsun NG Version 6.0 is a simulation software program that incorporates traffic models and real-time scenarios and fuses static and dynamic approaches within a single milieu [9]. Aimsun is probably one of the only tools on the market that integrates in a single software application several different types of transport models. These models include static traffic assignment tools, and a micro/meso/macro-scopic simulator. In addition, Aimsun can simulate vehicle trips from origins to destinations on the network traveling along routes than can change timely according to the variations in traffic conditions. The Dynamic Traffic Assignment (DTA) algorithm in Aimsun can be used in either the mesoscopic or microscopic simulations. DTA is an algorithm built into the simulation platforms that allows individual cars to use the best route possible for their specific needs. The microscopic simulator and the mesoscopic simulator can deal with different traffic networks such as urban networks, freeways, highways, ring roads, and arterials.

7 Summary and Conclusions
This paper describes the integration of various software packages for simulation and animation, for the purpose of developing security training and emergency evacuation planning as related to extreme anthropogenic and natural catastrophic events. The ability to replicate the existing environment in real-life fashion is a much more effective tool than the traditional descriptive but non-animated scenarios. The ability to develop multiple possible threat scenarios is invaluable for creating alternative prevention and mitigation planning.

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