PLOWSHARES: EMERGENCY MANAGEMENT TRAINING WITH A MILITARY CONSTRUCTIVE SIMULATION

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ABSTRACT

The Plowshares project is applying military constructive simulation technology to training for emergency management. The project team has enhanced the U. S. Army's Janus simulation model to support emergency management scenarios that include hurricanes, fires, and chemical spills. The enhanced Janus software, known as TERRA, will be used in a county Emergency Operations Center to provide the stimulus for training events structured as command post exercises. The first phase of the project culminated in a "Proof of Principle Demonstration" that occurred in August 1995. In that demonstration the Emergency Operations Center of Orange County Florida conducted a hurricane response exercise using the TERRA system.

AUTHORS' BIOGRAPHIES

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PLOWSHARES PROJECT OVERVIEW

Goals

The primary goal of the Plowshares project is to implement a computer simulation that can simulate natural and man-made disasters and the actions taken in response to them. The simulation is intended to serve the purpose of training local authorities. Implicit tasks associated with that goal are to:

1. Convert a military training simulation to a civil emergency management simulation.
2. Conduct a Proof of Principle Demonstration (POP-D) of that simulation.
3. Show software reuse capability to the sponsor (U.S. Army).
4. Serve as a technology transfer initiative.

Overall approach

The U. S. Army's Janus simulation model has been enhanced to support emergency management events, functions, and scenarios. The emergency management version of Janus is known as TERRA. TERRA will be used initially to train county-level officials responsible for controlling and coordinating county-wide emergency responses. TERRA will provide the stimulus for training events structured as command post exercises.

Figures 1 and 2 show how TERRA will do so. First, Figure 1 represents, in an abstract way, how actual emergency response operations are controlled at the county level. While Figure 1 is based on the emergency response control organization of Orange County Florida, it is very typical of counties nationwide. At the right of the figure are the field units, i.e., the fire trucks and fire fighters, ambulances and paramedics, police officers, and so on, that are in the field. They communicate with their respective agency headquarters via radio and telephone, passing information regarding emergency situations to those headquarters and receiving response instructions. The agency headquarters, or Agency EOCs (Emergency Operations Centers), may be located throughout the county or in the county EOC, a single facility devoted and equipped for emergency management response.

During an emergency or emergency management exercise, the primary control point or "nerve center" for the county is the Operations Room in the county EOC. The county EOC's Operations Room is staffed by twenty emergency management specialists (or teams of specialists) referred to as Emergency Support Functions (ESFs). Each ESF is responsible for coordinating and controlling all response actions of a particular type or category, such as communications, transportation, medical, or hazardous materials. The agency EOCs communicate status and situation reports to the ESFs via messages, which may be written, electronic, or verbal. The ESFs review all messages applicable to their respective areas and give instructions to the agency EOCs so as to best coordinate the activities in their functional area.

Supervising the actions of the ESFs are the county policy makers; that group includes the County Administrator, the County Commissioners, the county EOC Director, and other high-level decision makers. Overall policy questions and major priority decisions are referred to that group by the ESFs; the ESFs are responsible for guiding the execution of the policy decisions. Overall, in Figure 1 information flows from right to left and control from left to right.

Figure 2 shows how TERRA is used to provide a training stimulus to this command structure. TERRA simulates an emergency, such as a hurricane or chemical spill, and models its effects on the population and property of the county. TERRA also simulates the individual field units (e.g., fire trucks and bulldozers) and

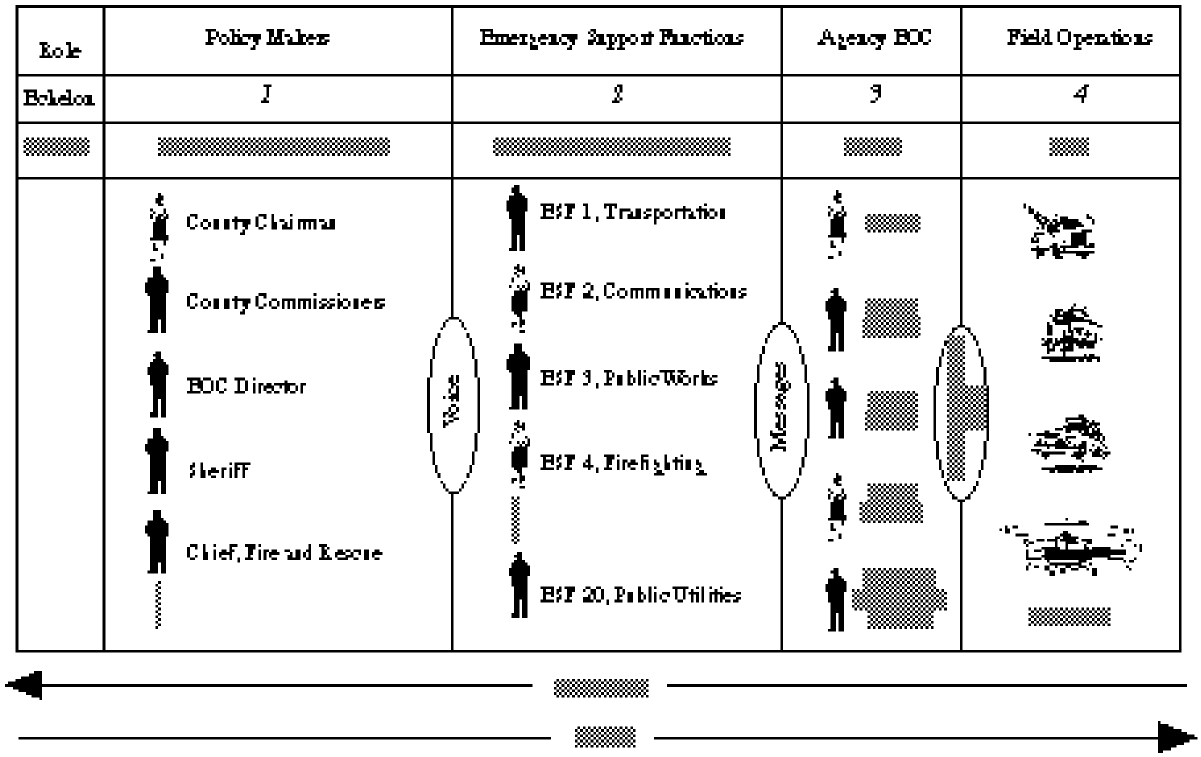


Figure 1. Emergency Response Control.

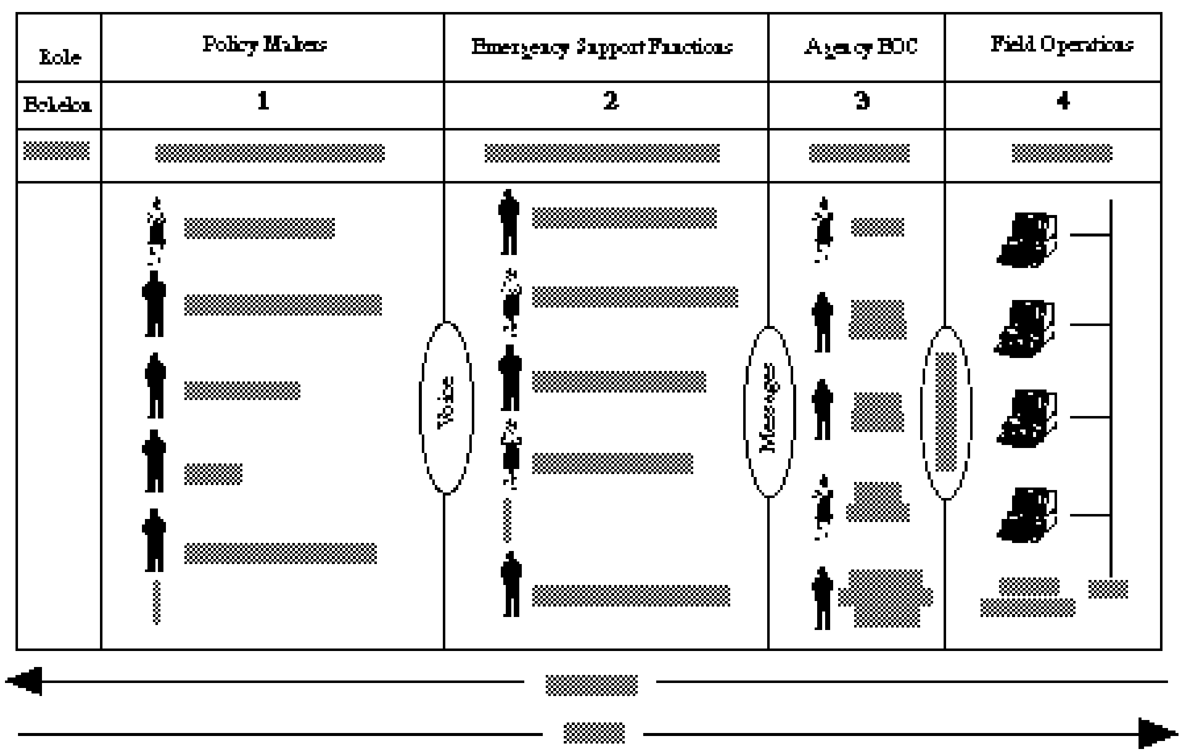


Figure 2. Training with Plowshares TERRA.

the actions those units can take in response to the emergency. As Figure 2 shows, TERRA replaces the field units. The agency EOCs receive emergency situation reports and issue commands not from and to field units but from and to the TERRA simulation. The radio and telephone interface is replaced with TERRA's graphical user interface and the TERRA Command and Control Logger (TCCL) (Figures 3 and 4). Other than these replacements, however, the emergency response control organization is unchanged and the personnel at each level continue to communicate the same types of information and make the same decisions in the same manner as they would in an actual emergency. This method of training command staffs is much like military command post exercises.

Organization

The Plowshares project team is led by the U.S. Army Simulation, Training, and Instrumentation Command and is composed of the following team members:

1. Institute for Simulation and Training
2. U.S. Military Academy at West Point
3. Training and Simulation Technology Consortium
4. Nations, Inc.
5. Resource Consultants, Inc.

In addition to the organizations listed above, Orange County Florida is also playing a key role in the project. County personnel provided considerable time and information in support of the requirements analysis process. Furthermore, county personnel operated the TERRA simulation during the POP-D.

INTRODUCTION TO JANUS

Janus is a constructive entity-level combat simulation. It is described in (Titan,1993) as an "interactive, two-sided, closed, stochastic, ground combat simulation". It is used by military officers for training; they control the actions of simulated combat entities during execution and acquire tactical decision-making skills by doing so. It is also used by military analysts for analytical purposes, including evaluating new weapons systems, tactics, and force structures. The primary focus of the Janus simulation is on ground combat maneuver and artillery units. Janus simulates individual vehicles and infantrymen, tracking their movement across the terrain and resolving combat at the level of the individual entity; groups of entities can also be represented. Combat, such as direct fire, is resolved stochastically.

Janus uses a digitized terrain database format that can represent contours, roads, rivers, vegetation, and urban areas. Terrain is represented as both polygons and grid cells. Terrain affects movement and visibility in a realistic manner. Janus typically supports scenarios of up to battalion size.

PRELIMINARY TEST DEMONSTRATION

Prior to the TERRA implementation effort, a preliminary test of the adaptability of Janus to emergency management simulation was performed. In the test demonstration, a moderate set of modifications were made to the Janus "databases", or configuration files, to adapt it to a simple hurricane scenario.

The implementation of the test demonstration served to reveal in Janus both its flexibility and its limitations when applied without code modification to emergency management simulation. For more information on the preliminary demonstration see (Petty,1995a).

MODIFYING JANUS FOR EMERGENCY MANAGEMENT

Software development process

As mentioned, the Janus simulation model has been enhanced to support emergency management simulation, resulting in TERRA. Initial requirements were determined using input from Orange County personnel. A set of Software Change Requests (SCRs) was then defined based on these requirements, with each SCR specifying the changes needed to Janus to provide one coherent unit of new functionality. The SCRs were assigned to the various project team members for implementation. After each SCR had been programmed and unit tested the revised source code modules were integrated into the working source code using a standard source code configuration management package and procedures. At the conclusion of the

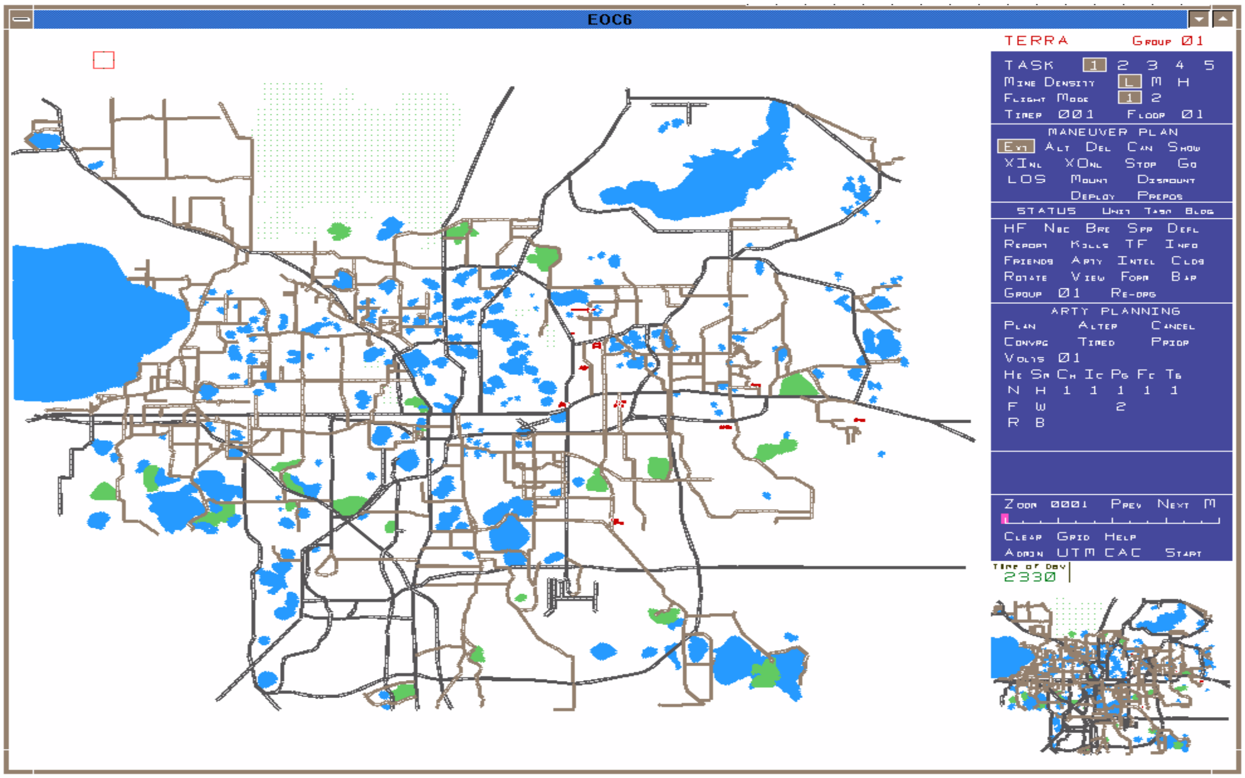
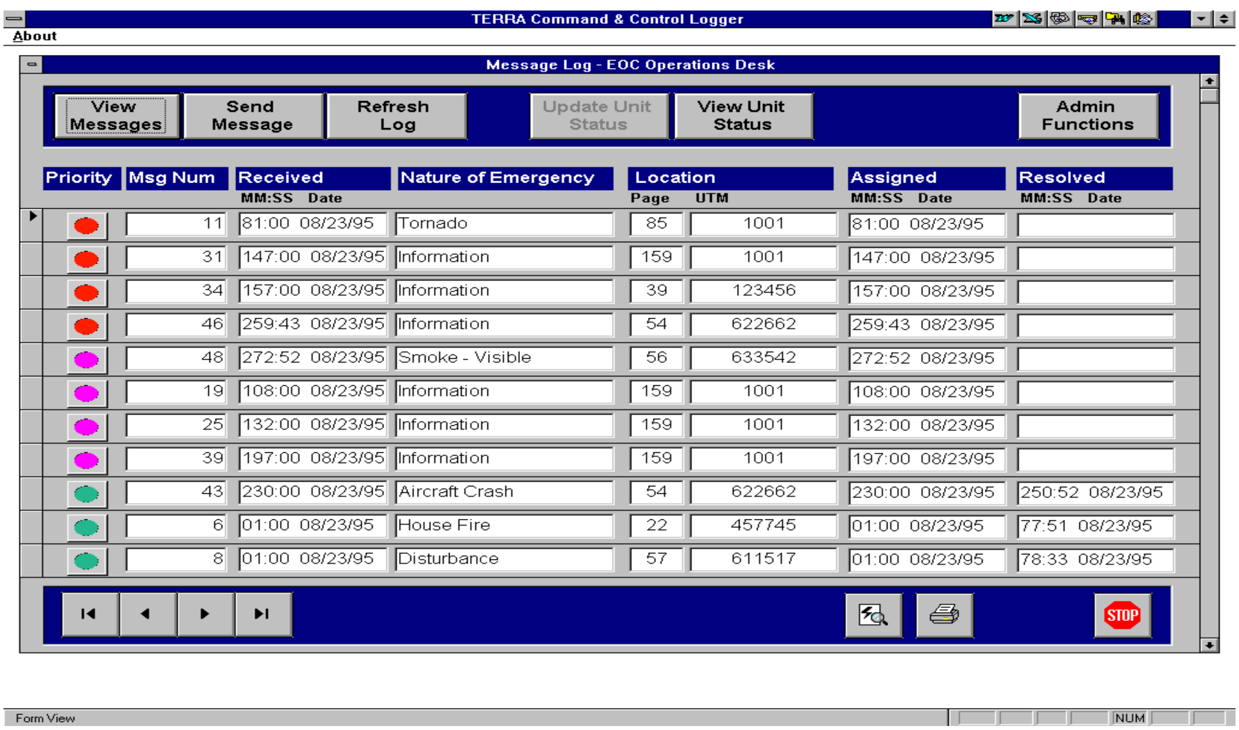


Figure 3. TERRA Command and Control



Priority	Msg Num	Received MM:SS Date	Nature of Emergency	Location Page	UTM	Assigned MM:SS Date	Resolved MM:SS Date
	11	81:00 08/23/95	Tornado	85	1001	81:00 08/23/95	
	31	147:00 08/23/95	Information	159	1001	147:00 08/23/95	
	34	157:00 08/23/95	Information	39	123456	157:00 08/23/95	
	46	259:43 08/23/95	Information	54	622662	259:43 08/23/95	
	48	272:52 08/23/95	Smoke - Visible	56	633542	272:52 08/23/95	
	19	108:00 08/23/95	Information	159	1001	108:00 08/23/95	
	25	132:00 08/23/95	Information	159	1001	132:00 08/23/95	
	39	197:00 08/23/95	Information	159	1001	197:00 08/23/95	
	43	230:00 08/23/95	Aircraft Crash	54	622662	230:00 08/23/95	250:52 08/23/95
	6	01:00 08/23/95	House Fire	22	457745	01:00 08/23/95	77:51 08/23/95
	8	01:00 08/23/95	Disturbance	57	611517	01:00 08/23/95	78:33 08/23/95

Figure 4. TERRA Command & Control Logger

development period a thorough system test of TERRA was conducted in addition to the unit testing done for each SCR.

Modifications made to Janus

The changes made to Janus to produce TERRA include:

1. Model Hurricane, Tornadoes, and Fire
2. Convert from UTM to Geodetic WGS Coordinates
3. Change Janus name on interface menus
4. Rename "Force" to "Response Unit"
5. Enable indirect fire Shoot on the Move
6. Allow damage and casualty assessment in urban areas
7. Customize standard Blue menu bar
8. Postprocess/transfer files to PC for analysis
9. Provide an icon for minimized windows
10. Provide key reference data in CACs
11. Demilitarize and simplify Janus commands
12. Demilitarize menus, databases, and symbols.

A short description of some of the more interesting software changes is included below.

Model hurricane, tornadoes, and fire. The mathematical model for the disasters of hurricane, tornadoes, and fire was designed approximating the first principles of physics. The hurricane is modeled as an ongoing event having large area affects, and can generate tornadoes and fires. There are seven hurricane types, as defined by the Saffir-Simpson Scale, that are available to the user in the database and are definable according to maximum wind speed, ground speed, and storm direction, among others. The wind speed at each grid cell of the terrain database is calculated based on the cell distance from the center, and wind damage is cumulative and based on the terrain type in addition to a result of the hurricane.

Tornadoes are modeled similarly to hurricanes but can also be prescripted or queued for immediate execution. The hurricane and tornadoes can cause rubble which act as barriers to movement. Rubble can be cleared by bulldozers.

Fires are created without user intervention as an effect of hurricanes, tornadoes, or other events. These events are randomly generated according to probabilities associated with the causing agent and the fuel contained in the terrain feature. Additionally, like tornadoes, fires can be either prescripted or queued for immediate execution. Fires can be spread, burned out, and put out when attacked with fire fighting vehicles.

Damage and casualties in urban areas. Property, population density, and fuel supply and rate are encoded into the terrain. Those attributes can be updated at run time by the disaster to reflect damage and casualties. Fires can spread if not contained and can be extinguished if battled. It also permits casualties to increase if fire is not contained. As damage and casualties occur, they are recorded for and After Action Review.

Coordinate conversion. Janus' map display coordinates have been changed from military-style map coordinates (UTM) to latitude and longitude (Geodetic). A toggle button allows the user to switch between UTM and Geodetic. Geodetic coordinates coincide better with typical U.S. Geological Survey maps. Additionally, a Command and Control (CAC) overlay was added which allowed location using Section-Township-Range, a coordinate system familiar to county personnel.

TERRA Overview

The core TERRA program is a real-time simulation of emergency events and response. Like the version of Janus used as the developmental starting point, the TERRA simulation is written in FORTRAN. It runs on Hewlett-Packard Apollo workstations under the UNIX operating system. X-Windows is used to provide TERRA's graphical user interface.

The complete Plowshares system also includes separate programs for terrain database creation, training program planning and scheduling, message trafficking, and after-action review and analysis of an exercise.

Figure 3 shows the TERRA screen that the trainees will use during a training exercise. This figure shows the Orange County, Florida terrain database, which encompasses a 60 km x 60 km area. There are three main areas on the screen: the Current View Display, the World View Display, and the TERRA Menu.

The Current View Display is the largest portion of the screen and displays the area of operations. On it, urban areas, vegetation, roads, buildings, bodies of water, and other features are displayed. This is the terrain on which the trainees will view the effects of the disaster and will respond by moving their rescue units around the terrain in the most expeditious manner.

The World View Display appears below the clock and displays the overall view of the area of operations. The size of this terrain does not change as the Current View does.

The TERRA Menu gives the trainee the tools with which to conduct the exercise. With this menu, the user has the ability to zoom in on an area of the terrain, move vehicles around the terrain, and much more.

PLOWSHARES PROOF OF PRINCIPLE DEMONSTRATION

Conduct of the POP-D

In August 1995, the Plowshares project conducted a Proof of Principle Demonstration (POP-D) in order to exhibit the applicability of the TERRA software to an emergency management training environment. This demonstration took place at the Orange County Emergency Operations Center (EOC) in Orlando, Florida with personnel from Orange County Fire and Rescue, Sheriff's Office, Public Works, Public Utilities, and Health and Human Services participating in the exercise.

In the weeks prior to the demonstration, the TERRA software was loaded on the computers at the EOC and the Systems Administrator preprogrammed the path of the hurricane. At each workstation was an agency EOC representative, called the Interactor, who was trained on how to use the TERRA workstations in order to perform such actions as moving vehicles and clearing rubble, but did not know what the scenario was to be or where events would take place.

To begin the POP-D, the exercise participants were briefed on the objectives and rules of the exercise. The Agency EOC managers took their positions near the TERRA workstations, with the Interactor at the computer ready to interpret what was seen on the screen and relay this information to the Agency EOC managers. Their cues as to the extent of the damage, which comes from field units in an actual emergency, came from the TERRA workstations during the exercise. Additional input to the Agency EOCs took the form of messages generated by the TERRA Command and Control Logger (TCCL), simulating 911 calls. The Emergency Support Function (ESFs) took their positions in the Operations Room where they had access to messages by radio, operating in a similar manner as in an actual emergency.

At the start of the exercise, the participants received a description of the current situation, including weather information and location of the hurricane, which had passed by this time. As the participants began the exercise, signs of damage were apparent on the TERRA workstations. The fallen trees, damaged buildings, and fires created by the hurricane took the form of icons on the computer screen. Additionally, messages on the TCCL screen indicated where the Interactor should look for activity on the computerized terrain. Once the incidents were relayed to the Agency EOC Managers, decisions were made regarding where and how to allocate resources to best manage the problems at hand. As more information came in during the exercise, it became necessary for ESFs to make decisions and coordinate responses with other agencies. The information was then passed down to the Agency EOC Managers who had the Interactor respond to the decisions by reallocating resources within TERRA as specified. Interagency cooperation is a vital training objective and was facilitated by the simulation.

The responses to the scenario events were recorded in two ways. First, the responses to

911 messages and visual cues were recorded in the TCCL. Also, vehicle movement was recorded using a feature called TERRA Replay. After the exercise, an After Action Review was conducted using TERRA Replay for the purpose of evaluating the strategies used by the different agencies in managing their resources.

Scenario Events

The events generated during the POP-D scenario were carefully selected by training experts on the project team. The final scenario was designed to replicate the kinds of events which the participating county agencies would most likely be faced with during and following a hurricane. Those events were automatically generated by the TERRA software. Their sequence and location were chosen so as to stress the resources of these agencies, thus forcing communication with other agencies, thereby maximizing the training benefit. A table of POP-D events and responses is given in Table 1.

TRAINING WITH PLOWSHARES

In recent years, simulators have been used as an effective, low cost training tool for military personnel. Other fields such as education and engineering have also made use of this unique technology. Due to their ability to represent hazardous or time-dependent events at a relatively low cost, simulators can be used effectively in these applications and others. Emergency management trainers are beginning to enlist the aid of simulators to enhance allocation of resources needed in their training exercises. The Plowshares project uses simulation to assist in creating the environment which emergency managers must react to. As decisions are made by emergency management personnel, the scenario changes based on these decisions, taking the trainees beyond a typical training exercise. However, a simulator alone does not yield adequate training. In order for the trainee to be provided with the best possible learning experience, the use of Plowshares within a properly designed instructional unit is necessary.

The learner must be the first consideration when designing training. Since the measure of success of any training program is the amount learned, the characteristics of the trainee must be determined. In the Plowshares project, the trainees will be the Orange County emergency management personnel. These are adult learners, high school and college educated, with varying computer skill levels. Training is an on-going activity in the professional lives of these learners. Recognition of the benefits gained by training gives these persons a positive attitude and the proper motivation to learn a new training method such as Plowshares presents.

The objectives of a training program must be clearly stated in order to properly design the instruction, guide the learner, and provide a framework for deciding ways to evaluate student learning. The overall objective for Plowshares is to enhance communication skills with other Orange County emergency management personnel. It will also serve to enhance the decision making skills of these personnel.

To design effective instruction, the designer must present the information in a manner that will help the learner achieve the objectives. The Plowshares project includes varying techniques to provide stimulus for the learner to meet the training objectives. The TERRA simulation software provides the visual cues (i.e., storm damage icons) for which the trainees respond to by allocating resources (i.e., moving vehicle). The results of these resource movements will in turn yield subsequent cues for which the trainee can respond. Other cues to the learner will be simulated radio and telephone messages. This continuous stream of information will stimulate the communication between and among agencies necessary to effectively and efficiently dispatch resources and successfully achieve the training objectives.

CONCLUSIONS AND FUTURE WORK

From this experience it is clear that valuable emergency management training can be accomplished in a command post exercise format, and that existing military simulations can be adapted to that purpose.

At this time, TERRA runs as a stand-alone constructive model. The possibility of interconnecting TERRA with virtual simulation, specifically Distributed Interactive Simulation (DIS), will be examined. Such a connection would allow low-level participation by trainees in virtual simulators (i.e. medical evacuation helicopters) in the same emergency response action that is being overseen by high-level response managers. Janus has already been linked experimentally to DIS (Pratt,1994), and some of that technology will be useful to bringing Plowshares into DIS. The applicability of DIS, in

Event Number	Exercise Time (Minutes)	Event	Agency Assigned*	Response
1	1	Street debris	PW	Dispatched graders
2	1	Street debris	PW	Dispatched graders
3	1	Street debris	PW	Dispatched graders
4	1	Street debris	PW	Dispatched graders
5	1	House fire	FRD	Put out fire
6	1	Blocked road	PW	Cleared road
7	1	Disturbance at shopping center	SO	6 looters arrested
8	3	Shelter collapse, tornado	SO HCS	Evacuated shelter
9	5	House fire, tornado, looter	FRD SO PW	Dispatched units
10	11	Power loss, Sewage Spill	PU	Generators put in service
11	27	Street debris	PW	Dispatched units
12	29	Street debris	PW	Road cleared
13	30	Train derailment/ chlorine leak	FRD SO	HAZMAT Unit responds to scene of derailment.
14	36	Chlorine fumes at shelter	HCS	Prepared for evacuee relocation
15	40	Escaped prisoners	SO	Captured 12 escaped prisoners
16	49	Sewage spill/ Road washout	PW PU	Spill contained, road cleared.
17	60	Tree Down	PW	Units dispatched
18	71	Street Debris	PW	Road cleared
19	75	Street Debris	PW	Road cleared
20	99	Auto Accident/ entrapment	FRD SO	Fire trucks and medivac helicopter dispatched to scene.
21	148	Truck accident/ Fuel spill	FD SO PU	Units dispatched to scene
22	155	Helicopter crash on interstate	SO FRD	Units dispatched to scene
23	167	Disturbance	SO	Units dispatched to scene.

*FRD=Fire & Rescue Division
SO=Sheriff's Office
PU=Public Utilities
PW=Public Works
HCS=Health & Community Services

Table 1. Proof-of-Principle Demonstration Events

both its current and future versions, to emergency management simulation in general is discussed in (Loper,1995).

To be fully useful, emergency management simulation will require autonomous simulated entities that can automatically perform low-level actions (like route planning) in response to commands given by trainees. At a higher level, replacements for missing exercise participants must also be provided in the simulation. These needed capabilities, analogous to computer generated forces in battlefield simulation, are explained in (Petty,1995b).

ACKNOWLEDGMENTS

This work was supported by the U. S. Army Simulation, Training, and Instrumentation Command under the Plowshares project, contract N61339-95-K-0003. That support is gratefully acknowledged. This paper was reviewed by Jean H. Burmester. Douglas D. Wood and Paul D. West provided information. The authors acknowledge their assistance.

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