National Institute for Occupational Safety and Health
Office for Mine Safety and Health Research, Pittsburgh Research Laboratory

Mine Emergency Response Interactive Training Simulation (MERITS)

*Note: The MERITS program is currently under development and is **NOT** available for use. The expected completion date is in the fall of 2000.*

Summary

As mines become safer and major disasters fewer, the number of experienced emergency responders is decreasing. This decrease will create a gap in response expertise that could have serious consequences at future mine disasters. The National Institute for Occupational Safety and Health, Pittsburgh Research Laboratory (PRL) is developing a computer program to simulate a major mine emergency. The Mine Emergency Response Interactive Training Simulation (MERITS) will help meet a variety of needs. It will allow personnel in leadership positions to evaluate their knowledge and skill. Groups consisting of representatives from mining companies, labor, and government agencies could practice working together during the simulated emergency in much the same way that an actual emergency would require. An individual could also run the program to enhance his or her response skills. A company's formal response plan will guide the simulated response and be tested at the same time. With this tool, responders will learn from their mistakes before facing situations with potentially deadly consequences.

The primary target audience for MERITS is command center personnel. The interface will provide information typically available to those decision-makers and require input from them. A map of an actual or computer-generated mine will be incorporated to add realism. An emergency will be randomly selected within specified conditions, and the underground situation will unfold through the simulation program. The progress of the underground simulation will be reported to the command center. Surface concerns, such as personnel scheduling, media interactions, and traffic problems, will also be included.

Background

Since 1984, PRL has pursued a program of research focusing on various aspects of mine emergency response. Research has included studies directed at effective use of self-contained self-rescuers, assessing miners' response to escaping underground mine fires, evaluating fire

fighting technology and workforce skills, and managing mine emergencies.

To transfer the information derived from this research to the mining industry, PRL has begun to develop the Mine Emergency Response Interactive Training Simulation. MERITS will be a tool for command center personnel to practice their skills at managing a major underground mine emergency via a personal computer and the Internet. Because of the focus of past related work, initial programming will address response to fires at underground coal mines. With additional resources, other mine emergencies in different types of mines, such as copper or limestone, could be added. The completed simulation will take the results of several past PRL research efforts "off the shelf" and put them into the hands of the people who help to keep mines safe.

The Current State of Mine Emergency Response Training

Miners in smoke using self-contained self-rescuers.

Federal and most State mine safety regulations require some level of mine emergency response training for mine workers. This mandated training is for front-line workers who often will be the first individuals to confront an emergency situation. Underground miners, for example, receive training in escape procedures, first aid, emergency breathing apparatus, and fire fighting equipment. When mine operators have rescue teams, Federal (and some State) regulations define minimum training requirements. Comprehensive training for responding to and managing mine emergencies is not required by regulation. Enhanced training, however, is available through several sources.

Since the 1980s, the Mine Safety and Health Administration (MSHA) has conducted Mine Emergency Response Development (MERD) exercises for interested mine operators, labor organizations, and State regulatory agencies. MERD exercises are approximately day-long role play events that present a realistic mine emergency scenario in the classroom to personnel who may be responding to future events. In these exercises, trainees play various roles, including those of mine management, Federal and State enforcement officials, mine rescue team members, labor representatives, media, and family members of victims. The objective of these exercises is to teach participants how to respond to a mine emergency in a correct, timely, and well-organized manner that ensures the safety of all involved individuals. MERD exercises are excellent tools for teaching mine emergency response tactics, decision making, resource allocation, and other concepts. However, they are time-consuming to develop, set up, and present. For MERDs to be

effectively administered, several rooms with telephone communications must be available to use as command centers, mine sections, rescue team staging areas, etc. In addition, several dozen or more individuals are needed to play roles during the exercise.

Mine rescue team exercise.

Another form of enhanced mine emergency response training is the mock mine disaster. Like MERDs, mock disasters are role play exercises designed to present realistic mine emergency scenarios. However, unlike MERDs, mock mine disasters use actual mine facilities and involve mine personnel in their assigned roles at the operation. For example, a mine in western Kentucky staged a mock disaster in which an imaginary earthquake occurred along the New Madrid fault. In the scenario, miners were trapped by massive roof falls in the mine caused by the earthquake. One fall also caused a mine fire when a mine car loaded with conveyor belt struck the battery compartment of a locomotive. A nationally recognized mine emergency response expert developed the content of this mock disaster. During the simulated emergency, responders had to manage a situation that included fire, serious injuries, the potential for an explosion, and entrapment. For this mine, the mock disaster was an excellent tool for validating the operation's mine emergency response plan and preparedness for a large-scale emergency. However, staging the event required significant time and the devotion of considerable resources from the mine and other organizations.

A third source of advanced mine emergency response training is offered through the Emergency Preparedness Center, operated by the Mining Extension Service of West Virginia University. This group offers training at MSHA's National Mine Health and Safety Academy (Beckley, WV) on a variety of topics including mine emergency preparation, basic and advanced mine fire safety, hazardous materials containment and control, and mine rescue team training. Recently, the Emergency Preparedness Center began to offer fire fighting and smoke training at mine sites via a mobile training vehicle. This unit is equipped to permit on-site smoke training for self-contained breathing apparatus (SCBA) and self-contained self-rescuer (SCSR) practice. It also includes pans for conducting live fire fighting demonstrations and practice sessions. Fire fighting training, smoke training, hazardous material containment and other emergency training, whether provided on site or at the Academy, will enhance some aspects of a mine's preparedness for responding to a mine emergency. However, the scope of this training is limited and does not touch on the more comprehensive issue of overall mine emergency response preparedness.

In summary, MERDs and mock disasters are excellent training exercises for mine emergency response tactics, decision making, resource allocation and other concepts. However, they are resource-intensive to develop, set up, and present. The West Virginia University emergency response training, while very useful, is specialized and thereby limited in scope. A computerized form of emergency response exercise such as MERITS will enhance the overall mine emergency response training infrastructure. It could be used with the training currently offered by West Virginia University. It will be less resource-intensive for individual companies, agencies, and labor organizations than current mocks or MERDs. It will be easy to set up at training locations and can be used by operators of small mines who have few resources to devote to emergency response planning and training.

Command center personnel during a mock mine disaster.

Another advantage of the computerized format of MERITS is the ability to track each stage of the resolution of the emergency. As a result, it will be possible to provide better and more detailed feedback on the user's performance. The software will monitor the speed and appropriateness of the actions, allowing for a thorough debriefing at the end of the exercise.

An Overview of the Mine Emergency Response Interactive Training Simulation (MERITS)

MERITS will be an interactive multimedia computer simulation, delivered via the Internet, of an underground mine that is undergoing some type of emergency. It will simulate both underground and surface activities at the mine site and provide a means to inform users (command center trainees) of those events and allow them to attempt to resolve the emergency. The users' decisions, in turn, will affect the progress of the simulated emergency.

MERITS will run on two computers that communicate via a local area network (LAN) or Internet connection. The **Host PC** will simulate the underground and surface activities at the mine site, except for the decisions of the command center. The host will pass (through a local area network or Internet connection) relevant information concerning those activities to the **Local PC**, which will communicate with the trainees. The advantage of this approach is that only a small amount of information needs to be sent over the communications link to the local PC. Because the CPU-intensive part of the simulation is done remotely on the host PC, mines that do not have high speed PCs will be able to use MERITS.

Some underground activities that MERITS will simulate include the spread of the fire and smoke under the influence of the mine's ventilation system, the actions of the miners attempting to escape the mine and the rescue teams attempting to find the miners, and unexpected events such as roof falls. The underground simulation will be based primarily on many PRL research studies concerning mine ventilation simulation, SCSR training and field audits, oxygen cost studies, miner demographics, and analyses of miners' behaviors during past emergencies.

Surface events will include interactions with the media, medical services, labor, government officials, and unofficial visitors (for example, victims' families), weather (such as flooding that interferes with the flow of supplies to the mine), and traffic problems.

At times, problems may arise that prevent the trainees from addressing all other issues until they resolve the immediate situation. For example, the unexpected arrival of a distraught family member at the command center (depicted via digital video) may interrupt the trainees from addressing other problems until the family member can be calmed down and moved to an appropriate facility away from the command center. If required resources (food, medical supplies, etc.) are exhausted or delayed during the simulation, or other unanticipated developments occur, it will be the responsibility of the trainees to address these issues while still attending to other ongoing activities. These "interruptions" will provide a sense of realism by exposing trainees to the stresses that can be involved in an actual emergency.

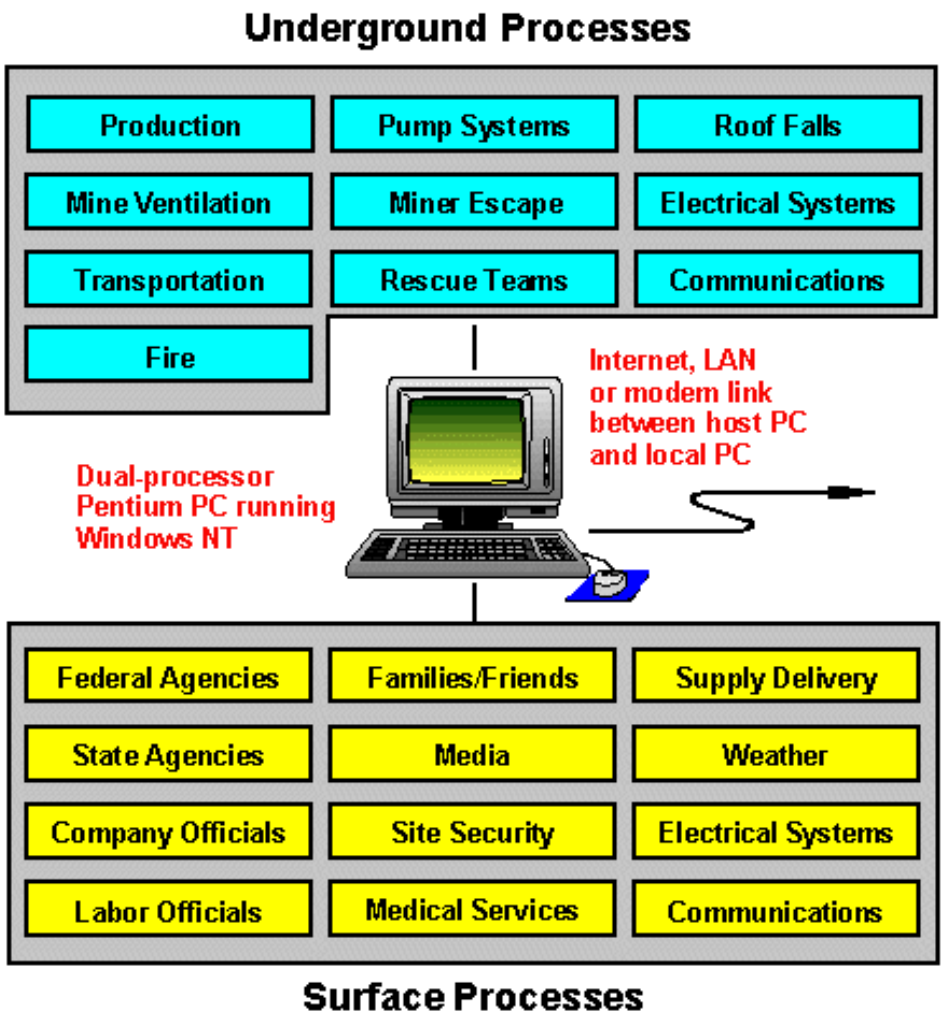
Although MERITS will be able to generate a random emergency, a scripting feature will allow trainers to develop specific simulation exercises. Trainers can update these exercises periodically to provide new and varied training experiences. This feature will also permit controlled experiments where a trainer knows in advance the type of emergency scenario that will be generated.

A mining organization at a central location will maintain the host PC (although mines with appropriate facilities could maintain both a host and local PC at their site). The host will provide security to "lock out" unauthorized users, so that only one site at a time can use MERITS.

The Host PC

The MODSIM® III simulation language and C++ are being used to develop the host software. The simulation paradigm supported by MODSIM is the *process*. A process is capable of carrying on multiple, concurrent activities, each of which can elapse simulation time.

The figure below illustrates some of the processes that will be included in MERITS to simulate surface and underground activities.



Underground Processes

The underground processes will simulate events relevant to the emergency that occur below the surface of the mine. Some of these activities include:

- ***Production*** - At the start of the simulation, the Production process will be initiated to generate realistic starting positions for underground miners and equipment. For example, face crews will begin mining activities, while beltmen begin to monitor the beltways. As each miner receives word that a fire (or other emergency) has occurred and he/she is to evacuate the mine, that miner will cease Production activities and begin the Miner Escape process.

- ***Mine Ventilation*** - Ventilation is an important issue in an underground mine evacuation. PRL research has shown that, in the early stages of a mine fire, evacuating miners will encounter visibility problems due to smoke before critical maximum carbon monoxide

values are reached. Reduced visibility will impair normal traveling speeds of the miners. In addition, miners are taught to don self-contained self-rescuers to isolate their lungs when they encounter smoke. This will also delay the mine evacuation.

It is anticipated that MERITS will track the progress of smoke and fire through the mine using a computer program called MFIRE, which was developed by Michigan Technological University with support from the former U.S. Bureau of Mines Twin Cities Research Center. MFIRE does normal ventilation network planning calculations and dynamic transient-state simulation of ventilation networks. The program can analyze ventilation networks under the influence of natural ventilation, fans, fires or any combination of these factors. It calculates the mine ventilation system's response to altered ventilation conditions, such as changes to ventilation control structures (opening and closing doors), external influences (such as changing outside air temperatures), and internal influences (such as fires). MFIRE will be initiated at the start of the simulation, in conjunction with the Production process.

- ***Fire*** **-** The Fire process will schedule a fire to occur at a specified time and underground location. By default, this time and location will be randomized. However, the scenario developer or trainer may choose a specific time and location to allow for controlled experiments.

- ***Transportation*** **-** Depending on the emergency scenario, resources such as railed or rubber-tired personnel carriers and/or hoists may be used to evacuate workers and bring in rescue teams. Electrically powered equipment will be impacted by electrical failures.

- ***Pump Systems*** **-** Pumps and piping are installed at sumps or low spots in the mine to drain unwanted water and avoid flooding. If these pumps are disrupted by the mine emergency (through a loss of electrical power, fire damage, etc.), it may impact escape routes and rescue efforts.

- ***Miner Escape*** **-** The Miner Escape process will simulate each miner's attempt to escape from the mine. Generally, miners take the shortest path to the primary escapeway and then follow that escapeway out of the section. However, they may deviate from this route under the guidance of the command center or as a result of encountering smoke or fire in an escapeway. During this evacuation, the speed and oxygen consumption of the miners will depend on the postures required to travel through the mine. For example, lower sections may require stooped or crawling postures. As the miners progress, the oxygen available in their SCSRs will be decremented appropriately. The fate of the miners is determined by the distance they can travel and the condition of the atmosphere if their SCSRs are exhausted. The model will include designated SCSR cache sites. Each site will have a predetermined number of SCSR units available for miners that can reach it.

- ***Rescue Teams*** **-** Under the direction of the command center, rescue teams may enter the mine to find and retrieve trapped or lost miners. These teams are well trained, follow a strict set of rules to carry out their mission, and are equipped with special breathing

apparatus. Maximum traveling speed of these teams will be based on the traveling speed of the slowest member and the posture that must be assumed to travel through each mine section. However, other factors may slow down or delay travel, such as using lifelines or stopping to take gas readings or update mine maps.

- ***Roof Falls*** **-** This process controls the timing and location of major roof falls (if any) during the emergency. Roof falls complicate the escape by potentially blocking an escape route or by taking out a mine system, such as a critical water pump.

- ***Underground Electrical Systems*** **-** The electrical system powers most of the major equipment underground (excepting diesel and battery-powered equipment used by some mines for haulage and transportation). Failure of the underground electrical system would have a serious impact on the mine emergency by shutting down pumps, transportation, and ventilation systems.

- ***Underground Communications*** **-** Communications are crucial to efficient evacuation of the mine. This process will model communications initiated by underground workers to underground or surface sections of the mine, including the command center (communications initiated by the surface are handled via a separate process described later in this document). Factors that affect communications include availability of phones and electricity. The completeness and correctness of the information is also important. PRL studies have shown that miscommunication is a frequent occurrence at mine emergency events. For example, if the caller neglects to identify the location of an underground fire to the underground workers, those workers may not be able to properly plan their escape. MERITS may occasionally introduce miscommunications as information passes from one recipient to another.

Surface Processes

The surface processes will simulate events relevant to the emergency that occur on the mine surface. This excludes the actions of the command center personnel, which are provided directly by the users/trainees. Some of these activities are listed below.

- ***Federal and State Agencies, Company and Labor Officials*** **-** Federal and State agencies, as well as company and labor officials, usually have a role to play during a mine emergency. These processes model the representatives of those agencies and allow them to interact with the trainees. For example, the Federal process will suggest (through digital video) what Government rules the command center has violated, what additional steps to take, what actions are not permitted, etc. Similarly, the State and company official processes, which operate on a different set of rules, would impose their own restrictions and make their own suggestions. During the emergency, someone represents the interests of the labor force at the mine. The labor official process interjects the workers' point of view, when appropriate.

- ***Media, Families, and Friends*** - A mine emergency is newsworthy and will quickly draw representatives from the media. It will also bring out family members and friends of trapped miners. These processes track the movements of media and family representatives, interrupt the trainee with demands for information (possibly during critical decision-making periods), and generate "press releases" on the progress of the emergency. At times, the media reports may not be complimentary to the rescue efforts and may even include incorrect information. This may create additional problems for the command center to resolve.

- ***Site Security*** - This process will simulate property entrance restrictions and security. This includes assignment of guards and monitoring by local law enforcement agencies. Failure of the command center personnel to properly provide for site security may result in unwanted individuals (citizens, media, etc.) invading the mine site.

- ***Medical Services*** - This process models the emergency medical staff on hand at the surface during the emergency. It tracks events such as the arrival and departure of ambulances, medical status and location of victims on the surface, and available medical supplies.

- ***Supply Delivery*** - In the event that the mine runs out of supplies and materials needed to manage the emergency (fire fighting and roof control materials, heavy equipment, etc.), it will be the responsibility of the command center to order replacements. This process models the ordering and delivery of those supplies to the mine, as well as locations of those items at the mine site.

- ***Weather*** - This process controls the timing of major weather events that could affect the emergency. For example, heavy rains could complicate the situation by flooding access routes to the mine or by taking out an important resource, such as a power line.

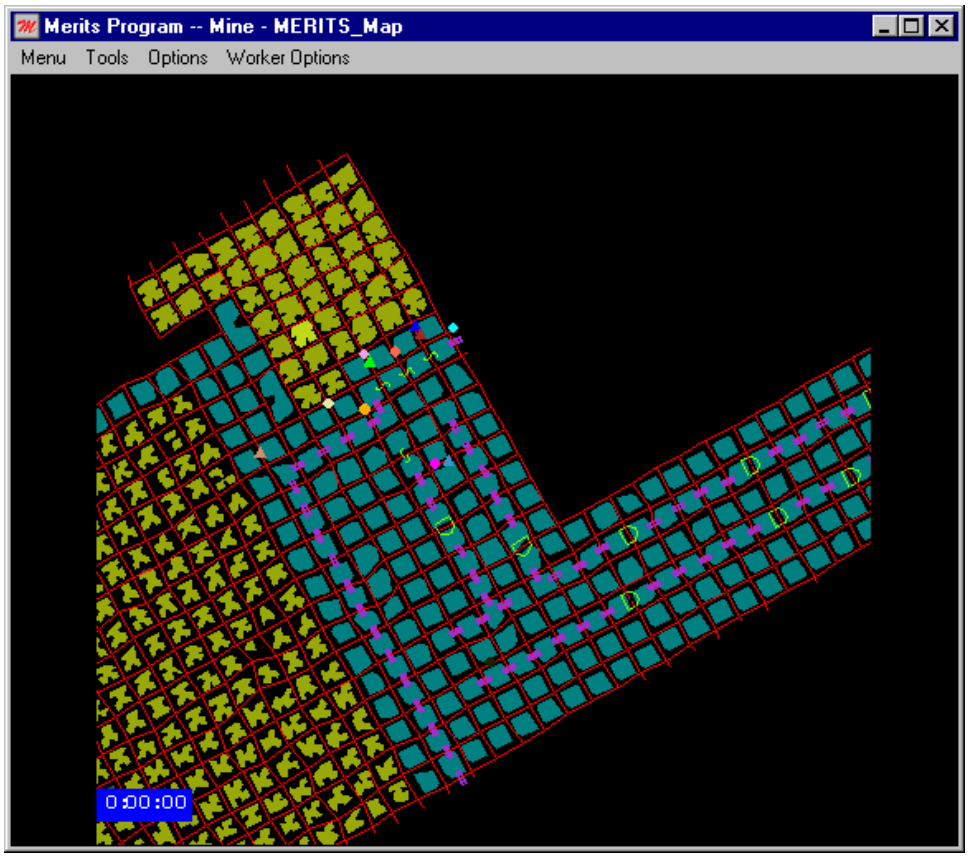
- ***Surface Electrical Systems*** - The surface electrical system powers the above ground facilities (including the command center). The failure of this electrical system would affect all surface operations (communications, transportation, and supply delivery, etc.).

- ***Surface Communications*** - This process will model communications initiated by surface workers to surface or underground sections of the mine. It will also convey communications initiated directly by the command center trainees (communications initiated by underground workers are handled by a different process described earlier in this document). As with communications initiated by underground workers, the availability of phones and electricity also affects surface communications. Similarly, MERITS may randomly alter messages to simulate miscommunications at the mine site with one exception: communications initiated by the command center will not be altered when delivered to a specific recipient (however, MERITS might introduce a miscommunication if that recipient forwards the information to a third party).

The simulation will operate on a set of "rules" that define its possible behaviors. The rules will cover classes of information necessary to create a realistic simulation. These classes of information will include (but not be limited to):

- Human factors - physiology, psychology, level of training, etc.
- Physical factors - mine location, ventilation systems, etc.
- Internal and external resources - fire fighting equipment, rescue team availability, roof control materials, food, transportation, etc.
- Political considerations - relations with Federal, State, and local authorities, media impact, relations with victims' families, etc.
- Economics - costs associated with rescue efforts, etc.

The host software includes a mine map display. Since it will never be seen by trainees, it can show all action that is occurring underground. This includes information that the trainee would not know, such as locations of underground miners. The figure below shows the host mine map program displaying a small section of a test mine. Small colored dots, squares, and triangles indicate miners. The simulation clock is currently set to 0:00:00 - the start of the simulation.

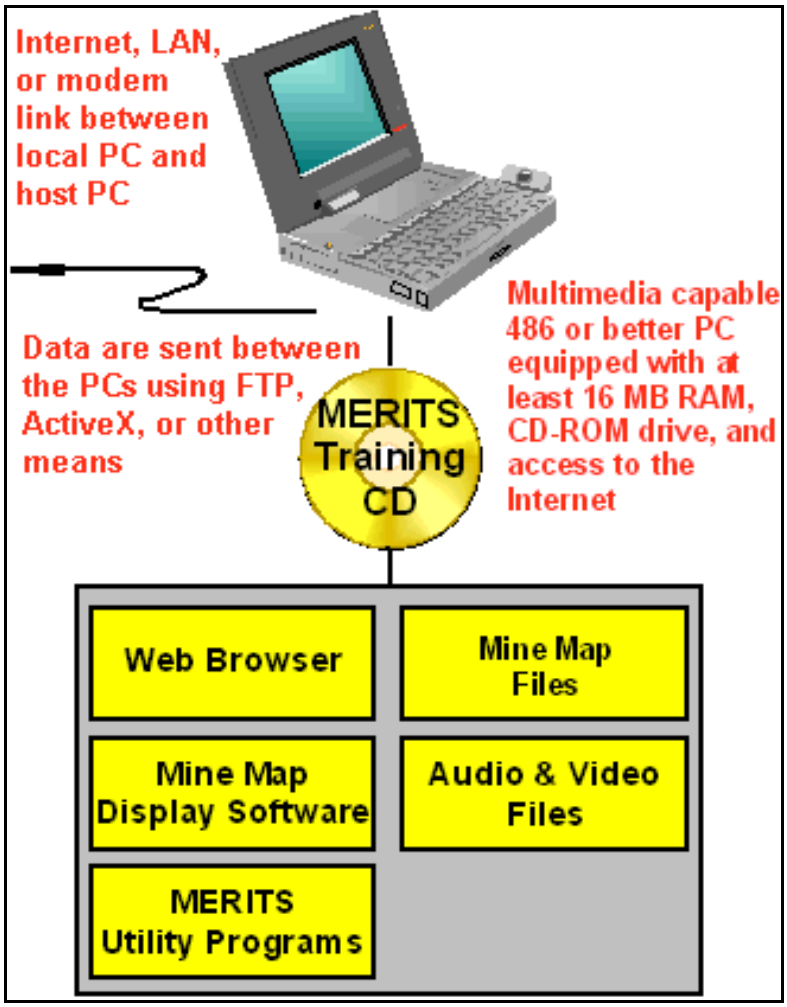


MERITS Host Mine Map Display showing a small section of a test mine.

The Local PC

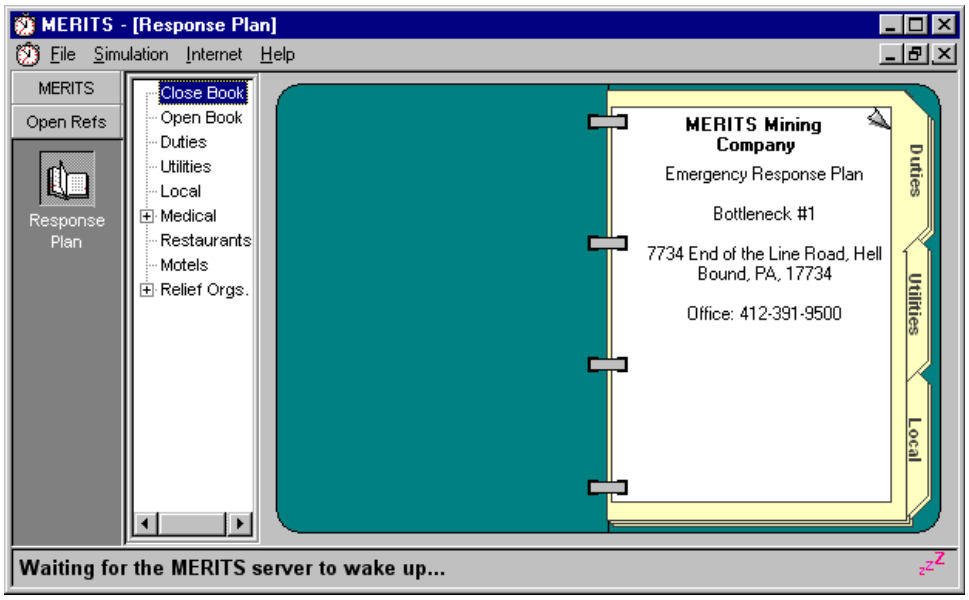
The MERITS Training CD will be shipped in advance to users at the designated training site. It will include two primary software programs: a custom Web Browser and the Mine Map Viewer Software. It will also contain mine map, audio, and video files for prewritten emergency scenarios, as well as utility programs for developing new scenarios and maps.

The trainees must install this software onto their local PC before contacting the host. They must also identify the mine map to use for the simulation, details concerning the mine's formal emergency response plan, and available resources (responsible personnel, medical and food supplies, housing and briefing facilities, phone lines, fire fighting supplies, roof control materials, names and phone numbers of contact persons, etc.). These may be customized to the trainee's own mine, or the trainee can use default setups provided with MERITS. (Audio and video files are not copied to the local PC to conserve disk space. Therefore, the CD must be accessible while the simulation is running.)



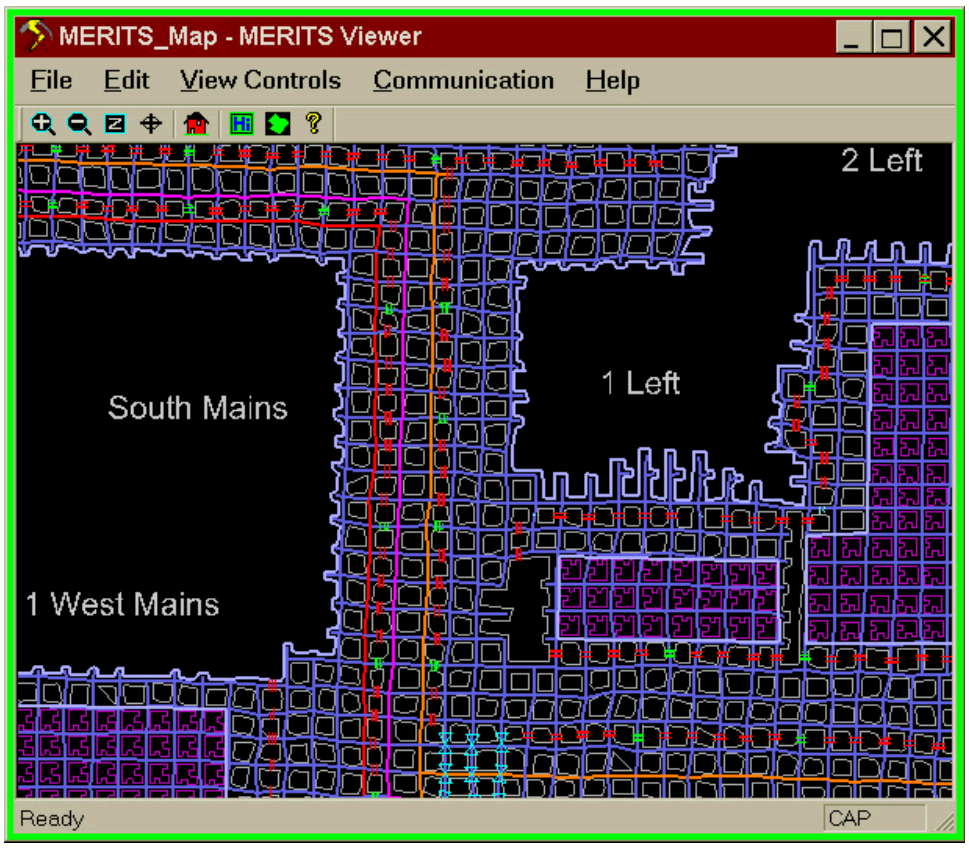
MERITS Local PC

- **The MERITS Web browser** - a custom browser written in Visual Basic® and ActiveX™ controls. This browser, based on Microsoft Internet Explorer 4.0®, is the control program for the MERITS client. It lets trainees communicate with the host simulation (e.g., send commands to rescue teams or other workers) and view reference materials (e.g., the mine's Emergency Response Plan and log of events). It also monitors the status of the Internet connection and provides feedback on the trainee's performance at the end of the simulation.



The MERITS Web Browser displaying the Emergency Response Plan Book.

- **The Mine Map Viewer** - a stand-alone C++ program (with graphical capabilities provided via the Open Inventor® graphics library) that can be accessed via the browser. This Viewer displays the layout of the simulated mine. It can highlight special pathways (e.g., ventilation routes and escapeways), network systems (e.g., water and phone lines), and other objects (e.g., stoppings, doors, overcasts). These are displayed as overlays on the map. In the future, it will also show dynamic information reported by the rescue teams (e.g., ventilation readings, locations of smoke, etc.). Only information known prior to the start of the emergency, or reported to the command center by simulated workers during the simulation, will be visible to the command center trainees.



The MERITS Mine Map Viewer showing a portion of a test mine map.

At times, the host PC may need to trigger certain events on the local PC. For example, it may use digital sound recordings to simulate ringing phones and interaction with the media and families of victims. Corporate personnel, political figures, and others may "visit" the command center (via a digital video recording appearing on the screen), demanding that the trainee take certain courses of action. The host will accomplish this by "playing" audio and video files from the MERITS CD. As another example, updates to mine maps based on data obtained by the "rescue teams" will be sent to the local PC for viewing.

Hardware and Software Requirements

The exact requirements for the hardware and software may change as the project develops. However, the hardware needed to run the simulation will be restricted to what will be available to most individuals, schools, training centers, and companies by the time the simulation is ready for distribution.

Host PC Hardware and Software Requirements

- Dual-processor Pentium® PC equipped with at least 32MB RAM, a 2GB hard disk, and access to the Internet (28.8 baud modem or LAN).
- Windows NT® operating system and the MERITS host simulation software.

Local PC Hardware and Software Requirements

- 486 or better PC equipped with at least 16MB of RAM, Microsoft® Windows®-compatible sound card and speakers, 4× speed or greater CD-ROM drive, a 1GB hard disk, a Super VGA monitor, a mouse, access to the Internet (28.8 baud modem or LAN connection), and a printer.
- The Windows 95® or Windows NT® operating system, and the MERITS local interface software (consisting of a custom web browser based on Internet Explorer 4.0®), Mine Map Viewer software, map data files, audio/video files, and MERITS utility programs - all distributed to the trainees in advance on CD).