MINE EMERGENCY RESPONSE COMMAND CENTER TRAINING USING COMPUTER SIMULATION

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ABSTRACT

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 which could have serious ramifications during future mine disasters. While working toward safety goals which may make emergency response obsolete, it would be reckless not to acknowledge that the potential for disaster still exists and that the protection of miners in such circumstances must remain a priority. The Mine Emergency Response Interactive Training Simulation (MERITS) is a computerized mine emergency simulation that meets a variety of needs. It allows personnel in leadership positions to test their knowledge and skill. Groups of individuals composed of representatives from mining companies, labor, and government agencies can practice working together during the simulated mine emergency much in the same way an actual emergency would require. An individual could also run the program to enhance his or her response skills. With this training tool, responders will be able to learn from their mistakes before facing situations with potentially catastrophic consequences. This paper discusses MERITS and its use in providing command center training.

INTRODUCTION

When the World Trade Center Towers were destroyed on September 11, 2001, the need for emergency response readiness was tragically brought to everyone's attention. Less than two weeks later, on September 23, the mining industry was dealt a blow when thirteen miners died in an explosion at an underground coal mine in Alabama. These experiences show that while working toward prevention of catastrophic events is important, we must also prepare to respond when the unthinkable happens.

Major mine emergencies have become relatively rare events in the United States and there has been a corresponding decrease in the number of people who have hands-on response experience. This gap in expertise could have serious consequences during future responses. Managers who are responsible for day-to-day operations may suddenly be called upon to act as command center leaders with little or no previous experience in that role. Their lack of knowledge and skills could put in danger the workers who were present when the emergency occurred and also those called upon to respond. The goal of MERITS is to better prepare managers and government and labor representatives for mine emergency response leadership roles. This paper: 1) presents the rationale for development of MERITS, 2) discusses how the simulation differs from other computer-based training, 3) illustrates basic components of the interface, and 4) presents results from field tests of the exercise.

BACKGROUND

In the early 1990's, researchers from the former Bureau of Mines conducted extensive interviews with 30 individuals who were nationally recognized experts in the area of emergency response. These experts were asked how they would train future mine emergency responders (Brnich, Mallett, and Vaught 1997a, 1997b). While responses provided by interviewees varied, nine of them believed that some form of interactive simulated response training would be the best way to train responders. Three methods of simulation were discussed: mock disasters, MERD exercises, and tabletop exercises. Nine veterans also suggested that future responders be trained in mine emergency response planning.

Ten veterans talked about the need to adequately train mine or corporate management personnel in emergency response procedures. As one interviewee indicated, managers will be the ones who will be playing major roles in the decision making process at the command center. In addition to training management, five veteran responders said that enforcement personnel should be thoroughly trained in emergency response. As mentioned by one interviewee, more and improved training for these individuals will enhance their ability to respond to a mine emergency when it occurs.

Why is the issue of training future mine emergency responders so important? The answer to this question can be found in one veteran's comment:

> ... a lot of people's come and gone since 1969. And we're having less problems. So, in the next 10 to 15 years, there's just going to be a hand-full of people that's had any experience. ∃Cause, we don't send people to go to the [mine emergencies] that we have. There's no way to get that on-hand experience other than to be there.

In short, mine emergency response veterans clearly indicated that training response personnel is paramount, if mines intend to be prepared to handle a major emergency should it occur.

COMMAND CENTER TRAINING

Emergency response is sometimes given a low priority in training planning because catastrophic events occur infrequently. While there are extensive training requirements for mine rescue team members, there is no mandated training for command center leaders. Many managers have little or no experience in dealing with large-scale mine emergencies. Since no one wants to believe a disaster will happen, day-to-day job pressures make taking time for emergency response training seem like a luxury for another day. Unfortunately, that day may not come before the emergency happens.

Command center training is available through the Mine Safety and Health Administration (MSHA) and other sources. Frequently training is the form of a full-scale simulation and presents the complexity of a major response to the trainees. It gives trainees the needed view of the overall response, but is resource-intensive to conduct. MSHA's Mine Emergency Response Development (MERD) training allows participants to act out various response roles. This type of hands-on experience is excellent command center training for those chosen to fulfill those roles, but is less effective, in terms of command center preparation, for those playing other roles.

Another form of enhanced command center training is in the form of a mock mine disaster. Like MERDs, mock disasters are role play exercises designed to present a realistic mine emergency scenario. However, unlike MERDs, they use actual mine facilities and involve mine personnel in their assigned roles at the operation. However, staging these events requires significant time and the devotion of considerable resources from the mine and other organizations. For personnel at small, remotely located operations, full-scale mock drills and even MERDs may seem out of reach.

MERITS augments existing command center preparation with a training simulation that can be delivered at any location with basic computer equipment and an Internet connection. Many, if not most, mine sites have such equipment. If nothing else, most mine sites are within a reasonable distance of a public or private facility such as vocational technical school or community college with the required tools. Even the most remote mining sites can be equipped with a lap top computer and a telephone connection. Aside from the computer equipment, MERITS requires few other resources. While a group of three to five participants is recommended, a successful training session can be run even for one individual.

During the session, all trainees are part of the simulated command center and receive the same experience. MERITS can be used to give select individuals a basic understanding of command center functions before they are placed in leadership roles during a MERD or mock drill. It could also be used to allow participants of other types of training, who were not in command center roles, an opportunity to have that experience. MERITS has also proven to be an effective way to give mine rescue team members the "big picture" of large-scale response activities. Knowledgeable trainers can tailor MERITS for the novice and for the veteran responder. In all cases, a trainer competent in the subject matter should be available to trainees.

HOW MERITS DIFFERS FROM OTHER COMPUTER-BASED TRAINING

Computer instruction is the process in which a computer is used to present information to the trainee. Computer-based training, or CBT, is generally used to describe the application of computer instruction to various training settings, including training in the workplace. CBT offers several advantages over other types of instructional methods: 1) it offers learning in the classroom but has the potential for learning in remote locations; 2) it can be standardized, customized, or changed as necessary to meet changing needs; 3) it is cost-effective in that large groups of trainees are not required to make up a class; and 4) it is convenient since trainees can attend training at their own workplace and work at their own pace (Anonymous, 1998; Charles, Black, and Murphy, 1992; Dennis, 1994; Drape, 1994; Guilar, 1994; Shaw, 1992). Computer-based training also generates positive attitudes and enjoyable experiences among trainees (Kulik & Kulik, 1991; Shaw, 1992).

The training objectives of MERITS are meant to enhance the decision-making performance of command center personnel during mine emergencies. This goal is achieved through the use of computer-based simulation problems. Potential users will ask how well an electronic emergency response will prepare them for the real thing. This is really a question of validity, and must be answered by beginning with the use of computers as teaching and assessment instruments.

If one draws a Venn diagram of computers, simulations, and instruction, the result might take the form of Figure 1 (Leonard, 2002). That is because computers are used for much more than simulation, even when they are employed for instructional purposes, and also because computer simulations are not always used to teach. Thus, actual instruction is only a small

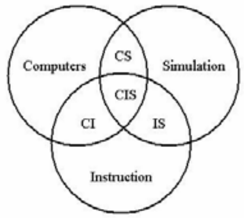

Figure 1 – Integrated relationships of computers, simulations, and instruction.

part of the potential uses for either computers or simulations. A brief discussion of some salient issues relating to each overlapping segment will put the diagram into better perspective.

CS - Computer simulations do not necessarily instruct, any more than life experiences necessarily teach us anything. Instead, they allow one to observe the playing out of certain hypothetical events, such as a drought on the farm, and may, in the case of expert systems, advise us on how to cope with the situation. While these types of tools are of value, they are not much use as stand-alone teaching devices. Not until an instruction plan has been incorporated into the simulation does structured learning and evaluation take place.

CI - In many instances, where computing and instructional methods overlap, computers are used not to simulate events, rather, they serve to deliver instructional material for individualized learning. Often they are electronic page turners, carefully metering stimulus and response, measuring out facts and figures in acceptable doses. While there is nothing wrong with this type of instruction and evaluation (or this use of computers), it is better suited to some purposes, e.g., teaching maintenance SOPs, than others, such as emergency response activities.

IS - Instructional simulations take many forms and all can provide powerful vicarious learning experiences that may better prepare workers to deal with actual events. Training of mine rescue teams, military personnel, and fire fighters routinely makes use of both full-scale field simulations and so-called paper and pencil (or "tabletop") exercises. Unlike case study reviews, instructional simulations do not present the outcome of an emergency as a means for evaluating individual decisions made during the course of the event. Rather, the simulation problem unfolds and requires decisions among alternatives to be made with incomplete information similar to the process involved in an actual emergency. Instructional simulations have an interesting advantage over participation in actual emergencies: They can provide the learner with an overall perspective on key relationships and interactions among the human players, physical factors, and equipment, as well as revealing both the predictable and capricious events that are always part of any emergency. This type of overall comprehension of the "problem space" is thought to result in greater wisdom on the part of the participant. In aviation circles, instructional simulations are used to teach what is often referred to as "air wiseness" with promising results [Flathers, et al., 1982; Giffin and Rockwell, 1984].

CIS - MERITS is in the smallest subset of the diagram’s intersection, because it is a computer simulation that is intended to deliver quality instruction. Quality begins with content. As Gibbons and Fairweather [1998] note, “In order to be used for instruction, a simulation has to be integrated into a larger instructional plan, and in many cases it has to be complemented with additional instructional features which are not part of the simulated model itself.” Additionally, however, the package must do the following: 1) allow trainees to construct knowledge for themselves from the elements of the simulation; 2) require trainees to engage heavily in forward planning and problem solving; and 3) encourage trainee initiative. In other words, the simulation must be grounded in lived experience and have specific performance objectives that are explicitly stated.

DESCRIPTION OF MERITS

Modeled after training simulations developed for other industries (e.g. to address nuclear accidents, chemical spills, evacuations), MERITS simulates underground and surface events related to the disaster. It exposes the user to events that typically occur during a mine emergency such as lack of information and miscommunication. It also presents trainees with issues that must be addressed such as making provisions for briefing news media and victims' families, ordering needed supplies, interfacing with enforcement agencies, and housing mine rescue teams. The outcome of the scenario will be determined by the users' decisions and their emergency response plans.

MERITS presents an underground mine emergency scenario that develops over time, with a continual unfolding of points at which the emergency managers must either initiate decision alternatives or do nothing. The decisions will of necessity be like those that individuals or groups have employed (or failed to employ) in actual emergency situations. Some will be good alternatives and some, while possible, may not be effective (or may even be harmful). Completion of this exercise will result in a hard-copy record of the individual or group's decision choices. A performance score is based upon the pattern of responses, and can be registered in terms of percent correct performance (mastery).

While individuals are working the simulation problem, they also receive feedback about what impact the chosen alternative has had upon the situation. Thus, the exercise teaches by reinforcing good decisions, concepts, and strategy, while providing a basis for remediating incorrect thinking. Accompanying study notes, reviewed and discussed following problem administration, further elaborate the information and strategies that are exercise objectives, and help to situate this information in the specific experience of those individuals who work the simulation.

Characteristics of the Simulated Mine

The MERITS simulation is set at a small underground coal mine called Bottleneck No. 1. A small mine site was chosen for the first MERITS scenario because it is appropriate for a wide range of trainees. Many people work at fairly small operations, and those who do not might be called to assist in a response at one. Bottleneck No. 1 mine employs 56 workers and has two daily production shifts. Maintenance is conducted on the midnight shift. Coal is mined using continuous mining practice in two working sections. One section is on development and one is on retreat. A spare, idle section is also available for production. Equipment on all three sections includes one continuous miner, one twin-boom roof bolter, two shuttle cars, and a battery scoop tractor. Coal is transported from working sections on 36- and 42-inch conveyor belt from sections to the outside and dumped on the raw coal pile near the portal. The coal is then trucked to the preparation plant at a sister mine located four miles away. The corporate offices are also at the sister mine.

Trainees are given information about the mine's current status. A mine map includes details such as air direction and the locations of power centers, belt, track, mine phones, and SCSR caches. Mine documents such as pre-shift and on-shift reports and roof and ventilation plans are available for trainees to review. A personnel list provides the name, job title, certifications, and the usual shift of each employee. A tag board can be checked to determine who is underground at any given time.

Bottleneck No. 1 Mine has an extensive emergency response plan (ERP). This plan was developed with the assistance of personnel from the Pennsylvania Bureau of Deep Mine Safety. These safety professionals have assisted many small mines in development of site specific plans. The plan for Bottleneck No. 1 was developed in the same way as those created for mines across the state. The first part of the plan includes items such as a call-out roster and emergency duty assignments. Trainees may or may not choose to follow these guidelines as the situation evolves. The second part of the plan is an extensive list of providers of services and supplies. The simulation recognizes the phone numbers that are given in the plan so trainees can contact the simulated individuals and businesses for assistance during the MERITS session.

The trainees serve in the role as superintendent of Bottleneck No. 1 Mine. The stage is set for the simulation to begin with the following information about the day of the event.

As you drove to work on Route 350 this morning, you noticed the recent heavy rains had caused a slide that covered part of the right-hand lane. A DOT crew was there getting ready to set up warning barrels. You went around, and within a mile came to the mine access road.

Around 7:30 a.m. you pulled into the small parking lot in front of your office and entered the building. Since then you've been doing routine paperwork.

It is around 9:30 a.m. As the simulation starts, routine conversations are heard over the mine pager phone. The trainee can look at various mine records including pre-shift and on-shift reports, fan and barometric pressure reports, and other information. The mine clerk comes in and gives the latest time sheets and vacation requests for review and returns to her office. From that point on, what happens or does not happen is related to the actions or inaction of the trainee. Figure 2 shows trainees and a trainers engaged in a MERITS session.

Interacting with the Computer Program

The computer interface is organized to serve as an interactive work space where trainees engage with the simulation. It consists of a number of web pages and methods for navigating them. A picture of a typical MERITS screen is shown in Figure 3. Most of the screen is the data area where information or tools selected by the trainee are provided. A toolbar is

Figure 2 – Trainers and trainees during a MERITS session.

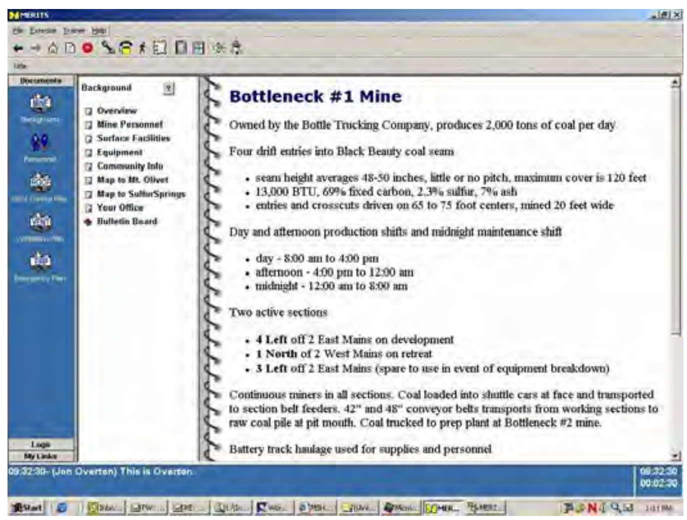

Figure 3 – Typical MERITS screen.

found across the top of the screen and the reference bars are located down the left side of the screen. The bars contain icons that can be selected to move among the available references, logs and tools. Trainees select icons on the left toolbar to display reference material and logs that are needed to analyze and resolve the emergency situation. The currently-selected reference or log appears in the data area of the screen. Tools that can be used to take actions (such as issuing orders to resolve the emergency situation) are provided in the top toolbar. When a tool is selected, a dialog box for that tool "pops up" over the data area of the screen requesting further information. Figure 4 shows the

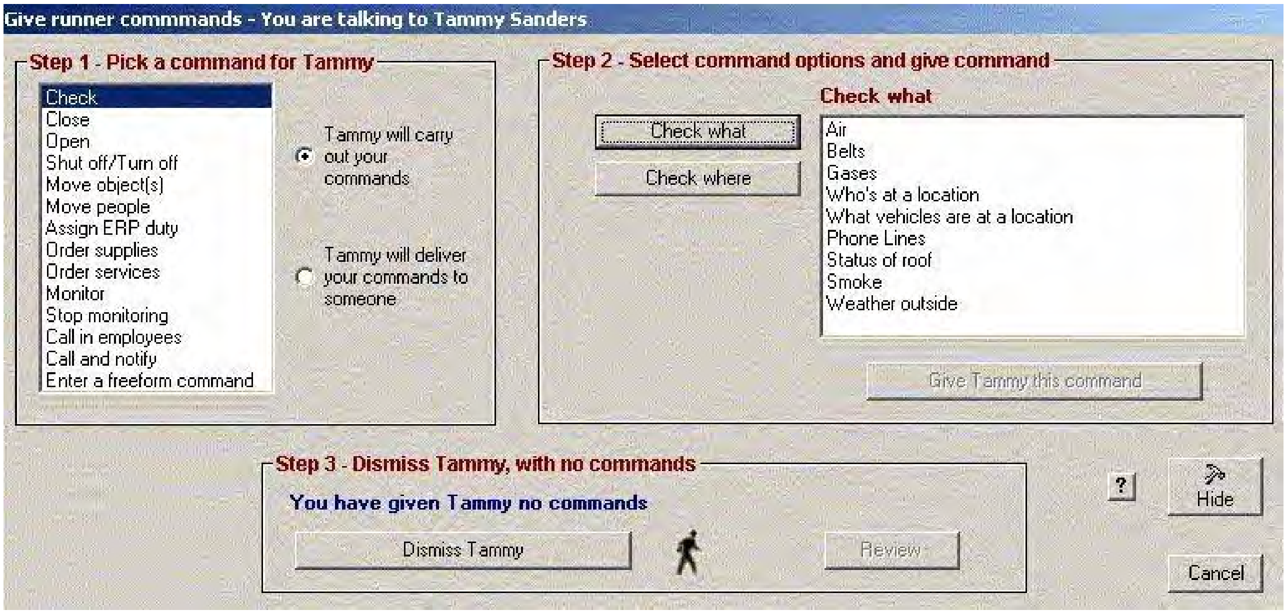

Figure 4 – Screen for issuing a command to a runner.

command box that "pops up" after the runner tool is selected.

After the simulation has started there are a number of tools, reports and communication devices that a trainee can access. These provide information or support interaction with the simulation. The following information can be referenced at any point during the simulation.

- General Mine and Community Information
- Roof Control Plan
- Ventilation System, Methane and Dust Control Plan
- Bulletin Board Postings
- Personnel List
- Emergency Response Plan
- Shift Reports
- Underground Tag Board
- Supply List

The interface includes tools that help trainees progress through the simulation. These tools can be accessed at any point during the simulation and include:

- Mine pager phone
- Telephone
- Runner(s) to do tasks and carry messages
- Mine map
- Clock showing simulation time
- Repeat last audio and visual communication
- A notebook to record trainee notes and reports from simulated miners
- Log that can be assigned to the runner to keep
- A log used to construct briefing/reports

Trainees can refer to help files for questions regarding the use of any communication devices or tools. These help files are accessible at any time during the MERITS simulation.

HOW MERITS IS EVALUATED

As with any training intervention, evaluation is critical to ensure its success. People typically think evaluation in terms of standardized norm referenced tests. The developers of these types of instruments attempt to construct exams that are restricted (not circulated) because they wish to measure performance with the same instrument in the future. Efforts are made to prevent feedback and learning during administration in order to avoid confounding an estimate of a person's ability with what he or she may have learned from taking the test. Such instruments are designed to rank persons by ability levels, but obviously not to maximize the learning experience.

MERITS does not evaluate trainees from a norm-referenced perspective. Instead, MERITS is criterion-referenced. Performance on this type of test is not defined by rank ordering a person's score according to the distribution of scores in some normative group, but is instead described by mastery of knowledge, skills, and strategies included in the exercise (Cole, 1994). If well constructed, such instruments are known to provide valid evaluations of what test takers know how to perform well or not so well. When individuals' scores fall below mastery levels, the performance data from these exercises are used to target areas that need further instruction. Criterion-referenced tests are also known to teach persons who complete them, and this is viewed as a proper outcome. In fact, criterion-referenced exercises is the method of choice for teaching and assessing critical skills and are widely used for this purpose. That is precisely the goal of MERITS.

The MERITS simulation focuses on specific performances in well-defined domains. Proper field-testing provides psychometric data on mental measurement properties of the exercise. At the same time, information is obtained to reveal skill areas in which the participants performed well and in which they performed poorly. Overall mastery levels can also be computed. This type of information can be used immediately to ensure that performance errors exhibited while working the simulation can be remediated by further instruction. Such corrective measures can help prevent these errors from occurring in actual emergencies. Aggregated data can also be used to compare the skill levels of groups who may have been trained: 1) by different persons; 2) using different methods; and/or 3) in different organizations (Cole, et al., 1988).

In summary, the MERITS simulation is clearly a training tool and was designed to be such. It is also a valuable evaluation tool that can reveal much about what different groups of participants know and do not know, as well as strengths and weakness in their logical decisions when they are faced with the predicaments involved in dealing with a mine emergency. This performance data can be used to improve training and policy. The military routinely uses similar simulation tasks to teach and evaluate the proficiency of individuals in specific areas, and to make changes in their training objectives and activities based on aggregated performance data. The same can be done in the mining industry.

VALIDITY OF MERITS

No matter how well designed a training simulation may seem, a critical question that must be answered is: "How well does the simulation prepare someone to cope in a real-world situation?" There is no group, including the military, that routinely conducts real-world validity studies of similar critical skills. Other groups who engage in good criterion-referenced skill training and evaluations do what has done with MERITS, that is, they go to great lengths to ensure that the simulation is grounded in significant real-world problems. Additionally, these groups enlist the assistance of experts in making judgments about the exercise's face validity. They then administer the simulation to experienced workers who have familiarity with the skills and performances involved. These persons are asked to rate the authenticity and value of the exercise, and their performance scores are recorded and analyzed.

It is important to ask participants if they: 1) could follow directions and comprehend the interface; 2) judge the simulation to be authentic; and 3) deem the exercise to be valuable in respect to its goal of improving their knowledge and learning. If a group rated these elements low, it should be clear that no matter what else was known about its properties, the simulation would be invalid because it would not be accepted or judged worthwhile by the very audience it was designed for. Such information is critical, and certainly an appropriate part of the face and content validity estimates for such exercises.

We may never know the "ultimate" validity of MERITS. Based on field test results, we can be fairly sure, however, that it provides useful information and an opportunity to practice those critical cognitive skills that are needed for effective performance during emergency management. We can also be sure that little current training in this area addresses similar types of "soft" skills. It is almost certainly better to have faced these decision-making tasks initially in the context of a simulation than during an actual event. This is especially true if one's earlier learning is mainly a set of rigid protocols about how things should be done, with little awareness of how unforeseen predicaments and dilemmas cause those protocols to break down.

Field Test Experience Initial field testing of MERITS was conducted with 27 individuals during eight full-day training sessions at four different locations in Colorado, Pennsylvania and West Virginia. These field tests benefited from the knowledge and experience of Pennsylvania mine inspection officials, representatives of the United Mine Workers of America, and private mine management, who all served as trainees for the MERITS training sessions.

Trainees self-reported an average of 20 years work experience in the mining industry. All trainees had participated in MERD training exercises and many had been involved in actual mine emergencies. Trainee evaluation of the MERITS program was based on responses to a series of statements regarding the simulation. Responses to each statement on the Likert Scale questionnaire could range from Very True, Very Useful, or Very Helpful to Not True, Not Useful, or Not Helpful. Table 1 presents trainees' responses to selected statements.

Subsequent to the initial field tests, MERITS was refined and retested during training sessions for individuals from state agencies, the UMWA, and private industry. Mining personnel from underground coal and underground stone mines participated and responded positively to the learning experience.

Continued Training and Evaluation MERITS researchers and industry and enforcement representatives have continued to work together to organize additional training sessions. At the request of the Pennsylvania Bureau of Deep Mine Safety, a series of training sessions was held at the agency's Ebensburg, PA mine rescue station for members of the state's mine rescue teams. A total of 21 individuals participated in MERITS training held in early 2001. As with the initial field tests, trainees evaluated MERITS by completing a Likert Scale questionnaire following the training session. The group of trainees reported 15.9 years of mining experience and all 21 had received mine rescue training.

Trainees' responses to selected statements are summarized in Table 2.

Table 1: Field test results.

Statement	Number responding	pct.
The simulation helped me know how to prepare for a real emergency.	26 “Very True or True”	96.4
The storyline for the simulation was realistic.	25 “Very True or True”	92.6
The simulation helped me learn how to better handle a real emergency.	27 “Very True or True”	100.0
I was **not** bored during the simulation.	27 “Very True or True”	100.0

Table 2: Results from additional field tests.

Statement	Number responding	pct.
The simulation helped me know how to prepare for a real emergency.	21 “Very True or True”	100.0
The storyline for the simulation was realistic.	20 “Very True or True”	95.2
The simulation help me learn how to better handle a real emergency.	21 “Very True or True”	100.0
I was **not** bored during the simulation.	21 “Very True or True”	100.0

CONCLUSION

Since research and development of MERITS began in 1996, the simulation has been constructed, field-tested, and authenticated. Field test results indicate the simulation has strong face validity and is a useful tool for teaching important decision making skills to command center personnel. Through calendar year 2002, MERITS will continue to be introduced to the mining industry through several venues, including technology transfer seminars, conference presentations, and train-the-trainer sessions. A four-volume NIOSH Information Circular, documenting MERITS and its use in emergency response training will be completed in 2002. This multi-document set will include: 1) a general overview volume; 2) a trainer’s manual on conducting a training session; 3) a software user’s guide; and 4) a software documentation guide.

Based on field test and training session results, MERITS is a robust training tool for teaching critical mine emergency response decision making skills for command center personnel. Although the simulation is based on an emergency incident at an underground coal mine, MERITS could be adapted for other types of mining operations, including underground metal/nonmetal and surface mines, as well as a variety of different types of emergency scenarios. While MERITS is no longer a funded research initiative under NIOSH, the authors hope other interested parties will build upon work already completed to further develop MERITS.

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