

A Study of First Moments in Underground Mine Emergency Response*

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Abstract

Researchers at the National Institute for Occupational Safety and Health (NIOSH) conducted seven focus groups and 10 individual interviews to gather data on what happens in the first crucial moments of a mine emergency. The goal of the project was to learn about responses on-site during the initial phases of a mine emergency to further improve response. The subjects represented underground coal and salt mines in the southern, western, mid-western, and eastern parts of the United States. They included on-site responders, mine rescue team members, and experts in mine emergency response with extensive experience in managing mine disasters. The types of disasters the subjects experienced were diverse, including explosions, fires, and inundations (sudden floods of water or inrushes of dangerous gases). This study was unique in its focus on the first moments in an emergency response, in studying underground coal mine emergencies and in utilizing a focus group methodology. Results indicated that there were common themes in initial response, which included the importance of mine emergency planning and training, quantity and

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The authors acknowledge the dedicated miners, mine rescue teams and their trainers, medical mine rescue teams, mine safety training professionals, and mine management across the country. Thanks to Melissa Silva, HUCAU Student Intern, Pittsburgh Research Laboratory and Michael Meighen, former NIOSH employee.

quality of communication providing information for decision-making, leadership and trust, plus individual personal issues. Previous relevant studies are presented and the researchers discuss the data providing specific examples. The article concludes with recommendations to enhance initial response in the first critical moments of an emergency.

1. Introduction

An underground mine is an inherently dangerous workplace. The safety of workers depends upon many interrelated factors, including knowledge of the dynamic, ever-changing environment, the ability to recognize and respond to hazards, training, experience, and communication. During an emergency, these factors can be crucial to response. When something goes awry in an underground mine, seconds count and the initial response can be critical to the outcome. Understanding the behaviors and issues present in the initial moments of a response to a mine emergency may enhance escape, facilitate rescue, and be helpful for training miners and decision-makers. The authors define *initial response* as what happens between the time an incident is determined to be an emergency (the decisions and actions undertaken by the underground miners, surface personnel, and gathering incident command personnel) and the time the rescue or escape is well underway (the command center and response personnel are in place, rescue teams functional, and plans developing).

In the United States, mine operators, federal and state mine safety agencies, and researchers have looked at numerous aspects of mine emergency response. The most intense efforts in this area have occurred following major mine emergencies. Some of the better-known events, most of which involved multiple fatalities, have included the Farmington No. 9 mine explosion in 1968, the Scotia mine explosions in 1976, the Wilberg mine fire in 1984, the Jim Walter Resources No. 5 mine explosions in 2001, and the non-fatal Quecreek water inundation in 2002. In 2006, several major incidents occurred in underground coal mines, resulting in 19 worker fatalities within a five month period. These events included two in West Virginia -- an explosion at the Wolf Run Mining Company's Sago Mine, and a fire at the Aracoma Coal Company Inc. Alma No. 1 Mine -- and an incident in Kentucky, an explosion at the Kentucky Darby Coal Company Darby No. 1 Mine. In 2007, a massive ground failure at Crandall Canyon mine in Utah resulted in nine deaths.

These more recent incidents have raised a number of new and re-occurring issues about mine emergency preparedness and response. In the months before the 2006 incidents, researchers at NIOSH conducted a series of focus groups and individual interviews with experienced mine emergency responders. The goal of the research was to determine the behaviors and learn about the issues present in an initial mine emergency response. After the events of 2006, several of the subjects interviewed individually and several subjects in the focus groups were randomly contacted to determine if these events altered their perceptions of the first critical moments of a mine emergency. These experienced responders indicated the more recent events did not change their views.

Focus group subjects had experienced a mine emergency on-site at their mines or were members of a mine rescue team responding to an emergency. Individual interview subjects had expertise in managing mine emergencies. The types of emergencies the subjects experienced were diverse, and included explosions, fires, and inundations. The locations and commodities also varied and included underground coal and salt mines located in the eastern, central, southern and western United States.

2. Framework of Key Issues

The focus group interviews yielded a myriad of data that, in and of itself, would be an amorphous mass of unstructured information. If such data are to be useful, they must be organized into a coherent and sense-making whole. This coherency does not occur whole cloth, but emerges during the process of grouping similar data and labeling it conceptually. These concepts, or “themes,” can then be organized by their relationship to each other and formed into a framework that possesses a significant level of explanatory power (Scott, 2004: 113-126).

There were several key themes that emerged from the focus group data which dealt with the first critical moments in a mine emergency response. These themes were as follows: 1) Mine emergency planning, which subjects identified as something that impacts the first moments of a response. The better planning there is in place, the smoother the first moments are likely to unfold. 2) The key issues that arise immediately after an event occurs involve communication and information gathering. The respondents considered good communication as critical to an informed response. 3) Leadership and trust emerged as important considerations, as did 4) training. The better trained individuals are, the better able they are to cope with exigencies. Finally, there is decision making, which is impacted by whether people are at risk and by 5) individual personal issues. The decision making process defines the actions that are to be taken, and as there are further communication and information gathering, the dynamic process continues.

Once these themes were identified, it was then necessary to show their relationship to each other as the next step in sense-making. To do this, the authors developed a framework to illustrate the themes and suggest their relationship to each other. (Figure 1) There are three points to be noted about this framework. First, the framework deals with a carefully circumscribed set of phenomena – first moments in an underground mine emergency. As such, it is simpler than it might have been had it incorporated a broader range of issues. Second, the framework depicts a dynamic process that unfolds as more information becomes available during an event. Third, the framework fits with, and adds to, existing research that covers a more general depiction of emergency response. Section 3 explores related research that has a bearing on the present problem.

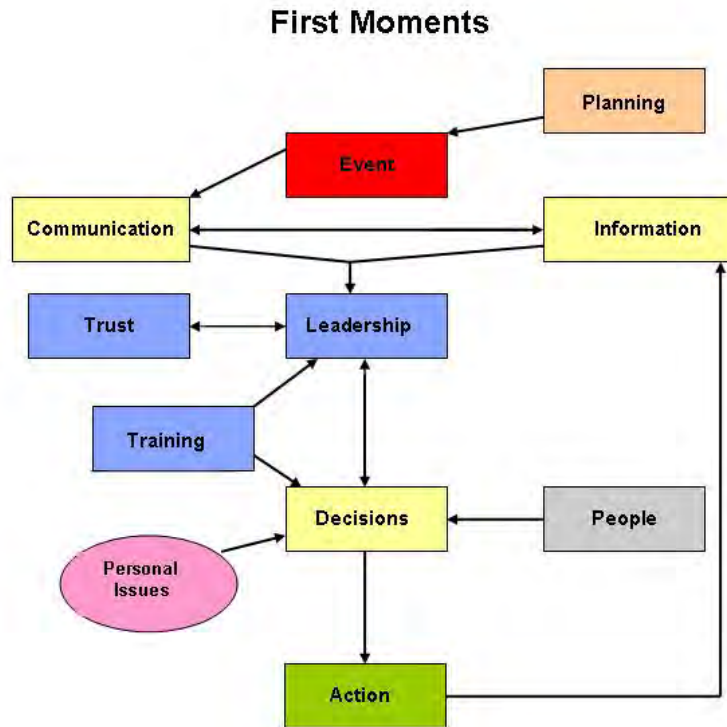


Figure 1 Framework of First Moments in Mine Emergency Escape

3. Background and Relevant Previous Studies

In the aftermath of the mining deaths of 2006 and 2007 in the United States, various commissions were convened and reports issued examining mine escape and rescue. These included a report by the National Mining Association's Mine Safety Technology and Training Commission (MST&TC) released in 2006. In addition, new federal (MINER Act, 2006; Title 30 Code of Federal Regulations, 2007; and the proposed S-MINER Act, 2007) and state legislation, along with new mine safety regulations, have passed. These sources and other previous studies may provide the reader with some context for the identified themes resulting from this study, although none directly addresses the question of what happens in the first critical moments of a mine emergency. The documents do examine important pre- and post-incident issues that can influence the first moments of response.

There are also studies on the human response to mine emergencies conducted by NIOSH researchers over the past twenty years (Cole et al, 1985;

Cole et al, 1998; Vaught et al, 2000; Vaught et al, 1997; Mallett et al, 1993, 1994, 1999; Kowalski et al, 2008).

3.1 Mine Emergency Planning

Mine emergency plans are mandated in the U.S. mining industry at the federal level. All miners should be trained to understand and follow the mine emergency plan where they work. Some companies see emergency response planning as developing a written response plan that can be pulled from the shelf and used to manage an emergency when it occurs. These organizations see having a written plan as sufficient. In actuality, a response plan is only one piece of the continual, dynamic process of emergency response planning.

Preparedness suggests a well-rehearsed, comprehensive emergency plan. A number of researchers support the notion that planning for an emergency is a process and follows a continual, dynamic cycle (Pelfrey, 2005; Perry and Lindell, 2003). Perry and Lindell illustrate the relationships of three critical components of emergency preparedness: planning, the presence of written plans, and training. Pelfrey suggests a model of preparedness that contains five broad phases including prevention, awareness, response, consequence management, and recovery. Pelfrey contends the cycle allows for a dynamic, flexible, and continuous process of interaction and integration, and functions as a self-organizing mechanism that improves preparedness for anticipated events and for the unimagined events. The research discussed here supports the concept of planning as a continual process.

Orasanu and Connolly (1993) attempted to specify what goes on when real-world decisions are made in response to written plans. They arrived at eight characteristics of real-world decision making: 1) ill-structured problems; 2) uncertain, dynamic environments; 3) shifting, ill-defined, or competing goals; 4) multiple event feedback loops; 5) time constraints; 6) high stakes; 7) multiple actors; and 8) goals of the organization balanced against the decision maker's personal choice. These characteristics dovetail into the concept of planning as a continual process with respect to the dynamic environment, the presence of time constraints and the multiple event feedback loops demanding continual evaluation.

An additional factor to consider is that people tend to initially try to normalize the situation in an emergency. They tend to interpret events as normal as long as possible before defining the situation as out of the norm and needing action (McHugh, 1968). Over-planning, or attempting to plan for every possible emergency, can be a major pitfall and may in fact result in inadequate planning. Good planning should be based on accurate knowledge of known threats.

Identifying threats and their associated risks will help establish planning process priorities. As a first critical step in emergency response planning, a thorough hazard analysis and risk assessment should be conducted (Perry and Lindell, 2003; Pelfrey, 2005). Pelfrey (2005) also surmises this will help in keeping emergency response plans simple and easy to use.

The Mine Safety Technology & Training Commission report (2006) recommends developing a comprehensive emergency response plan that is risk-based and mine specific. A risk-based plan is targeted for the most likely threats and assumes that preparing for them also prepares for unrecognized hazards. The report suggests that the competencies required for successful escape include: *technical knowledge*, *mine specific knowledge*, and *escape conceptual knowledge*. *Technical knowledge* is the understanding and proficiency in the use of emergency breathing apparatus (self-contained self-rescuers, or SCSRs), lifelines, refuge chambers, etc. *Mine specific knowledge* refers to knowledge of the mine maps, the escapeways, the ventilation system, where the SCSR cache is located, the mine emergency response plan, and familiarity with escape capsules. *Conceptual knowledge* refers to the ability to think and adapt to changing conditions, to be resilient, to be able to problem solve and make decisions, and to understand the dynamic of human behavior in escape, including leadership and other psycho-social issues.

Research conducted by NIOSH, assessing response to underground mine fires, reported on the importance of good emergency response planning (Vaught, et. al. 2004; Mallett, et al, 1994). The authors found that while there are many different kinds of situations, adequate planning and preparation for dealing with mine emergencies will ensure an effective response. Effective response, in turn, will allow mine operators to deal with the situations, protect both workers and others during response events, and return the operation to production as quickly as possible.

3.2 Communication

Communication, both the process and the content, is important in relaying accurate *information*. Information about the situation affects the initial response and defines the first moments of an incident. In addition, both technical and interpersonal communication play a central role in the first critical moments of a mine emergency response. Previous NIOSH studies indicate that the effectiveness of a mine's communication system is a key factor in the initial response. Research has suggested that effective communication will "...reduce confusion, increase confidence in decisions, stop rumors and incorrect information, and improve the likelihood of success" (Mallett, et al, 1999:3). Kowalski et al, (2003:283) noted that "emergency decision makers under stress not only have the effects of their

own stress response and its resulting consequences but the information they must base their judgments on is often unclear, faulty, and incomplete.” NIOSH researchers developed the Emergency Communication Triangle which indicates three primary and three secondary key pieces of information necessary to communicate in the event of an emergency. The primary information is *who*, *where*, and *what*; the secondary information is *miners* (people involved), *event* (what are you facing), and finally *response* (what is the response so far) (Mallett, et al., 1999).

Two communication issues related to an individual’s tendency to believe a warning and take action more quickly have been identified: the *credibility* of the source and the *content* of the message. The more credible the source, the quicker people are likely to respond. The more accurate the content, the better are the response decisions (Mallett, 1993). One undesirable effect of inaccurate or inadequate information is that it allows individuals to define their circumstances as normal, sometimes long after it is time to take action. For example, at a mine fire in western Pennsylvania, miners treated the situation as routine until presented with overwhelming evidence that the mine was, indeed, on fire. “Lack of detailed information ... enabled miners to continue acting ‘as if’ they were not in a threatening circumstance long after they should have been responding differently.” (Mallett et al.,1993:721).

3.3 Training

Many experts consider training to be one of the most essential elements in the emergency response planning process. Training, in the form of drills, mock disasters, and even tabletop simulations, affords the opportunity for planners to identify and resolve problems, examine and evaluate the utility of developed procedures, refine plans, and train individuals who will be responding to emergency events (Perry and Lindell, 2003; Ernst, 2006; Jennings and Lush, 2004; Smith et al 2001). Training and drills also allow responders to come together and develop personal and working relationships with each other (Perry and Lindell, 2003). Training for mine emergency preparedness is addressed at length in the document produced by the Mine Safety Technology & Training Commission. In general, preparedness training focuses on the mine emergency plan, self-escape, and aided rescue (mine rescue). Since the present study is focused on the immediate, at-the-mine aftermath of an incident, this literature review does not address aided rescue. It is significant to note that the MST&T Commission’s priority recommendations concluded that regulatory training was not sufficient training for preparedness. The Commission stated, regarding the training required by 30 CFR Part 48, “training requirements are not sufficient to deal with the training gaps that exist in this area” (p. 88). In addition, they noted

that in the U.S. there is an over-reliance on rote learning and passive training methods such as videos. Findings from the Conduct of Simulated Emergency Exercises on emergency response capability held at Southern Colliery in Queensland, Australia supported the value of simulated exercises and self-rescue (Rowan, 1998). The key finding from the conduct of the training simulations was to validate self-escape (as opposed to aided rescue or mine rescue) as a robust and efficient strategy to enhance the survival of underground personnel. Support of self-escape includes ensuring that all underground personnel will have adequate oxygen supplies to escape along a designated escapeway. Rescue is provided for personnel unable to reach safety on their own.

The Australian report notes that objective data support what the industry has long suspected: that reactive responses through surface management and mine rescue teams, which take time to assemble, have limited impact on survival rates of underground personnel during the first few hours of an emergency. The report notes that a robust, pro-active, integrated, and well-rehearsed self-escape strategy is the single best chance for survival for those personnel. Rescue activities rarely impact the events in the first critical hours of an incident. Other studies also support the conclusion that although there will always be a requirement to have rescue teams available to respond to a mine emergency, the greatest impact on survivability is the effectiveness of the self-escape response of the workforce in the critical minutes after an incident (Brenkly, et al., 1999).

In general, miners are trained to take time to gather everyone in the first moments after a mine emergency is identified. Thus, identifying gathering locations in an underground work area is an important part of preparedness because it reduces the amount of time needed to gather personnel and begin an evacuation. Researchers have noted that the greater the time delay in response, the more problematic the response becomes. Mine industry emergency response personnel often paraphrase Don Mitchell, a U.S. expert in mine emergency response, as saying "In a mine emergency, time is not your friend."

3.4 Decision-making

Decision-making directly relates to communications issues. In an emergency, decision-making relies on 1) the quality of the information received by everyone immediately following the incident and 2) the technical communication system in place in the mine. Research has suggested real world decisions made in a mine emergency are arrived at in a context characterized by sometimes uncertain information that must be acted upon in a short time frame under stressful conditions. The process is iterative, meaning that one choice leads to another until the incident is resolved.

Decision-making is also affected by the experience level of the people involved. Many events, such as an underground mine emergency, are handled by multiple decision makers, not all of whom are experienced in reacting to such a situation. In their study of experienced fire ground commanders, Klein and Klinger (1991) note that, if the veterans were to take the time to generate a large set of options and evaluate them in order to arrive at the optimum choice, the fire could get out of control before any decisions are made. These individuals are reaching decision points as the event unfolds, and, rather than analyze each decision, the commanders rely upon their experience to help them recognize and classify each event. Klein (1989) called the strategies the commanders used to reach their classification "recognition primed decisions." The present authors suggest that this classification is fit into a sort of template, which allows the veterans to quickly arrive at a response that seems appropriate. The fire ground commanders will then imagine the option being implemented in order to discover potential problems. If the commander foresees problems, he or she might then modify the option, or reject it and go to another template.

Such template-style thinking requires an experienced decision maker (the fire ground commander or mine emergency response veteran). In emergency situations, there are many instances, especially in the first moments of an incident, when a response veteran might not be available and a novice may need to make critical choices. The question then becomes one of how he or she functions in a situation characterized by a lack of templates to guide decisions. How is the novice's decision-making different from a veteran's decision-making? Are his or her actions merely random reactions to the event, or do they have meaning and purpose?

Cohen and Freeman (1996), writing about time-stressed decision making, argue that any decision maker gives meaning to a novel or unfamiliar situation by building a "story" about what is going on. Hunter et al, (2000) note that this story building is one way to distinguish between experts and novices. In diagnosing a situation, experts are more adept at recognizing when they do not have enough information to make an adequate assessment. Novices, by implication, may take longer to come to the same recognition. Either way, however, more information must be extracted from the situation before a diagnosis can be reached. Pennington and Hastie (1993), in their study of jury members, argue that jurors extract information in bits and pieces from various sources and impose a story type structure on the process. This story construction is a strategy for understanding human action, but, as Cole (1997:331) notes, these constructed stories usually must fill in gaps by integrating facts, perceptions, intentions, actions and their consequences into coherent meaning. In the same vein, the respondents in this study used stories to make sense of their past involvement in emergencies.

3.5 Leadership/Trust

Kowalski, et al (1994) examined miners' responses during their escapes and found miners tend to respond as a group and the quality of leadership affects the group's behavior. In addition, the authors found that leadership *emerges* during an escape such that the boss is not always the escape leader. In the study, which evaluated eight separate groups escaping from three separate underground coal mine fires, six characteristics of a leader in escape from an underground fire were determined. These included: 1) incidental learning, being attentive to the environment; 2) leadership developed naturally, not coerced; 3) leaders were flexible, yet decisive; 4) leaders were open to input from others; 5) leaders provided a reassuring, calming effect for the escaping miners; and 6) leaders used a logical decision-making process.

3.6 Personal Issues

Personal issues affecting response include medical conditions, emotional state, fatigue, social support, and trust in leadership. The RAND Report, "Protecting Emergency Responders Lessons Learned from Terrorist Attacks" (Jackson et. al., 2002) found that the personal and professional bonds of the responders led to greater risk-taking during the response. This conclusion is relevant in the small mining community where everyone knows everyone. A further RAND report (Willis, 2006) found that "some PPE equipment, such as helmets and fire-protective clothing can be very heavy. Some boots and respirators may cause discomfort or increased risk of heat stress because of prolonged use. These issues can lead to rapid fatigue or distractions, placing responders at greater risk in an already hazardous work environment. "(p.9) Mine rescue team equipment fits this description.

The duration of an emergency response may create the need for additional safety activities. Responders often work extended work shifts. This can result in fatigue and affect decision-making. It was reported that responders and managers worked unsustainably long work shifts at Hurricane Andrew, the World Trade Center response, and the anthrax attacks. Command personnel and mine rescue team members have reported similar long hours over many days in response to mine disasters. (Jackson, 2004).

The traumatic nature of a major disaster can have significant effects on individuals and organizations responding to the event. The 2004 RAND study indicated that focus groups discussed a culture shift in so far as the understanding and need for traumatic incident stress information and training. Researcher also showed that support provided for families of responders could be an important component in meeting the emotional needs of responders.

4. Method

The research questions for this study were: 1) What happens in the first critical moments of an emergency response? What are the first reactions and decisions? 2) What are the key issues of importance in the first moments of the response? What is the role of communication? 3) What *should* be happening – what are the lessons learned? How can we improve initial mine emergency response?

Qualitative data were gathered through focus groups and individual interviews. To allow participants greater freedom of expression, the individuals and organizations represented are not identified. Three different experienced researchers served as scribes and the sessions were mechanically recorded. The focus groups were all facilitated by the same research psychologist, in order to provide consistency in the data collection method. Researchers developed a pre-planned discussion guide, which provided further consistency. Once the sessions were transcribed, the data were analyzed for specific patterns, key concepts, and trends.

Each focus group included different participants and was two to three hours in duration. There were seven focus groups composed of individuals who were *knowledgeable* in mine escape, experienced in mine escape, and/or who had expertise in the area. Three focus groups contained members of a mine rescue team, while four groups were comprised of on-site responders. Participants, including individual interview subjects, comprised supervisors, rank-and-file miners, industry representatives, mine rescue trainers, as well as state and federal mining agency personnel.

NIOSH researchers developed a discussion guide (Appendix A) to be used with the focus groups. The questions were open-ended in order to encourage discussion. The discussion guide was designed to target the three key areas and generate discussion and interaction among the participants, while answering the research questions. The guide consisted of these questions to provoke discussion and answer the three research questions.

- 1) What happens in the first critical moments of an emergency response? What are the first reactions and decisions? A) What were your *first reactions* after understanding that there was a real emergency? B. What were the *first decisions* made?
- 2) What are the key issues of importance in the first moments of the response? What is the role of communication? What role did *information* play in the emergency (i.e. communication)?
- 3) What *recommendations* would you suggest to improve mine emergency response? What *should* be happening – what are the lessons learned? How can we improve initial mine emergency response?

In addition, there was opportunity during the focus group sessions and the individual interviews to discuss other issues pertinent to the topic and the participants.

Researchers performed a multi-stage qualitative data analysis. Preliminary analysis allowed the researchers to identify major patterns and topic areas. Each topic area was targeted in a second analysis for validation and more in-depth understanding. A third analysis targeted specific examples of each topic and the inter-relatedness of topics. Finally, a framework was developed to illustrate the relationship between the topic areas (Figure 1). Key concepts were identified within topic areas.

Lessons learned and recommendations were the objective of the final data analysis.

It was determined that the data from the three mine rescue team focus groups provided additional and some different information than those focus groups comprised of on-site responders. Mine rescue teams respond within the first or second day of an incident as opposed to within the first critical moments. These subjects provided an important contribution to the study because of the teams' insights into the consequences of initial on-site decisions. Often, the mine rescue teams have to "live" the consequences of the initial on-site response. The topic areas that impact the initial moments of a mine emergency response, as identified by the focus groups and subject interviews included: *preparedness/planning, communication/ information, training, leadership/trust, decision-making, and personal issues*. The authors utilized these key topic areas to organize the selected literature review and to organize the data for the reader. As noted, these data were collected shortly before the events of 2006, but they include informal follow-up discussions with targeted subjects after the events of 2006 and 2007. These subjects were a sample of convenience available to researchers during the year after the events. These follow-up discussions further confirmed the results of this study.

5. Results and Observations

5.1 Planning

Every focus group or individual interviewed talked about emergency response planning and its importance in managing the initial aspects of mine emergencies and the on-going incident. The list below depicts key points made by focus groups and individuals, related to aspects of emergency response planning.

- Having a plan helped or will help in managing the emergency.
- Know your plan thoroughly.
- Every person should have a job under the plan.

- Everyone must be trained on the response plan.
- Revisit the plan constantly as the situation changes. Flexibility is important in real life emergencies.
- You must be prepared for emergencies - no matter what. It must be a priority.

Many groups and individuals emphasized that it is necessary to develop a comprehensive plan for mine emergencies. As one group noted, "It's important to be prepared before any emergency. Good structure and good procedures need to be in place." Another group acknowledged that a mine can prepare for an event but not necessarily what transpires during the event. That group felt that having a good response plan will help responders adapt to the situation. Knowing the plan thoroughly was deemed as important as having it in the first place. Knowledge of the plan can help provide an appropriate response in those first moments after a mine emergency is determined. One group said "You have to know your plan so it can be activated effectively." Another said that it is essential for people at the mine to be knowledgeable in the response plan for their operation. They suggested that the way to be knowledgeable about the plan was through training and practice.

Both focus groups and interviewees stressed the importance of training people on the mine's emergency response plan. One focus group held that people who will be responding to mine emergencies must be trained on the mine's emergency response plan with hands-on training. Another group felt that every person at the mine should be trained on the response plan. This would ensure that all players know the plan, should they be called upon to undertake a role in dealing with the emergency. Finally, two groups discussed the importance of ensuring every person has a job under the emergency response plan. They stressed this would help workers become familiar with both the plan and the roles they will assume, should an event occur.

Subjects discussed the importance of cross-training, as it is rare for all personnel to be available or present at the time of an emergency. Cross-training provides backup for filling crucial roles and an understanding of other jobs which can improve teamwork. Four focus group participants felt that having an emergency response plan either helped in managing a past emergency or would help in dealing with a future event. As one individual said, "The rescue went well due to [the mine] having a good response plan in place." In another instance, participants noted their mine had a good response plan and had adequately trained employees on the plan. The group felt this helped mine personnel focus on the need to be prepared for emergencies.

Finally, two groups talked about the importance of revisiting the emergency response plan. The first group suggested that a mine use their response

plan repeatedly. If decisions are made based on the plan and the situation changes, responders can go back to the plan and make a new decision to fit encountered changes. The second group advised that operators “reiterate the response plan” as the emergency unfolds, consulting and restudying the plan as the event continues to develop.

The overarching theme identified from study participants was that mine operators must have an emergency response plan to successfully manage emergencies that will arise and on which workers must be trained, and practice the plan before an event occurs.

Training and practice of the mine emergency plan impacts what happens in the first critical moments of a mine emergency.

5.2 Communication/Information

In general, subjects agreed that “most of the problems (in emergency response) come from communication breakdown”. Information is an important part of the first reaction to an event and most focus groups and individuals began with a discussion of information. Several focus groups and individuals argued that an initial response is only as good as the information received. Critical information must be conveyed; the information must be accurate, precise, and from a trusted source; and if possible, should come directly from the source rather than through middlemen or an information chain. Mallett, et al, (1999) identify crucial information that must be conveyed in a mine emergency.

- Who are you? (Identify yourself)
- Where is the problem?
- What happened?

Subjects in the present study identified these same topics. Besides these three pieces of information, other important information is needed to make informed decisions. One must find out details of 1) the event (how large is the fire or how much water has come in); 2) miners involved (is everyone accounted for or are any miners missing or injured); and finally 3) the response (is the fire being fought, etc.).

Many of the focus groups and individual subjects told the interviewer that their first question is generally "*What is the nature of the emergency?*" quickly followed by "*Are there people involved?*" Next, they need information to assess the safety of the scene: "*Could this happen again?*" In other words, could there be another explosion, inundation, or belt fire. In order to answer these questions, one interviewee said, “The first thing I do is gather accurate information.” Subjects reported that accurate information is critical in any emergency. One decision-maker said that he told his people he did not want to hear any information unless it was accurate. He did not want to hear “I think” or “it would

appear” or “it seems”. He wanted only correct information of which they were certain.

The source of the information is often a key consideration in the credibility of that information and can increase or decrease confidence in that information. Every focus group and interview discussed evaluating the source of information. “Who is giving you the information? Is this a trusted individual? What is your personal experience with the person? Are they a credible source? You evaluate the source based on your own experience with the individual.” One respondent posed the question, “How do you sort out and distill the information? There are rumors and confusion and you must find the most valuable person to convey what’s going on.” For example, more weight is afforded a 25-year veteran miner reporting fire and smoke than a new miner with four months' experience excitedly reporting “Fire! Smoke!”

Particularly in the early stages of an emergency, denial and chaos can increase confusion. Decision-makers indicated that they rely on trust. One decision-maker said "It becomes a matter of trust. Who do you trust? Who can you trust?" Trust was the common thread in evaluating information, and trust of the source of information was closely linked with decision-making. Those in charge of emergencies rely on the knowledge and experience of the people providing information, whether on the nature of the emergency or resources available.

There are, then, certain questions those in charge ask about the information itself: “Is the information reliable? Is it first or second-hand? Does the information make sense based on my own perceptions and knowledge of the environment?” Subjects agreed that the responder needs to be able to communicate with the information giver and ask the right questions to ferret out as much information as possible. Subjects felt that direct communication was important and that it is advisable to “cut out as many middlemen between the recipient and provider as possible. Information is changed as it is passed along. Bits and pieces get lost.”

Interviewees were unanimous in the observation that accurate, detailed information is basic to good decision-making, while too much information or conflicting information is a serious problem. Other information factors affecting the response included the context of the information, the detail or precision of information, time factors, and information about the involvement of people. Subjects reported that it was important for leaders to determine the context of information they received, and that after accuracy of information, detailed or precise information became important. The need for more precise information increases as the event progresses

Subjects indicated that the involvement of people changed the nature of the response, which became more intense if people were trapped or hurt.

Interviewees told researchers that miners and mine rescuers take more risks when people are involved. Information about injured or trapped people is, therefore, important.

Time factors are a consideration. Although quick responses are essential, acting on incorrect initial information can cause problems. One decision-maker indicated that "there is a thin slice of truth in initial information". This is especially relevant in an underground mine where, once committed to a plan of action, reversing that plan is not an easy task logistically due to the environment. One seasoned emergency decision-maker, who had led numerous emergency responses, said he would advise one critical initial action: "STOP". At a time when everyone is scurrying, his advice to stop is meant to gather accurate information. He had witnessed numerous incidents where decisions were made on initial and, oftentimes, incorrect information. Because of the logistical difficulty of correcting incorrect action deep within an underground coal mine and the further issue of possible disrupted communication, pausing the initial response to re-evaluate the emergency makes sense. Whereas, telling the local fire department to stop while managing a community emergency is not necessarily appropriate because the fire fighters and their command have more flexibility in the ability to manage and quickly adjust decisions and actions. . The rule of thumb from some of the mining experts seems to be to "make haste slowly". An underground coal mine fire is very different than a structural blaze. Workers' escape paths in a low coal seam may be such that workers cannot walk upright; workers may have miles to travel to safety; the coal itself is a fuel. Underground salt mines pose problems with inundations since the water dissolves the salt. Initial decisions in these environments are crucial.

5.3 Leadership

Leadership is a key issue in mine emergencies, for both the escaping miners and the rescue command center. The leader's first responsibility is the safety of the miners during escape or working at the site. Leadership characteristics applicable to the initial response mentioned by subjects, included the appearance of confidence and calmness, and being able and willing to make tough decisions. In addition, flexibility in leadership is important and trust in the leader impacts followers in the initial phases of an emergency.

Subjects were near unanimous in saying that a disaster cannot be managed if the primary concern is for political or economic consequences. Ideally, decisions will be made quickly, based on the leader's knowledge and on accurate information, and these can be implemented promptly. Flexibility is difficult to maintain if the command center or designated leadership is away from the scene. Subjects emphasized that operations and rescue operations should be led from on-

site and not from a headquarters located far away from the scene. Leaders need to be present and able to focus on the here and now. Subjects noted that such focus is critical for both underground and on the surface managing a disaster. Subjects noted that such focus is critical for both those underground and for those on the surface, managing a disaster.

Finally, trust and an underlying belief in the leader are critical on the surface as well as underground. Escaping miners or members of the command center team must trust that the leader can do what is necessary in response to the situation.

5.4 Training

Five focus groups and a number of individual interviewees mentioned training as affecting decision-making and every other aspect of emergency response. In general, subjects agreed that there should be training in decision-making, as well as universal training in emergency response. One subject said “Emergency response training is necessary for individual miners and additional response training is necessary for those in charge, foremen, etc.” More hands-on training should include the “why we do this” and how it will help in an emergency.

Subjects suggested that the same basics exist in all kinds of emergencies, surface and underground, and, therefore, basic, general emergency training could be valuable. One said: “It’s important to study what really happens each time. Everyone must be trained and cross-trained. People can find themselves in an unfamiliar situation, like a foreman working on a particular section for only one day. Regardless, everyone must be trained to know, in general, what to do in an emergency.” One group said “[We] need more training on things a miner needs to know and be responsible for – knowing where escapeways are and how they are marked, fire extinguisher locations and how to use them, where you are in the mine, and how to find your way out of the mine.” Hands-on training in realistic situations is the best way for miners to become prepared and confident. Working and training together enables members to get to know and trust each other. “Better and more training make the proper reactions instinctive and people are less likely to panic or mess up.”

5.5 Decision-Making

Decision-making is a critical outcome of the activities that take place in an emergency’s first moments. Many of the issues impacting decision-making have been discussed in the preceding text and depicted by the framework in Figure 1. Subjects provided a plethora of information on decision-making, and the authors

conducted a content analysis of the data from all focus groups and all individuals. Responses were categorized and tabulated.

The subjects discussed twelve identifiable factors that had an impact on decision-making. These factors were organized into five categories ranging from circumstances outside the individual (situational and organizational), to thinking (cognitive), and automatic reactions, both mental and physical (autonomic and physiological). The factors and the number of groups or individuals discussing each factor are presented here.

Factors Affecting Decision Making and Frequency of Responses

Factors	Frequency
Situational	
<ul style="list-style-type: none"> • Circumstances – The type of problem, its severity and whether there are people involved, influences decisions. 	8
Organizational	
<ul style="list-style-type: none"> • Roles – Whether one plays one’s role calmly and with confidence influences decisions. • Objectives – Conflicting agendas affect decision making. 	6 3
Cognitive	
<ul style="list-style-type: none"> • Information – The source, the relative certainty, the relative accuracy and the flow. • Communication – The source is most important. • Knowledge – Whether knowledge is gained directly or Indirectly, and whether it is adequate or inadequate. 	9 3 3
Autonomic	
<ul style="list-style-type: none"> • Training – Good training leads to good decisions. Makes decisions “instinctual.” • Instinct – When one is well-trained, “instinct” kicks in. This reduces the number of decisions that have to be made. 	5 4
Psychological	
<ul style="list-style-type: none"> • Stress – Stress leads to bad decisions. • Fatigue – One cannot make good decisions when fatigued. 	4 2

- Adrenalin – Too much adrenalin can lead to bad decisions. 2
- Fear 1

Examples of representative responses that touch on these issues follows. The circumstances discussed by the subjects ranged from chaotic to straightforward. In one chaotic instance, where there was a massive roof fall and inundation in an underground salt mine, there were people involved but the response was characterized by several key failures. First, upper management seemed overwhelmed and made little effort to coordinate the response. Second, the chain of command broke down and people were reacting by “shooting from the hip”. One subject noted the situation needed someone who was willing to make decisions because the event involved such life-or-death choices as saving the mine versus saving people. Several subjects, discussing two separate incidents (one relating to a loss of life and the other to the loss of the mine), concluded that good decisions cannot guarantee good outcomes and vice versa.

Subjects felt that "instinct" could affect emergency response and that “...situations sometimes dictate that you trust your instincts.” One subject gave the following example. “A group of firefighters worked underground in high humidity and heat; they felt exhausted. The mine manager felt they suffered heat stroke and evacuated them to the outside before they were physically compromised. Instincts can be good or bad; the adrenalin rush may tend to lead you to pursue bad instincts such as staying in a situation beyond a reasonable time with respect to the limits of your breathing device technology. The more experiences you have with emergencies, the better you get at trusting your instincts; however, you never know how the situation will turn out.”

The focus groups and individual interviewees suggested that stress may lead to bad decisions, but that is not necessarily so. Subjects noted “Stress comes from the lack of information and lack of confidence. At [our mine], we were scared. It was a stressful situation with a heightened awareness. The adrenaline was flowing and the feeling was of self-preservation for yourself and the group.” Another noted “The effect of stress is different on different people and in different situations. Are you underground and making the decisions with the disaster in your face or the authority initiating decisions from the surface? A characteristic of a good leader is the willingness to make decisions. It helps to know your reaction to stress so you are able to deal with it.”

When an incident occurs, organizational objectives change from routine production to emergency response activities (saving people, saving the mine, saving equipment). In the same vein, workers must shift from the roles they play during routine production to non-routine roles; everything from evacuee to director of the command center. People will, therefore, be making decisions in less familiar circumstances than usual. Good plans, according to one focus group,

identify who should do what. Because a plan is mine-wide, it defines roles according to one's position in the organization, not to particular persons. For example, one subject reported that he was a shift foreman at the time of a fire at his mine and was also captain of the mine rescue team. As the shift foreman, he was responsible for both evacuation of the mine and firefighting; as the captain of the mine rescue team, his role was to coordinate above ground. Initially, this was not a conflict, because evacuation of the workers was the primary objective. After the evacuation was completed, fighting the fire became the primary objective, and the subject faced a decision: the "question of staying in charge above ground or leading the team – which role do I take?" He stated that he was "very conflicted." Since all miners were evacuated, he chose to lead the firefighting team. At that point, he shifted from the role of directing the command center to directing the team in its firefighting efforts and having to deal with the command center in that role instead of a directorial role. Subjects reported other instances of role conflict as well.

5.6 Personal Issues

Subjects discussed the impact of personal issues on their behavior during an emergency. Personal issues included fear, not knowing what to expect in certain circumstances, physical fitness for escape, and concern for their families. Almost every subject noted that there was a time when he experienced paralyzing fear, that he might not make it out of the mine, that he would be injured, or that he was going to die. This fear interfered with their ability to function in the emergency. Many mentioned the importance of expectations training, such as what to expect when wearing an SCSR, or needing to understand how people react in an emergency situation, including information about traumatic stress. There was mention of the generation gaps of the miners mainly in terms of physical fitness for escape. Concern for families was universal.

6. Discussion

The research questions for this study were: 1) What happens in the first critical moments of an emergency response? What are the first reactions and decisions? 2) What are the key issues of importance in the first moments of the response? What is the role of communication? 3) What *should* be happening? What are the lessons learned? How can we improve initial mine emergency response? Results indicated that there were common themes in initial response. The key issues in the first critical moments were threefold. First, communication and information, influenced by accuracy, shaped the response. Second, decision-making based on that information and knowledge of this or similar situations influenced actions.

Finally, leadership and trust played a significant role in the first moments of a mine emergency. Background issues included preparedness/planning and training, and individual personal issues. This study was limited by the number of subjects and the nature of self report and focus groups. Researchers purposefully provided anonymity to subjects to allow them greater freedom of expression resulting in richer data.

What happens in the first critical moments of an emergency response? People tend to normalize the situation as long as possible until the facts dictate a serious problem and action is absolutely necessary. Time is critical.

What are the key issues of importance in the first moments of the response? Previous planning and training come into play immediately. The quality of, and experience with, planning and training can make a substantial difference in the initial decisions about, responses to, and outcome of a mine emergency. Adequate communication and accurate information from individuals and technical information from monitoring devices is vital. Leadership, trust in that leadership, and the ability to make decisions rapidly comes into play along with any personal issues such as fear, stress, and fatigue. Research supports self-escape as opposed to rescue as the most likely scenario for reducing fatalities. The data supports the MST&T Commission report that three areas of importance in escape include *technical knowledge, mine specific knowledge, and escape conceptual knowledge.*

What are the lessons learned? How can the mining industry improve initial response? Planning is critical and realistic training makes a difference in response. Subjects stated that their experiences show that cross-training is important. Cross-training allows for personnel substitutions and better understanding of team roles. Identifying and developing leaders for emergencies, and providing leadership with realistic emergency drills and simulations, are valuable for a timely and coordinated response. Realistic emergency escape training should be provided for all miners, including some of the training and rescue devices presently only given to mine rescue teams. Subjects indicated that training should include such topics as traumatic incident stress and SCSR expectations training.

There are three fundamental ways in which this study differs from other studies reviewed in this article. First is the subject itself. An underground coal mine is many orders of magnitude larger than a surface structure and also much more complex and dynamic with its machinery, entryways, crosscuts, air shafts, escapeways etc. Second, this study focuses on *first moments* of an emergency, and as nearly as can be done, only on that time frame. This means the authors must make sense out of what the respondents report about a time usually

characterized by chaos and uncertainty. Third is the methodology itself. By the use of focus groups the authors have obtained much richer data than is generally gotten through such techniques as questionnaires or even one-on-one interviews. The rationale behind the use of focus groups is that the combined responses of the group working together will yield more insight than will talking to subjects individually. With this in mind it is instructive to examine ways in which the focus group data, while supporting findings from other studies, adds something new to the discussion about behavior in emergencies.

Some of the more interesting findings were in the areas of communication, decision making, and leadership. Regarding communication it was found that great weight is placed on identifying the credibility of the source of the information being gathered. If the source is considered not to be credible, much time can be lost while additional information gathering is conducted. Communication also affects decision making. There are two factors involved here: First, given the nature of the enterprise, there is a significant amount of dependence placed on technology. If the technology isn't working correctly, there can be a breakdown in the information gathering/decision making process. Second, the quality of information received has a great bearing on the outcome of a response. Also, in reference to decision making, the use of a cognitive "template" aids the decision making ability of an experienced responder, while an inexperienced person would be slowed down because of the necessity of constructing a "story" that will help him or her to integrate bits and pieces of information into coherent meaning. Finally, as regards leadership, it was suggested that leaders "emerge" and the amount of trust they garner as the emergency goes on has much to do with their success. In addition, it was found that how effectively and calmly one plays the leadership role has a great bearing on the response outcome. All-in-all, the present research yielded many insights that contribute to our understanding of what happens at the start of an emergency.

7. Conclusions and Recommendations

NIOSH researchers conducted seven focus groups and ten individual interviews to gather data on what happens in the first crucial moments of a mine emergency.

The authors' conclusions and recommendations from the study are focused on four key areas.

1. *Preparation and Planning* are crucial to successful emergency response. Good planning is based on risk assessment, and assessment of hazards is the first step. Preparations must be a continuous, dynamic cycle. Knowledge of the response plan must be required learning for all miners, and realistic practice and plan re-evaluation must be a part of preparation.

Previous researchers (Pelfry 2005, Perry and Lindell, 2003) support the dynamic cycle of emergency planning and response. Mine emergency plans must be mine specific (supported by MST&TC 2006).

2. *Communication and information* are critical. Even with a good plan, escapees and responders cannot respond adequately without accurate and timely information. The authors recommend mine trainers teach the NIOSH Communication Triangle (Mallett, et al., 1999), which provides an empirically based sequence of information for accurate communication. Although this study was not focused on technology, researchers recommend investing in and remaining current in communication technology.
3. *Leadership and Trust* are key issues often not taken into consideration in planning and training for a mine emergency. Research is available on issues of leadership in escape, command center leadership, and on building trust. Leadership is most effective when on-the-scene.
4. The authors recommend providing mine management and miners with the information in these areas to integrate into planning and training.
5. *Training* is one of the most essential elements of a coordinated and timely mine emergency response, according to our subjects. The authors agree and suggest that the industry should
 - a. Employ realistic training
 - b. Train everyone, not just rescue teams. Everyone should have a role in mine emergency response.
 - c. Include cross-training to provide better role interface and substitution of roles when necessary.
 - d. Focus on miners in the training for mine emergency, not just on technical solutions.
 - e. Teach decision-making.
 - f. Standardize communication, both technology and protocols.
 - g. Teach miners about stress responses in an emergency to help them normalize their responses in an emergency situation.
 - h. Include SCSR expectations training.

Understanding the factors important in the initial response to a mine emergency can provide direction for future mine emergency planning, response, and training. Evaluating past outcomes with respect to these key topic areas can help improve initial response in areas including planning, communication, leadership, training, and decision-making. Miners can develop a better

understanding of appropriate actions that can translate into quicker response and positive outcomes. Mine operators can learn what they need to address in their emergency planning to incorporate successful strategies and to improve response behaviors and communication.

Appendix A

Discussion/Interview Guide

Mine Emergency Response: Focus on Initial Response and Communication

Introduction: *Thank you for volunteering to participate in this research focus group. The information you share with us will be used to understand key issues in the first critical moments of a mine emergency. You are the experts in mine emergency response and we are looking to learn from your experiences. We are not concentrated on one event or doing a case study of one event. We are interested in your expertise in mine emergency response. (Focus group leader introduces self and the recorder to the group.) We will be taking notes, as what you have to say is very important to us. It is important that you understand that you will not be identified individually or through any organizational affiliation. Your responses are anonymous. This exchange of information is confidential and we ask all participants to respect that confidentiality. Do you have any questions?*

Our Research Questions include: **1. What happens in the first critical moments of an emergency response? 2. What *should* be happening? 3. How can we improve initial mine emergency response?**

1. First Reaction

What is the first reaction when an alarm or a warning is given and affirmed to be critical?

How have you reacted after receiving the initial warning of a problem?

What factors influenced how you reacted?

How have others reacted after the initial warning was received?

How near were you to the problem? Were you given instructions? By whom?

Research on initial response to a disaster indicates that most people do not panic, but fall into their normal roles. Has your experience supported this? How?

2. First Decisions – What are some of the first decisions that must be made after the initial warning is given and how are these decisions made?

Do you try to learn more about the event before initially responding?

What do you want to know before initially responding?

Did you seek information from others in your group, a supervisor?

How does stress play into decision-making and initial response?

Did you ever trust your own instincts in determining how to respond?

What are the first five (?) initial steps taken when responding after the initial warning has been received?

Do these steps vary by the type of event or are there steps which are common to all events?

What kind of underlying problems i.e. information uncertainty, knowledge of the mine, etc. made it difficult for you to make initial decisions?

What did you observe in people responding under the stress of an emergency?

What positive behavior/characteristics did you observe? Negative behavior/characteristics?

3. Information is critical to making good decisions in the initial stages of a mine emergency.

Do you evaluate the source of information you received?

How do you evaluate the source?

Is the source a reliable source?

What kinds of criteria do you use to evaluate the information source?

How do you evaluate the content of the information?

What kinds of questions do you ask when finding out about the problem?

How do you sort through all of the initial information and distill it down?

What information do you need to make quality decisions in the first moments of a mine emergency?

4. Recommendations - Improving emergency communications can help ensure a successful response.

What recommendations would you suggest to improve emergency communications?

What would you teach mine personnel to help them improve emergency communications?

Would the content of what you teach differ among miners, supervisors, and communications personnel (the person outside)? If so, how would it differ?

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