

**From:** Maochen Ge [mug10@psu.edu]  
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The comments provided here are the response to the request for information by MSHA on Underground Mine Rescue Equipment and Technology (RIN 1219-AB44)

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Comments on  
*Underground mine rescue equipment and technology (RIN 1219-AB44)*

Maochen Ge  
The Pennsylvania State University, State College, PA 16802  
Email: [mug10@psu.edu](mailto:mug10@psu.edu) Tel. (814) 865 5861 Fax (814) 865 3248

**Summary of the comments**

The comments provided here are related to the following key issues: *A. Rapid Deploy Systems, E. Communications, and J. Government Role.*

The focus of the comments is the microseismic monitoring technique for locating trapped miners. The proposed technique serves mine rescue for two vital purposes. First, it is a miners communication system in that it listens the roof-tapping signals sent by trapped miners. The second function is to provide the rescue command center the location information of the trapped miners.

The summary consists of six sections:

1. *Executive summary*
2. *Importance of location information: lessons learned from three recent rescue operations*
3. *Why conventional wireless techniques are difficult for underground mines?*
4. *Potential pitfalls of unconventional wireless techniques*
5. *Advantages of the microseismic technique*
6. *Future work on microseismic based trapped miner location technique*

**1. Executive summary**

The three recent high profile rescue operations at the Quecreek Mine, the Sago Mine and Alma No.1 mine have all shown that the ability of acquiring the location information of the trapped miners holds the key for success. These operations have also shown that the mining industry is lack of reliable techniques for this purpose and the priority should be given for developing the related techniques.

The conventional wireless techniques, such as cell phone and GPS, which appear to be the natural choice at the first glance, are inherently difficult for underground applications. With the operation frequencies used by these techniques, their signals are not capable of penetrating the earth material.

The unconventional wireless techniques, generally speaking, have to use underground tunnels and openings as their signal passages. Wireless signals are transmitted through a relay system or network. A potentially fatal problem for these unconventional wireless techniques is that the required passages (tunnels and openings) are likely being damaged or blocked at the sense during the disaster, such as explosion, flooding, rockburst and roof fall. A good example to illustrate this concern is the Quecreek incidence in 2002. If a non-conventional wireless technique which needs relay stations had been used at the time, the signals from the trapped miners would not have been able to go out because 1) the airways were blocked by water, and 2) many relay stations would have been submerged and damaged.

The technique that exhibits the best potential to become the primary means for locating trapped miners is the microseismic technique. A particular advantage of this technique, which makes it outstanding from the others, is its reliability for any given conditions: the system will not be disturbed by the disaster no matter how severe it is. This is because the technique uses the near surface mounted sensors to acquire the seismic signals generated by trapped miners (roof tapping). The other important advantage of the technique is that it has a relatively simple operational procedure and can be rapidly deployed. If such a system had been available during the Sago Mine incident, all trapped miners might have been saved, assuming that the system could be deployed within the first several hours and the drill hole could be completed within the next several hours.

In addition to its technical advantages, the potential of the technique is also due to the fact that the feasibility to develop it into a practical industrial tool was already demonstrated by extensive studies carried out in the 1970s and early 1980s. Two fundamental aspects of these studies are signal detection and source location. Furthermore, the microseismic technique has advanced significantly during the past twenty years, which has laid a foundation for the significant enhancement of the existing microseismic based trapped miner location technique. With these considerations, the risk associated with the development of this technique is minimal.

## **2. Importance of location information: lessons learned from three recent rescue operations**

When miners are trapped underground, the knowledge of their precise location is essential for a successful rescue operation, which was demonstrated during all three recent high profile mine rescue operations: the Quecreek Mine rescue operation in 2002, the Sago Mine and Alma No.1 mine rescue operations in January 2006.

The success of the Quecreek rescue operation was largely due to the fact that the trapped location was able to be determined accurately at the beginning of the rescue operation based on the underground topography and the borehole drilling could start at the very early stage. The drill hole that was used to create an air pocket was completed within 18 hours after the incident began. In contrast, the rescue operation at the Sago Mine was much delayed due to lack of the location information. Although three boreholes were drilled at a later stage, none of them were at the right location. It is known from the notes left by the trapped miners, some of them were still conscious ten hours after the blasting. If their location had been known and the drilling had been able to start earlier, the outcome could have been very different.

In addition to borehole drilling operations, the precise location is essential and critical for planning underground operations, including choosing the rescue route, determining the potential problems along the route and preparing the corresponding solutions. Finally, the precise location is essential for efficient searching operations. For instance, during the Alma No. 1 mine rescue operation, the bodies of two trapped miners were found many hours later after the rescue team reached to the incident scene even though the bodies were nearby the scene. The cause of the delay was largely due to the low visibility. If their location were known, the search could be carried out much more efficiently within a well defined smaller area. From a rescue point of view, the difference of several hours may have the decisive impact on the final outcome.

### **3. Why conventional wireless techniques are difficult for underground mines?**

A question that is frequently asked is: Why do we have no problems to communicate billions miles away in space, but difficult for a mine just few hundred feet deep?

The simple answer is that the attenuation of the earth material is too high for the conventional wireless signals. As the consequence, once these conventional wireless signals hit the ground, such as cell phone and GPS signals, they are rapidly absorbed by the earth material. The difficulty to make a cell phone call from the basement of a large building is exactly due to this reason. Because of this, it is inherently difficult to use the conventional wireless methods for underground communications.

### **4. Potential pitfalls of unconventional wireless techniques**

There are several unconventional wireless techniques which may be used for the purpose of underground communication. One is to use very large surface mounted antennas (in the order of km) to send powerful low frequency signals from the surface to underground, such as the PED (Personal Emergency Device) system. The other general means is to relay the wireless signals through the relay system, such as the TAG IV system. With this system, each miner has to wear a transmitter and the signals from this transmitter are transferred by a network of relay stations.

Although each of these methods has its advantages, each also has its limitations. PED is a one-way communication system, which can send the message to the miners, but can not provide any information about the miners. Therefore, if this system is used, another location system is still needed. The TAG IV is a miner's location system. The major concern for non-conventional wireless techniques, such as TAG, is that they could be quite vulnerable when a major disaster occurs, such as explosion, flooding, rockburst, or severe roof fall, which may damage the relay system or block airways. A good example to illustrate this concern is the Quecreek incidence in 2002. If a non-conventional wireless technique, such as a relay system, had been used at the time, the signals from the trapped miners would not have been able to go out because 1) the airways were blocked by water, and 2) many relay stations would have been submerged and damaged.

### **5. Why microseismic technique?**

The microseismic technique uses surface or near surface mounted sensors to detect the signals sent by trapped miners (roof tapping) and then utilizes these signals to determine the trapped location. From a mine rescue point of view, it is both a location system and a one-way communication system from trapped miners to outside.

The research of using the microseismic technique to detect and locate trapped miners started in 1970 and carried out through the 1970s and the early 1980s. These early studies convincingly demonstrated the feasibility of the technique from two critical aspects: surface mounted sensors could detect the seismic signals generated by trapped miners and the seismic sources could be located with a reasonable accuracy.

In comparison with the other methods, the microseismic technique is relatively simple and can be deployed rapidly. The most important advantage of this system is its reliability. For miners, they do not need any additional device in order to send a signal; all they need is their own hands. During the Quecreek incidence, the trapped miners were keeping tapping the roof to signal their location for the entire trapping period. For the system, it will never be disturbed by the disaster itself no matter how severe it is. If such a system had been available during the Sago Mine incident, all trapped miners might have been saved, assuming that the system could be deployed within the first several hours and the drill hole could be completed within the next several hours.

### **6. Future work on microseismic based trapped miner location technique**

To make the microseismic technique based location system a practical and reliable means for the mine rescue operations, the major improvements on signal detection, data processing, and source location are needed. The advancement of the microseismic technique during the past two decades has shown that these improvements are not only necessary, but also entirely possible. For instance, since the later 1980s, the microseismic technique has been used extensively at those rockburst prone mines on the daily basis and has become the primary safety and ground control means for these mines. The author has intimately engaged in the development of this daily monitoring technique (Ge, M., 2005. Efficient mine microseismic monitoring. *International Journal of Coal Geology*, **64**, 44 -56) and believe that the trapped miner location system can benefit significantly from this daily monitoring technique.

## **III. Key Issues on Which Comment Is Requested by MSHA**

### **A. Rapid Deploy Systems**

1. What kinds of rapidly deployable systems could be used to locate miners who are trapped by a mine emergency?

**Answer:** When considering the choice for rapid deploy systems, there are three important criteria. The first and the most important one is the reliability. The central issue is whether the functionality of the system will be adversely affected by the mine disaster. Second, the feasibility of the technique for the mine rescue condition should have been clearly demonstrated. Third, the technique can be developed into a practical industrial tool within a reasonable time frame, say several years. A practical industrial tool implies that the technique should be relatively easy to use, can be rapidly deployed, and most importantly, has the predictable performance.

A technique which satisfies all these three criteria is the microseismic technique. The microseismic technique can be considered both a location system and a one-way

communication system originated from trapped miners. It uses the near surface mounted sensors to acquire the seismic signals generated by trapped miners (roof tapping). Because of this mechanism, the system is extremely reliable for any given conditions: it will not be disturbed by the disaster no matter how severe it is.

Second, the feasibility of this technique was already convincingly demonstrated by the studies in the 1970s and 1980s from two critical aspects: surface mounted sensors could detect the seismic signals generated by trapped miners and the seismic sources could be located with a reasonable accuracy.

Third, the microseismic technique has advanced significantly during the past twenty years, which has laid a foundation for the significant enhancement of the existing microseismic based trapped miner location technique. Therefore, the risk associated with the development of this technique is minimal.

An added advantage of this technique is that it can be utilized as a real time system for monitoring the underground conditions during the rescue operations. For instance, if the incidence is due to explosions, rockbursts, or major roof falls, the system can provide the information whether these activities have been stopped or not and the location of the activities if they are still on. This information will be extremely valuable for the successful rescue operation.

- 2. How would such a system work?

**Answer:** The microseismic technique uses surface or near surface mounted sensors to detect the signals sent by trapped miners (roof tapping) and then utilizes these signals to determine the trapped location. From a mine rescue point of view, it is both a location system and a one-way communication system from trapped miners to outside.

- 3. Is the system currently available? If not, what obstacles are there to the development and implementation of this type of system? How long would it take to develop the system?

**Answer:** The earliest microseismic system for locating trapped miners was developed in the 1970s and further improved in the later years. MSHA has such a system. There are also commercially available microseismic systems which are used for general monitoring purposes. In the author's opinion, neither the specialized system nor commercially available systems can be considered reliable for locating trapped miners. To make the microseismic technique based location system a practical and reliable means for the mine rescue operations, the major improvements on signal detection, data processing, and source location are needed. The advancement of the microseismic technique during the past two decades has shown that these improvements are not only necessary, but also entirely possible. For instance, since the later 1980s, the microseismic technique has been used extensively at those rockburst prone mines on the daily basis and has become the primary safety and ground

control means for these mines. The author has intimately engaged in the development of this daily monitoring technique (Ge, M., 2005. Efficient mine microseismic monitoring. *International Journal of Coal Geology*, **64**, 44 -56) and believes that the trapped miner location system can benefit significantly from this daily monitoring technique.

## E. Communications

- 1. What types of communication systems can be utilized in an emergency to enhance mine rescue?

**Answer:** Among many possible systems, the microseismic technique should be considered as a primary communication means for trapped miners sending out their signals.

- 3. Should a particular system be required over another? If so, which system and why?

**Answer:** Priority should give to those techniques which are not vulnerable to mine disasters, such as the microseismic technique. There are two important considerations for the technique. First, as a communication system from trapped miners, this is the system which will never break down. Second, the information provided by the system is critical for the entire rescue operations. The following is a brief discussion of the second reason based on the experiences from three recent rescue operations.

When miners are trapped underground, the knowledge of their precise location is essential for a successful rescue operation, which was demonstrated during all three recent high profile mine rescue operations: the Quecreek Mine rescue operation in 2002, the Sago Mine and Alma No.1 mine rescue operations in January 2006.

The success of the Quecreek rescue operation was largely due to the fact that the trapped location was able to be determined accurately at the beginning of the rescue operation based on the underground topography and the borehole drilling could start at the very early stage. The drill hole that was used to create an air pocket was completed within 18 hours after the incident began. In contrast, the rescue operation at the Sago Mine was much delayed due to lack of the location information. Although three boreholes were drilled at a later stage, none of them were at the right location. It is known from the notes left by the trapped miners, some of them were still conscious ten hours after the blasting. If their location had been known and the drilling had been able to start earlier, the outcome could have been very different.

In addition to borehole drilling operations, the precise location is essential and critical for planning underground operations, including choosing the rescue route, determining the potential problems along the route and preparing the corresponding solutions. Finally, the precise location is essential for efficient searching operations. For instance, during the Alma No. 1 mine rescue operation, the bodies of two trapped miners were found many hours later after the rescue team reached to the incident scene even though the bodies were nearby the scene. The cause of the delay was largely due to the low visibility. If their location were known, the search could be carried out much more efficiently within a well defined smaller area. From a rescue point of view, the difference of several hours may have the decisive impact on the final outcome.

## **J. Government Role**

- 1. What equipment and technology should be promoted to improve mine rescue?

**Answer:** The microseismic technique should be promoted to improve mine rescue. The detailed discussion has been given earlier. This conclusion is based on both the significance of the technique and its potential to succeed.

The importance of the microseismic technique has been discussed extensively earlier. The most important fact given in the earlier discussion is that the experiences from all three recent high profile rescue operations (the Quecreek Mine, the Sago Mine and Alma No.1 mine) have shown the critical importance of the location information. For instance, in the case of the Sago Mine incident, the author believes that all trapped miners might have been saved if the proposed technique had been available at the time.

The consideration of the potential to succeed is important for the techniques which allow almost no room to go wrong and have to be developed within a relatively short time period. After the Challenge incident, the author had several discussions with the NASA officials who were in charge of the development of the techniques for monitoring damages caused by space debris. The author was told by these officials that NASA was not necessarily looking for high-tech methods, rather, it was looking for the most reliable ones which may well be conventional techniques. In the earlier discussion, the author proposed three criteria to measure this potential, which are: reliability, that is, the functionality of the system will not be adversely affected by the mine disaster; feasibility of the technique for the mine rescue condition, and practicability as a reliable and convenient industrial tool.