

ground specimen from the minus 14 mesh material. XRF provides only total metal content and does not reflect bio-availability. Table 3 presents the total metals that characterize the samples.

## Conclusion

It is believed that the final outcome of the project will result in significantly improved reclamation of the BPSOU through tree growth. This will result in improved and maintained water quality in Silver Bow Creek in Butte Area One. Finally, it is projected that this can be accomplished with lower development and maintenance costs. ■

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**Table 3** – Total metals by XRF (wt %).

Sample ID	Al	Ca	Fe	K	Mg	Mn	P	Si
1	6.47	1.40	4.94	3.18	1.01	0.62	0.06	22.7
2	8.30	0.49	2.85	5.68	0.62	0.11	0.06	21.9
3	7.07	0.44	1.58	4.73	0.19	1.07	0.04	29.0
4	7.86	1.62	3.24	4.07	0.80	1.36	0.05	23.4
5	9.74	1.78	1.61	3.09	0.91	0.02	0.04	32.0

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## Mineworkers’ perceptions of mobile proximity detection systems

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To read the full text of this paper (free for SME members), see the beginning of this section for step-by-step instructions.

### Special Extended Abstract

*As manufacturers and mine operators develop and implement proximity detection systems (PDSs), they need to be mindful of the systems’ compatibility with mineworkers’ tasks, and possible unintended consequences. Researchers at the U.S. National Institute for Occupational Safety and Health (NIOSH) interviewed mineworkers at mine sites that currently use or previously have used PDSs on mobile equipment, including shuttle cars, battery haulers and scoops. Mineworkers reported that mobile PDSs affect loading, tramming, section setup, maintenance and general work on the section. Mineworkers discussed the operational effects and increased burden, exposure and risk. Mineworkers also suggested that improved system task compatibility, training, logistics and PDS performance might help address these issues. Manufacturers and mine operators implementing this or similar technologies may also consider mitigating task incompatibilities up front, performing additional site-specific usability testing and restricting the use cases of the system to improve performance.*

### Introduction

Pinning, crushing, and striking accidents are a large problem in underground coal mines, especially for mobile haulage. Between 1984 and 2014, there were 179 nonfatal and 42 fatal pinning, crushing and striking accidents involving mobile haulage vehicles, including coal hauling machines and scoops [1]. Proximity detection systems (PDSs) — automated electromagnetic systems that decelerate a vehicle to prevent a collision by detecting the presence of a miner-wearable component — have the potential to protect mineworkers in these situations. The U.S. Mine Safety and Health Administration (MSHA) estimates that the adoption of mobile PDSs could prevent approximately 70 injuries and 15 fatalities over the next 10 years [2].

As is the case with mobile PDSs, reliability and safety are often driving factors toward automation [3]. Consequently, many technologies have been developed with the intention of eliminating human error under the assumption that some

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human action can be directly substituted with automation. However, actions within a complex system are not so easily decoupled, often resulting in unanticipated problems and failures [4]. Lack of user and system knowledge in the design processes can result in task incompatibility. For example, researchers found that mineworkers testing the continuous personal dust monitor (CPDM) had difficulty sitting down while wearing the unit [5]. Because technologies are typically a part of a highly complex environment and deployed to a wide variety of users, intended actions may result in unintended consequences. For example, while remote operation of the continuous mining machine reduced operators' vibration and dust exposure by moving them away from the cutting face, it also unintentionally increased pinning, crushing, and striking accidents [6].

## Methods

Researchers conducted short interviews with mineworkers according to an approved Institutional Review Board protocol (17-PMRD-02XM) in order to identify the top usability concerns. Researchers began by recruiting mines that were early adopters of mobile PDSs. Mines were targeted based on geographic region (West, Illinois Basin and East) and PDS model (Matrix IntelliZone/Joy SmartZone, Strata HazardAvert). Researchers attempted to achieve equal representation for mines in each region and using each PDS model. Recruited mines varied in size, mobile PDS system use, and degree of implementation.

The interviews were conducted individually and lasted approximately 10 min. They included these five questions:

1. What do you like about this mobile proximity system?
2. What don't you like about this mobile proximity system?

3. How did you learn how to use the mobile proximity system?
4. Can you imagine a situation where the mobile proximity system could put you in danger?
5. What would you change about the mobile proximity system?

Following the interviews, researchers also observed a subset of the participants working on the sections equipped with mobile PDSs while performing their normal duties. In total, there were 223 participating mineworkers from seven mines.

## Results

Mineworkers indicated that mobile PDSs predominantly affected four major mining tasks (Fig. 1):

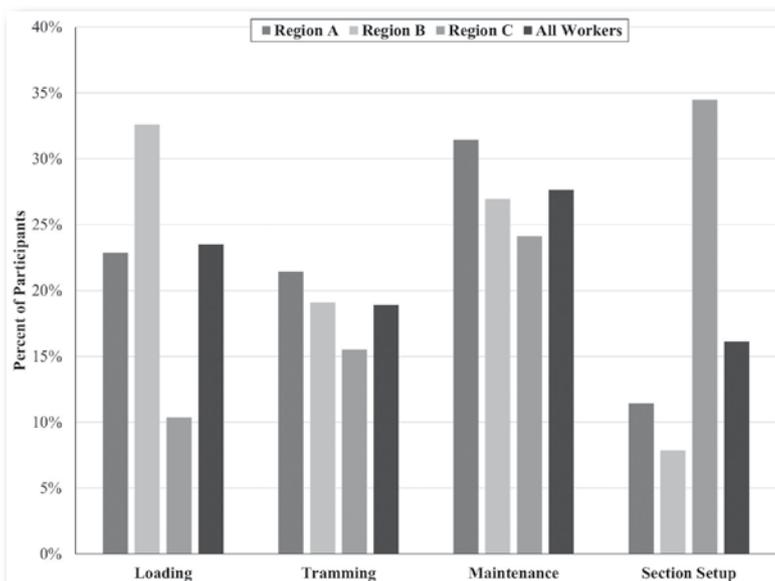
1. Loading of coal.
2. Trimming of mobile vehicles.
3. Maintenance on mobile vehicles.
4. Section setup.

However, the regional differences in the percentage of mineworkers who reported specific task compatibility issues suggest that the issues may be site-specific. Mineworkers also identified usability challenges for mobile PDSs. More than 80 percent of the mineworkers talked about how mobile PDSs generally made working in the area more difficult, regardless of task. Additionally, nearly 70 percent of mineworkers were concerned about how and when the mobile PDS takes control of the vehicles, and 30 percent of the mineworkers found some aspects of interacting with the specific systems burdensome. The usability trends were fairly consistent across mobile PDS models.

Mineworkers also discussed how mobile PDSs interfered with how they previously performed tasks, causing them to be in different locations and changing how they performed work. Related to these changes, mineworkers expressed concerns about changes in the information available, a reduction in task flexibility, and an increase in the time and resources required to complete tasks. Mineworkers also expressed concerns about how mobile PDSs could endanger mineworkers and lead to unintended consequences. Mineworkers identified situations that could lead to increased cumulative physical exposure, increased traumatic injury risk, and interference with emergency response.

## Conclusion

While proximity detection systems on mobile equipment have the potential to save lives, it is necessary to critically evaluate their implementation in order to identify incompatibility issues and unintended consequences. This study explored mineworkers' perceptions to better understand how the implementation and systems can be improved to address mineworkers' usability and safety concerns. Overall, mineworkers reported that mobile PDSs can (1) make mining tasks more difficult, (2) create additional safety concerns, and



**Fig. 1** Graph depicting percent of participants grouped by region who indicated that mobile PDS hindered or endangered mineworkers performing each of four mining tasks.

(3) increase mineworkers' exposure and risk. In order to combat these unintended consequences, mineworkers have expressed a need for:

1. Improved system-task compatibility.
2. Additional training.
3. Improved mobile PDS system logistics.
4. Improved mobile PDS performance.

The results of this research also suggest that user acceptance of mobile PDSs in the mining industry could be improved through (1) the mitigation of task incompatibilities, (2) additional site-specific usability testing, and (3) restricting the use cases of the system to improve performance. ■

### Disclaimer

The findings and conclusions in this paper are those of

the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. Mention of company names or products does not constitute endorsement by NIOSH.

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## Influence of temperature on generator current and magnetic field of a proximity detection system

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To read the full text of this paper (free for SME members), see the beginning of this section for step-by-step instructions.

### Special Extended Abstract

#### Abstract

*Electromagnetic-based proximity detection systems (PDSs) are used on mining machinery to protect workers from being pinned or struck. These systems generate magnetic fields covering the space around a machine, and a miner-wearable component (MWC) detects the field. The PDS determines the distance of miners relative to the machine based on the detected magnetic flux density in the magnetic field. This information is used to establish warning and shutdown zones around the machine. Maintaining a stable magnetic field is essential for system accuracy. However, components used to generate magnetic fields can be influenced by temperature changes. Depending on ventilation conditions and*

*seasonal alternation, a PDS can be subject to significant temperature fluctuation. To better understand and quantify this phenomenon, researchers from the U.S. National Institute for Occupational Safety and Health (NIOSH) developed an experimental apparatus to study the influence of temperature on magnetic field generator circuits used in PDSs. Results from the study show that the electric current through a generator can be influenced by both ambient and internal temperatures, modifying the magnetic field that is produced. These findings show that temperature can significantly influence the ability of PDSs used in underground coal mines to accurately determine a worker's position in relation to a mining machine. The study also presents methods to overcome the effects of*