Overview of NIOSH Research on Proximity Detection Systems for Underground Mining Equipment

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Source: http://media.web.britannica.com
Outline

• Why investigate proximity detection systems?
• Past NIOSH research and findings
• Current NIOSH research efforts
The Mine Health and Safety Administration (MSHA) is working to eliminate crushing/pinning fatalities and accidents with proximity detection

**Continuous Mining Machines – Final Rule:**

**Mobile Equipment – Proposed Rule:**
Early NIOSH Research focused on continuous mining machines

- Hazardous Area Signaling And Ranging Device (HASARD) concept proposed by NIOSH researchers in the 1990s
- Formal development started in 1998
- Patents awarded to NIOSH in 1999 (Patents 5,939,986 & 6,810,35)

Contour map of HASARD magnetic field
MSHA-approved proximity detection systems are electromagnetic based.

Ferrite-Cored Magnetic Field Generator

Increasing Magnetic Flux Density

Miner Wearable Component (MWC)

Distance from Generator ↓, Field Strength ↑
The mining industry has adopted several features developed through NIOSH research:

- Electromagnetic based systems
- Operating frequency (73 kHz)
- Location of generators and miner-wearable components
- Localization technology

![Diagram showing electromagnetic-based systems in mining](image)
Multiple magnetic field generators can be used to localize a miner’s position around a machine
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NIOSH developed system features to integrate selective shut down of hazardous machine movements

- Real-time tracking of multiple people
- Programmable, dynamic warning and shutdown zones
- Provides “intelligent” protection
- Minimizes false alarms
New technology may initially:

- Increase worker responsibilities and mental demands;
- Disrupt workers’ abilities to make safe, well-informed decisions;
- Misjudge feelings of risk, influence risky decisions, and contribute to human error.

This worker/technology research is limited in the mining industry

Research conducted by the Human Factors Branch
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Behavioral Scientist: Emily Haas (EJHaas@cdc.gov)
Mechanical Engineer: Jennica Bellanca (Jbellanca@cdc.gov)
Impact of PDS on SA & Risk Perception

1. PERCEPTION: Difficulty recognizing and troubleshooting “new” hazards
   - Where is the Shuttle Car?
   - CM Loading / Production?

2. INTERPRETATION: Relearning safety
   - How is my cutting head alignment?

3. PROJECTING: Reestablishing situation awareness
   - How are the roof & rib conditions?
Impact of PDS on SA & Risk Perception

1. **PERCEPTION:** Difficulty recognizing and troubleshooting “new” hazards

   “In general, I feel like I have less control over my environment now because I have to be aware of so much more. I can’t ensure I’m in the safest place I should or could be.” (Operator 1)

   “In general my behaviors are much better than they used to be. I am less likely to be struck now than I was before, I would say...It has shut off many times while I’ve been using it and I’ve had to move...out of a bad spot...Honestly, I was surprised when we started using this. I eventually learned to do things different. I learned what I shouldn’t be doing but was.” (Operator 4)

2. **INTERPRETATION:** Relearning safety

   “It’s shown me where I was when I shouldn’t have been. So obviously my risk is lower since I can’t stand there anymore and still be able to do my job. Before you kind of know you shouldn’t be there but now you really know and you can’t be there.” (Operator 5)

3. **PROJECTING:** Reestablishing situation awareness

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NIOSH has extensive experience testing and researching proximity detection for Continuous Mining Machine (CMMs)

- Developed evaluation protocol
- Executed multiple field tests
- Seam heights: 54” to 84”
- MWC tested at 16” and 46” heights
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NIOSH has extensive experience testing and researching proximity detection for CMMs.

Average zones - Baseline

Average Zones – Mining Mode
Current NIOSH Research on Proximity Detection Systems for Underground Mining Equipment

Jim Noll

Pittsburgh Mining Research Division

Source: http://media.web.britannica.com
NIOSH is investigating the performance of MSHA-approved proximity systems for mobile equipment

- Shorter travel distances
- Slower machine
- Pivots

- Travels longer distances
- Faster moving machine
- Travels through check curtains and around corners

Source: http://www.miningconnection.com
Source: http://www.coaleducation.org
Research is focused on developing guidelines for the implementation of PDS technology for mobile equipment

- Characterizing interferences and developing mitigation strategies
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• Characterizing interferences and developing mitigation strategies

• Identifying human factors considerations
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- Characterizing interferences and developing mitigation strategies
- Identifying human factors considerations
- Investigating performance of existing proximity detection systems
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- Characterizing interferences and developing mitigation strategies
- Identifying human factors considerations
- Investigating performance of existing proximity detection systems
- Characterizing the benefits and potential integration of alternate technologies
NIOSH is studying the environmental effects on the performance of proximity detection systems

- Identifying susceptibility of existing PDSs
- Determining interference sources
- Developing mitigation strategies
Human Factors Considerations

• Identifying scenarios where proximity detection systems hinder production and/or endanger miners
  • How might the user put themselves at risk?
  • How might the PDS put the user at risk?

• Identifying factors that affect proximity detection systems
  • Environmental concerns
  • Administrative challenges
The human factors methodology is a multi-faceted approach

- Evaluating commercially available systems
  - Meeting with manufacturers, MSHA, SMEs
  - Interviewing operators, mechanics, and supervisors

- Performing hazard analyses
  - Human reliability analysis
  - Failure modes and effects analysis

- Obtaining Miner Feedback
  - Focus groups with miners (with/without proximity experience)
  - Validate critical use cases and factors
NIOSH is applying previous experience with CMMs to test and research proximity detection for mobile equipment.
NIOSH has characterized the performance of proximity detection systems on shuttle cars and battery haulers at underground coal mines.
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Field test results show varying performance between mine locations and equipment.
NIOSH is investigating the use of alternate technologies to enable improved proximity detection performance

- Light Detection and Ranging (LiDAR)
- Radio Detection and Ranging (RADAR)
- Ultrasonic
- Radio Frequency Identification (RFID)
- Ultra High Frequency RFID (UHF)
- Computer vision + Thermal imaging cameras
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<thead>
<tr>
<th>Technology</th>
<th>Pros</th>
<th>Cons</th>
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<tbody>
<tr>
<td>Computer Vision (IR cameras)</td>
<td>• Can detect radiant heat of miners&lt;br&gt;• Computer vision algorithms can detect presence of miners within camera field of view very effectively</td>
<td>• Does not provide distance measurement&lt;br&gt;• Cannot detect through barriers</td>
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<tr>
<td>Technology</td>
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<td>Electromagnetic (EM)</td>
<td>• Accurate and reliable in the short range&lt;br&gt;• Not obstructed by barriers</td>
<td>• Short range&lt;br&gt;• Requires PAD to be worn&lt;br&gt;• Potential interference issues</td>
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<tr>
<td>Radio Frequency Identification (RFID)</td>
<td>• Accurate and reliable in the medium range&lt;br&gt;• Not obstructed by barriers</td>
<td>• Not accurate enough for short range&lt;br&gt;• Susceptible to interference&lt;br&gt;• Requires PAD to be worn</td>
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<td>Ultra High Frequency (UHF)</td>
<td>• Accurate and reliable in the long range&lt;br&gt;• Not obstructed by barriers</td>
<td>• Not accurate enough in short and medium ranges&lt;br&gt;• Requires PAD to be worn</td>
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<td>Light Detection and Ranging (LiDAR)</td>
<td>• Very accurate distance measurements&lt;br&gt;• Measure mine geometry relative to machine&lt;br&gt;• Does not require PAD to be worn</td>
<td>• Susceptible to obscurants (smoke)&lt;br&gt;• Cannot detect through brattice cloth</td>
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<tr>
<td>Radio Detection and Ranging (Radar)</td>
<td>• Reliable distance measurements&lt;br&gt;• Simple, cost effective detection units&lt;br&gt;• Does not require PAD to be worn</td>
<td>• Low data rate compared to LiDAR&lt;br&gt;• Susceptible to reflections&lt;br&gt;• Could be difficult to discern some equipment vs. personnel&lt;br&gt;• Typically cannot detect through barriers</td>
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<tr>
<td>Ultrasonic Detection</td>
<td>• Very accurate ranging measurements&lt;br&gt;• Medium range, cost effective</td>
<td>• Susceptible to sensor saturation</td>
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Summary

• Commercially available proximity detection systems are based on electromagnetic technology developed by NIOSH

• MSHA has mandated the use of proximity detection systems on continuous mining machines and have proposed a rule which would require proximity detection on mobile equipment

• Challenges for electromagnetic-based proximity detection systems include environmental interferences such as wire mesh, power cables, and electromagnetic interference

• NIOSH has extensive experience in characterizing performance of proximity detection systems on CMMs and other mobile equipment

• NIOSH is enacting a multi-faceted approach to investigate the human factors associated with the integration of PDS to underground mobile equipment

• NIOSH is examining alternate technologies to enhance current systems and enable additional protections
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