

Overview of Proximity Warning Technology and Approaches

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NIOSH - Office of Mine Safety and
Health Research

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for Mining Equipment
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Presentation Outline

- Problem
- Approaches and considerations
- Brief history of NIOSH research
- Technology overview
- Future directions
- Available standards
- Resources



What is the Problem?



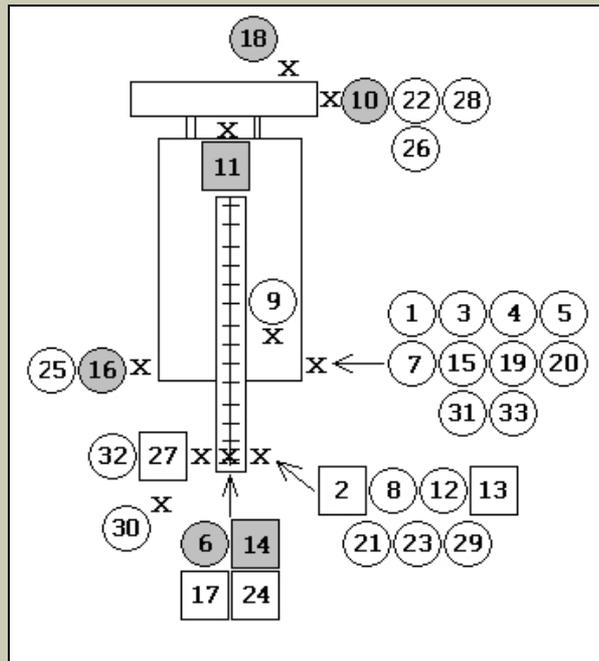
What is the Problem?



Personnel near underground coal mining equipment in confined areas:

– Continuous mining machines

- 33 pinning/crushing fatalities related to operation of CMMs (1984-present)
- Two this year involving the remote operator



○ = Operator
□ = Other worker



What is the Problem?



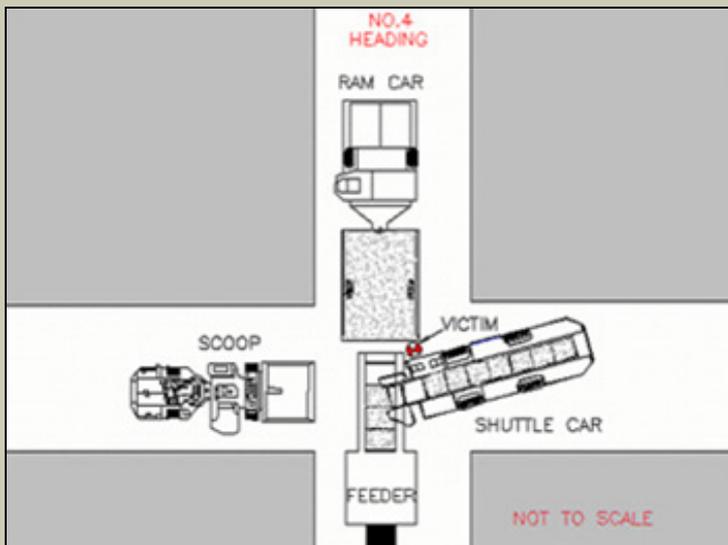
Personnel near underground mining equipment:

- Shuttle cars

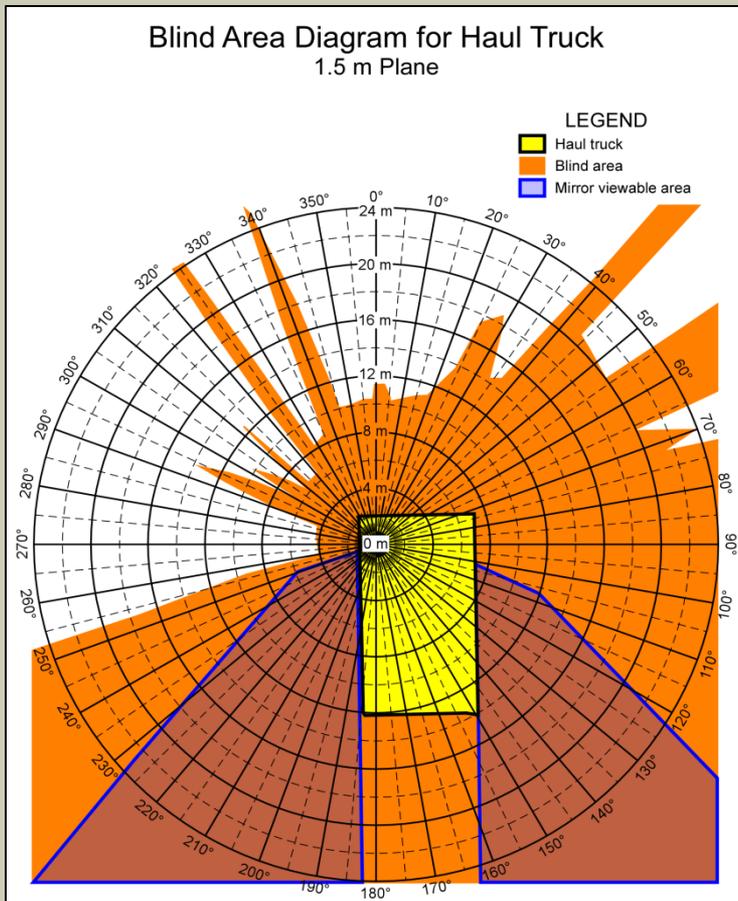
- 12 fatalities (1995-present)
- Three this year involving a CM operator, an electrician, and a foreman

- Other equipment

- Scoops
- Locomotives
- LHDs
- UG haul trucks



What is the Problem?

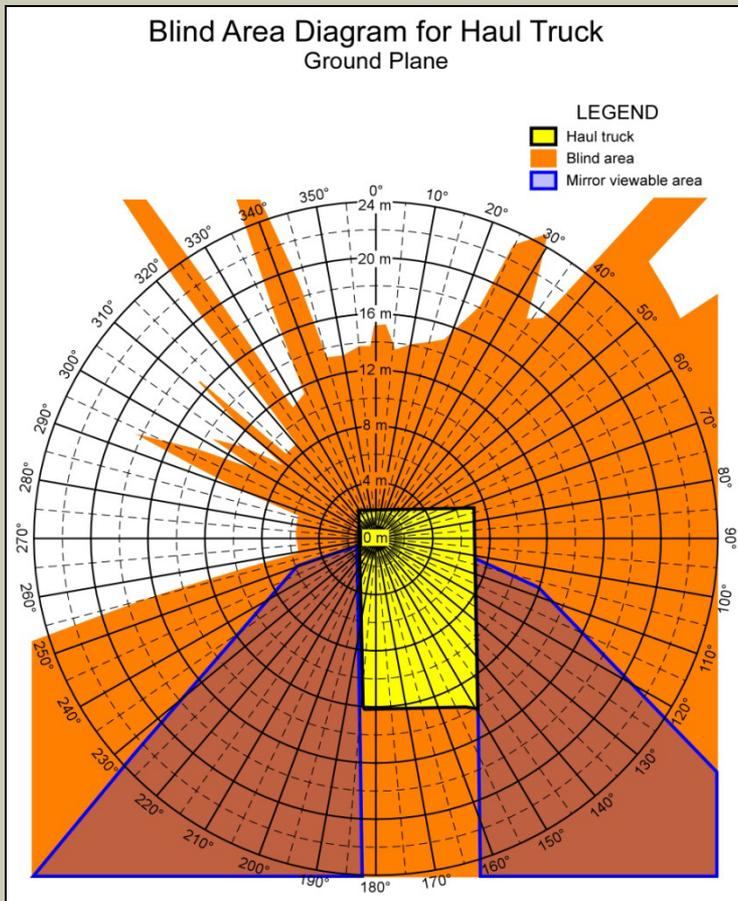


Surface mining equipment:

- Blind areas around haul trucks, front-end loaders, dozers, etc.
 - Collisions
 - Backing over an edge



What is the Problem?



Surface mining equipment:

- Blind areas around haul trucks, front-end loaders, dozers, etc.
 - Collisions
 - Backing over an edge



What is the Problem?



MSHA-2010

Surface mining equipment:

- Average of 2 fatalities per year involving collisions
- Haul trucks:
 - One fatality and one serious injury this year involving a light vehicle
- Front-end loaders:
 - Fatality in 2009 when loader backed over a delivery person



Approaches and Considerations



Terminology

- **Proximity Detection:** detection of personnel, vehicles, and other objects near a machine using some type of sensor technology
- **Proximity Warning (aka Collision Warning):** detection of personnel, vehicles, and other objects near a machine resulting in alarms
 - Warn the operator only
 - Warn the operator and nearby personnel (two-way)
- **Collision Avoidance:** the processing of sensor information resulting in control signals or actions that alter machine status/movement to avoid a collision
 - Computer control
 - Human control



Approaches to Solving the Problem

- Administrative controls:
 - Procedures for approaching or working near mobile equipment
 - High risk areas to be avoided
 - Parking, passing, etc.
 - Procedures for checking blind areas
 - Traffic control



Approaches to Solving the Problem

- Engineering Controls:
 - Visibility aids:
 - Mirrors
 - Cameras
 - Proximity detection:
 - Independent or stand-alone systems
 - Network-based systems requiring some infrastructure
 - Actions range from simple alarms to machine control (setting brakes, limiting movement, etc.)



Proximity Detection Approaches

- Independent systems (no infrastructure required):
 - Passive sensing of obstacles and personnel
 - Reflected signals
 - Non-discriminating
 - Cooperative: requires communication between machine-mounted systems and systems on obstacles/personnel
 - Obstacles/workers participate in detection
- Network-based systems:
 - Cooperative and require other infrastructure in the mine (mine-wide communications, GPS)



Collision Avoidance Approaches

- Increase situational awareness:
 - Visual, audible, tactile alarms
 - Two-way alarming
 - Human in the loop
- Machine control:
 - Processing of sensor information
 - Automatic control of machine functions
- Combination of both



Considerations

Approach to avoiding collisions or pinning against the mine wall depends on type of machine and associated risks:

- Operator onboard
- Operator adjacent to machine
- Remote control operator
- Blind areas
- Movement and speed
- Risk to nearby personnel or vehicles
- Mine environment



NIOSH/USBM Research History

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NIOSH/USBM Research History

- Research has focused on sensor-based detection and warning systems
- Underground mining equipment:
 - Focus on remote control continuous mining machines
 - In-house development of a proximity detection system based on magnetic field strength measurements
 - Commercialization through partnerships
- Surface mining equipment:
 - Focus on haul trucks and loaders
 - Assessment of available technology
 - Technology development through partnerships:
 - Radar
 - GPS-based system





NIOSH/USBM Research History

Proximity detection of personnel near a continuous mining machine:

- Hazardous Area Signaling And Ranging Device (HASARD) concept proposed by NIOSH researchers and early tests in the 1990s
- Formal development started in 1998
- NIOSH awarded patents in 1999 (Patents 5,939,986 & 6,810,35)
- Licensed by Geosteering Mining Services and Matrix Design Group
- Frederick Mining Controls HazardAvert™ and Matrix Miner Monitor MSHA approved and available in 2009
- NIOSH currently developing an intelligent proximity detection system





NIOSH/USBM Research History

Proximity warning for surface mining equipment:

- Evaluation of IR, sonar, radar, and radio tag concepts by USBM in the 1980s
- MSHA proposes rule requiring cameras and sensors to avoid collisions in 1998
- Comments indicate technology not ready and NIOSH starts proximity warning project in 2000
- Evaluation of existing technology early in project
- Modifications and new sensor development through partnerships
 - Radar, GPS, Stereovision
- Field tests in cooperation with Phelps Dodge Morenci
- Final recommendations in 2006



Available Technologies Underground Mining

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Available Technologies Underground Mining

Dominant technology is based on marker fields and two-way communications between system on machines and detectors on workers or other machines (tag-based systems):

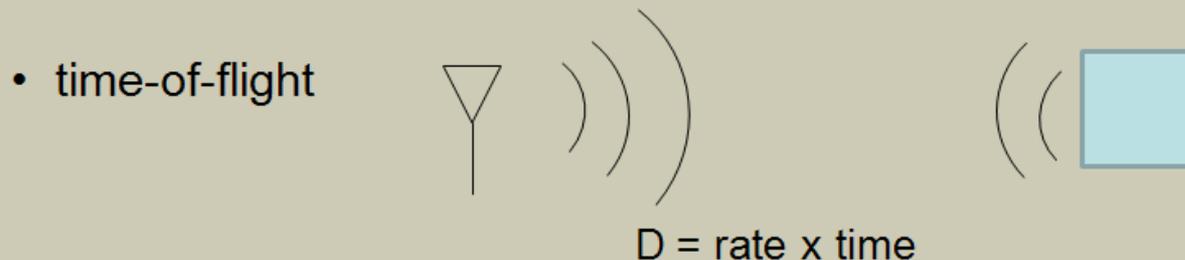
- Marker field generated to monitor hazardous zones
- Field generated by device on machine or...
- Generated by device on worker:
 - Magnetic field (VLF or LF spectrum)
 - Radio Frequency (VHF or UHF)
 - Combination



Available Technologies Underground Mining

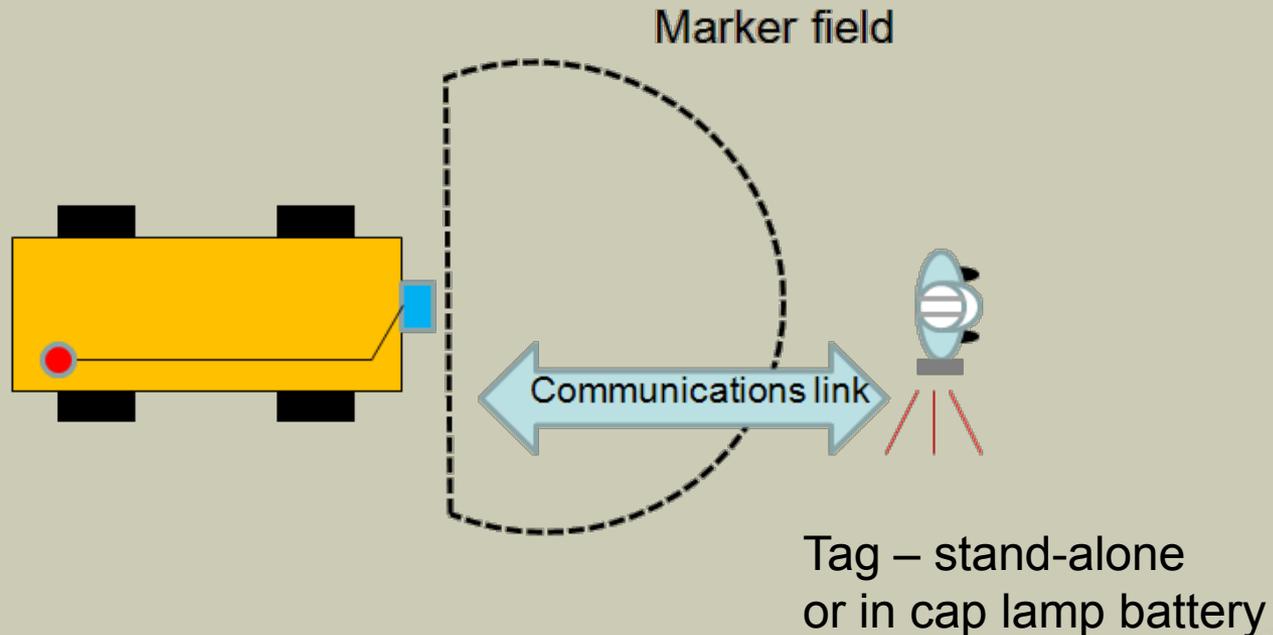
Dominant technology is based on marker fields and two-way communications (tag-based systems):

- Device on worker measures field strength and provides alarm
- Detection, distance, and ID transmitted via RF link
- Distance to tag determined by:



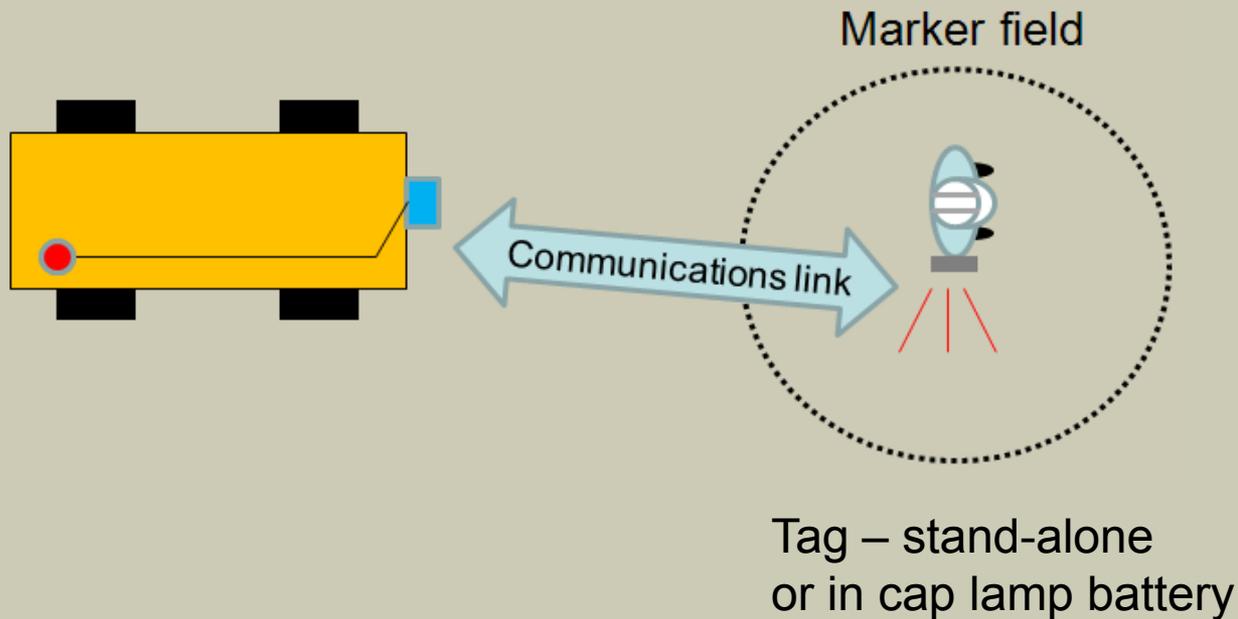
Available Technologies Underground Mining

Tag-based systems – marker field generated on machine



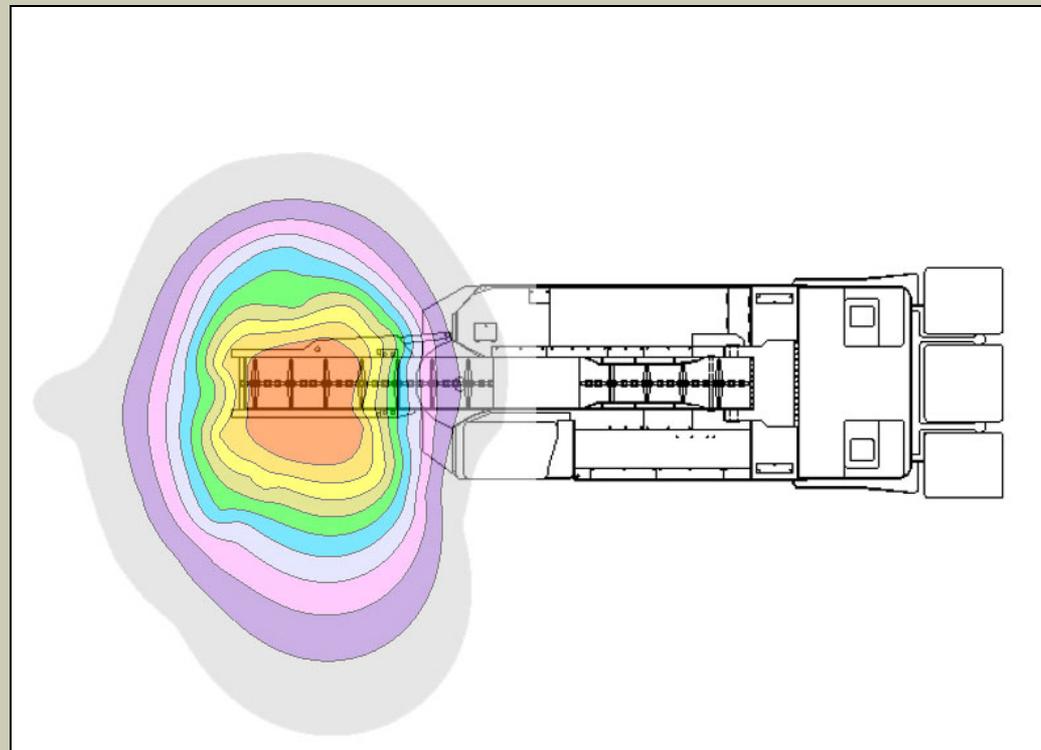
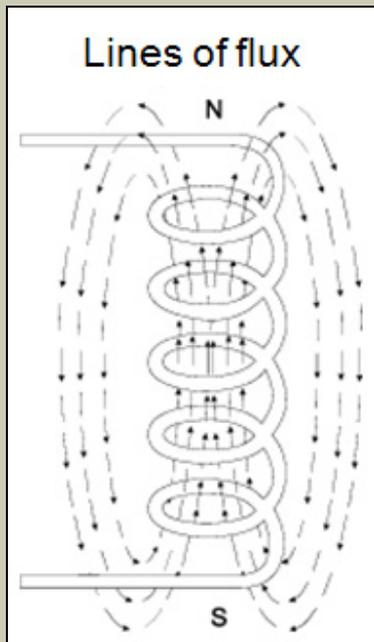
Available Technologies Underground Mining

Tag-based systems – marker field generated on worker



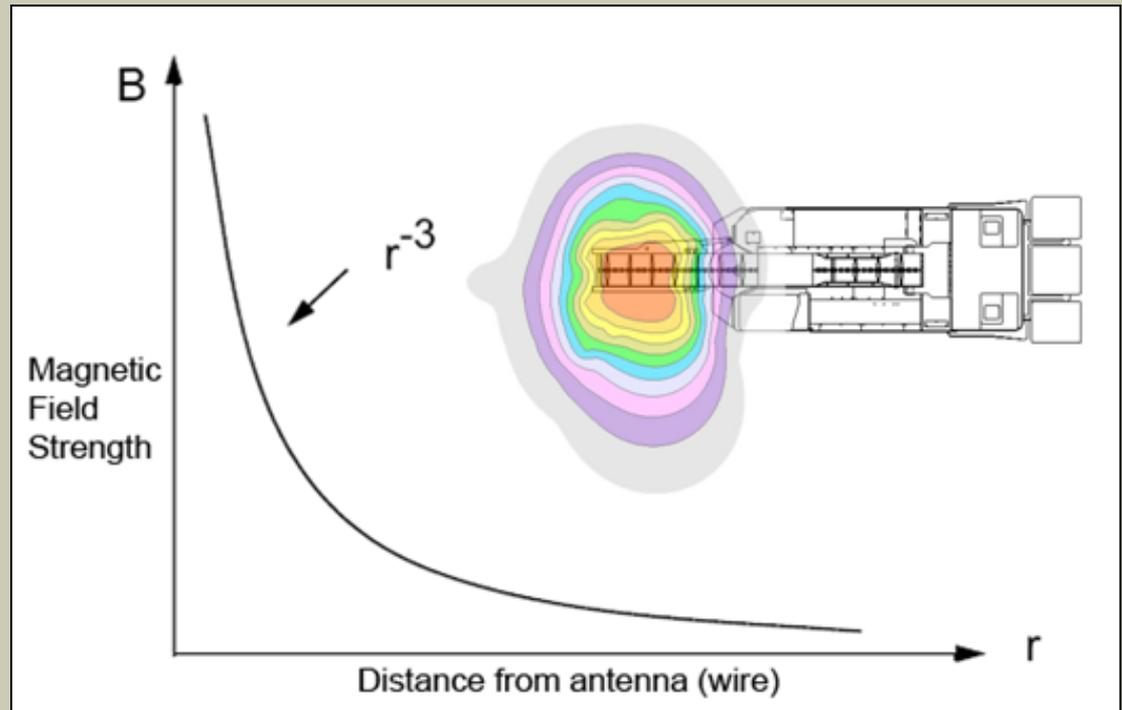
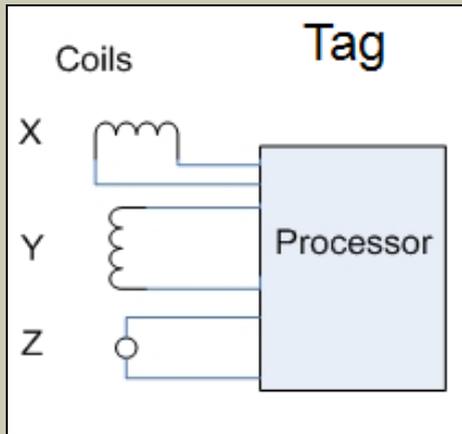
Available Technologies Underground Mining

Magnetic marker fields and distance measurements



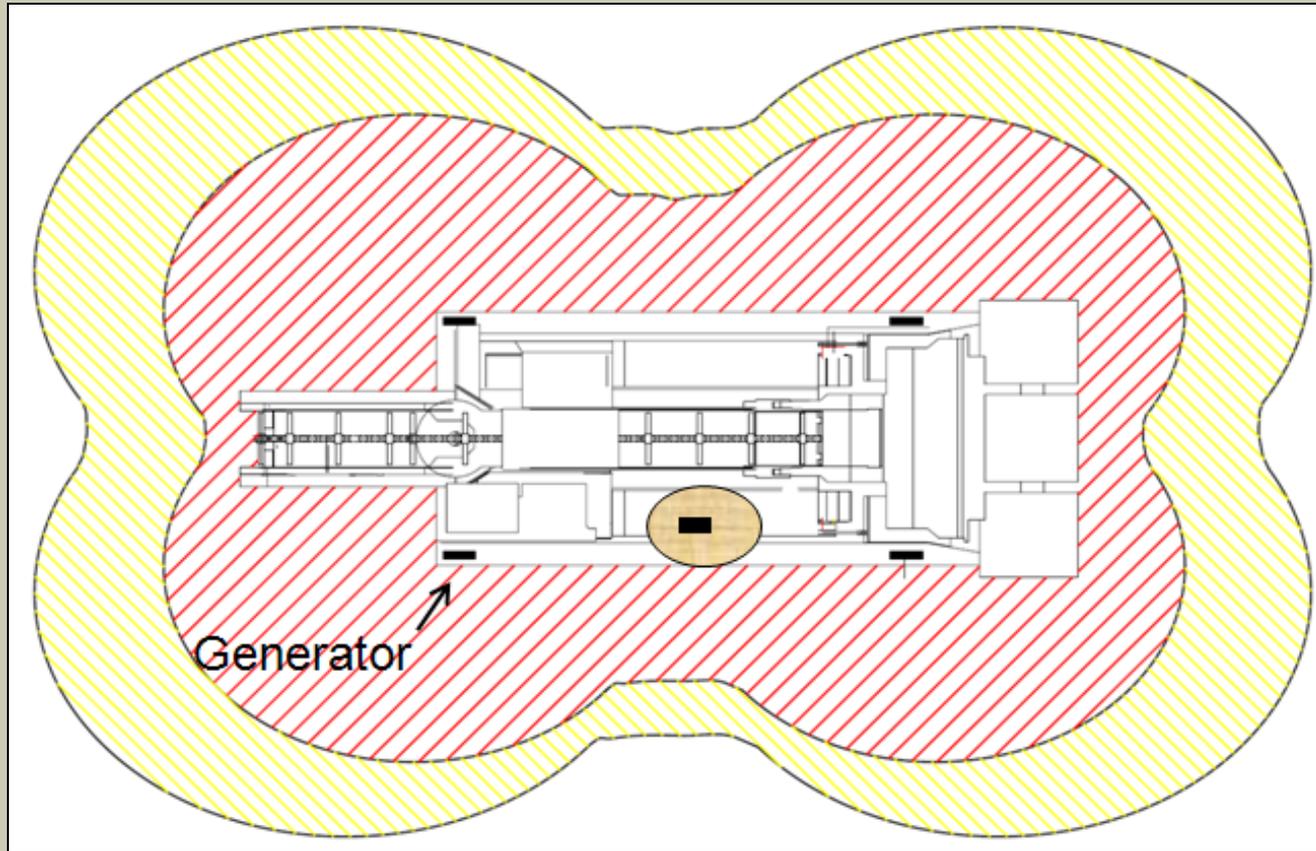
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Magnetic marker fields and distance measurements



Available Technologies Underground Mining

Magnetic marker fields



Available Technologies Underground Mining

Available technologies (in use or undergoing trials):

- Becker CAS
 - Mine Site Technologies ImPact TRACKER
 - Booyco/VAK CWS
- } RF or combination
- Frederick Mining Controls HazardAvert™
 - Matrix Miner Monitor
 - Nautilus Coal-Buddy
- } Magnetic



Available Technologies Surface Mining

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Available Technologies

Surface Mining

- Passive detection
 - Radar
- Cooperative detection
 - RF transceivers (RFID or tag-based)
 - Mesh
 - GPS-based
- Combination of sensors and cameras

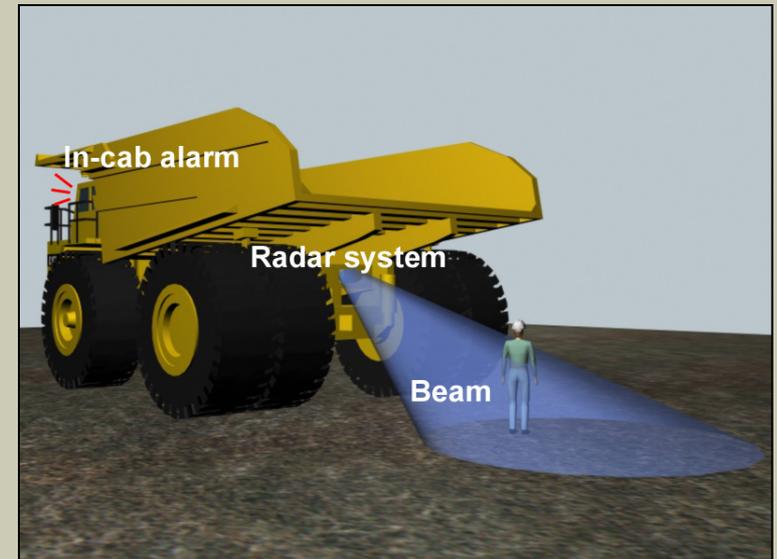


Available Technologies

Radar

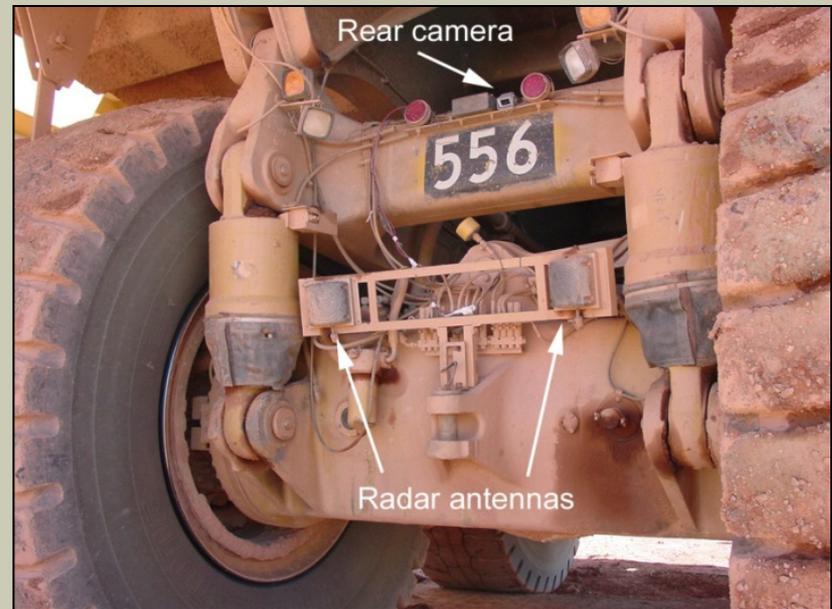
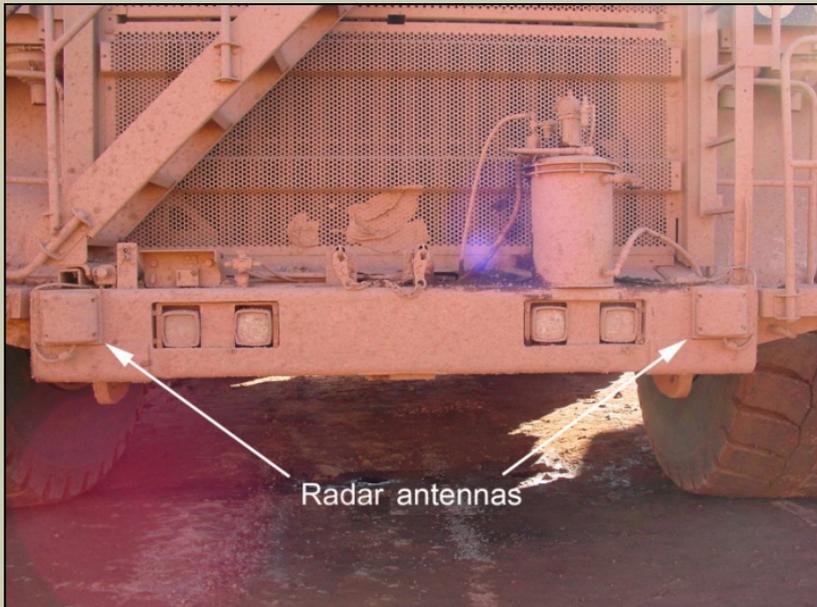
Radar-based proximity detection:

- Pulsed or continuous wave
- Multiple antennas positioned to monitor blind areas
- Display in cab provides audible and visual warnings, often with graded alarms
- Typically short range and for slow moving scenarios (25 – 75 ft)



Available Technologies

Radar



Available Technologies Radar

Available systems (in use or undergoing trials):

- Caterpillar Integrated Object Detection System
- Ogden Radar
- Preco Preview™ Radar
- Eaton Vorad EVT300

Most of these systems offer a camera option in combination with radar.



Available Technologies

Surface Mining

Radio Frequency Transceivers/Tags:

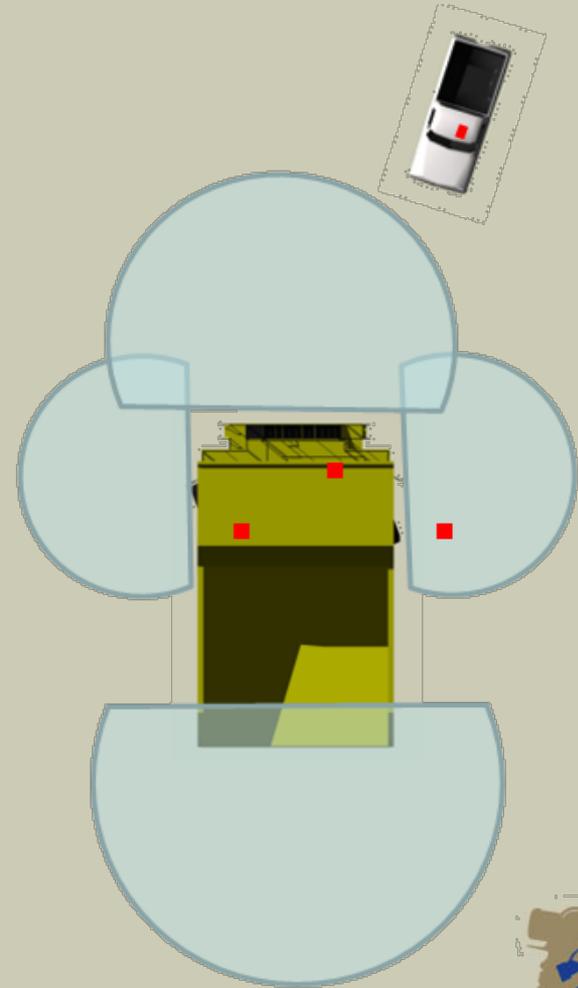
- Radio Frequency Identification (RFID)
- All heavy equipment and light vehicles are outfitted with transceivers
- UHF or VHF
- Mesh radios can also be used



Available Technologies

RFID

- Multiple RF units on heavy equipment
- Single RF unit on light vehicles
- RF tags for personnel are available
- Two-way alarms warn operator and others nearby
- Vehicle ID displayed
- Location determined by the RF unit that detects the other system (front, rear, L or R side) and shown on display
- Adjustable range
- Combined with cameras



Available Technologies

RFID

Available systems (in use or undergoing trials):

- Advanced Mining Technologies CAS-CAM/RF
 - Blue Glue CAT
 - Becker CAS
- } RFID
- Frederick Mining Controls HazardAvert™

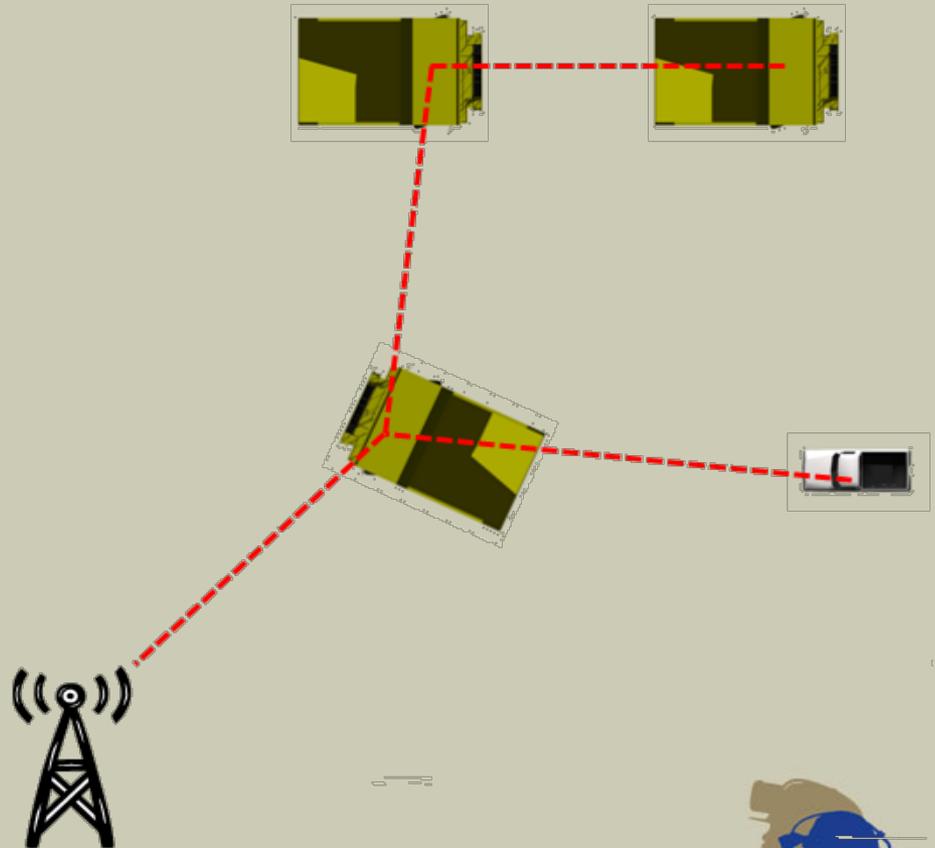


Available Technologies

Mesh Radios

Mesh-style communications and proximity detection:

- Wireless mesh networking
- Each vehicle has a mesh node or radio
- Each node acts as independent router
- Nodes interconnect dynamically and signal hops from node to node
- Signal strength of nearby nodes can indicate distance



Available Technologies

Mesh Radios

Available systems (in use or undergoing trials):

- 3D-P Proxis™ (combined with GPS)
- Acumine ACASS (combined with RFID, GPS)



Available Technologies

Surface Mining

Global Positioning System (GPS) - based proximity warning:

- Equipment/vehicle location determined using GPS
- Location broadcast to all nearby equipment
- Proximity warning alarms and location displays



NASA.gov

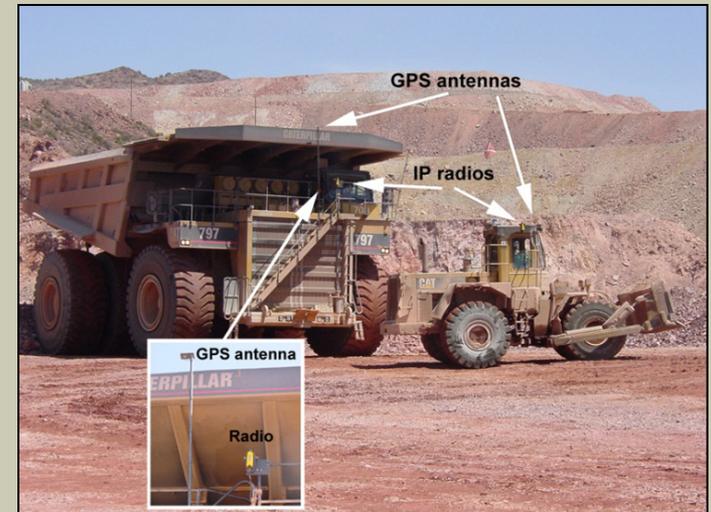


Available Technologies

GPS

Global Positioning System (GPS)-based proximity warning:

- GPS antenna, receiver, and processor on each piece of equipment and light vehicle
- Alarm display
- Radio communications to transmit locations to nearby equipment
- Database of stationary obstacles
- Exclusion zones
- Path calculations to determine potential collision



GPS-based Proximity Warning



GPS-based Proximity Warning



Available Technologies

GPS

Available GPS-based proximity warning systems (in use or undergoing trials):

- SAFEmine™
- Modular Mining RoadMap™
- Acumine ACASS (combined with RF and mesh)
- 3D-P Proxis™ (combined with mesh)



Future Directions

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New Technology

Combine miner location tracking with proximity detection in underground coal mines:

- MINER Act of 2006 requires tracking location of all underground coal miners
- Requires device to be worn or carried by each miner
- Can same device used for proximity warning also be used to track location throughout the mine?
- Reduce number of systems miner must carry



New Technology

Intelligent and accurate position tracking of CM operators:

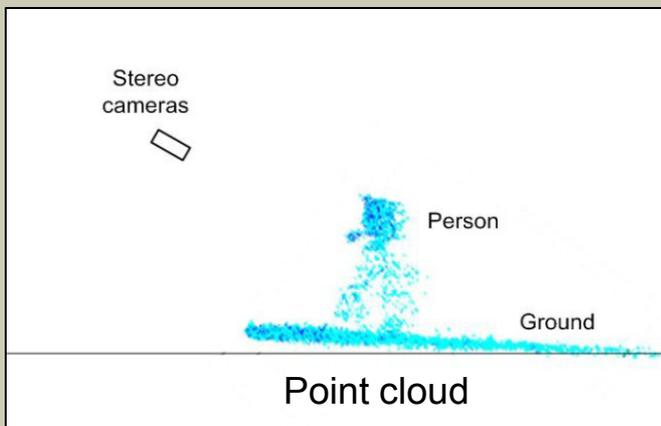
- Knowing operator location (within inches) and posture may allow operators to safely remain near the machine when required
- Reduction of false shutdowns and nuisance alarms
- Restrict specific machine motions when operator is in certain areas
- More details later



New Technology

Intelligent video systems:

- Computer-assisted stereovision cameras
- Video signal processing allows for obstacle detection based on 3-dimensional position information of objects
- Provides view of blind areas near equipment and proximity warning using only cameras
- Proof of concept by NIOSH/CSM and several others working on this
- HAZ CAM system trials on haul trucks



Future Work

Specific to CMMs:

- Accurate operator position and posture determination

In general:

- Reduce nuisance alarms and false stops
- Effective alarm presentation and context considerations
- Operator interfaces and combined displays
- Are systems overloading operators or causing distractions?
- Behavior changes in operators
- Wearable sensors appropriate for environment and tasks



Standards



Proximity Detection Standards

- Performance criteria and test procedures:
 - ISO 5006: Earth moving machinery-Operator's field of view
 - ISO 14401: Field of vision of surveillance and rear-view mirrors
 - ISO 16001: Earth moving machinery-Hazard detection systems and visual aids
 - SAE J1741: Discriminating back-up alarm system standard
- Need for underground mining and tunneling equipment standards



Resources



Resources

NIOSH Mining Proximity Detection Web Page:

<http://www.cdc.gov/niosh/mining/topics/topicpage58.htm>

- Engineering Considerations and Selection Criteria for Proximity Warning Systems
- Recommendations for Evaluating & Implementing Proximity Warning Systems on Surface Mining Equipment
- Operating Speed Assessments of Underground Mining Equipment
- NIOSH video and reports: HASARD Proximity Warning System
- Links to other sites



Disclaimer

The findings and conclusions in this presentation are those of the authors and do not necessarily represent the views of NIOSH. Mention of company names or products does not constitute endorsement by the Centers for Disease Control and Prevention.



Thank you!

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