Presentation Overview

- Background
- Goals of the Communication “Roadmap”
- Review of communications development considerations
- Proposed phased approach for mine communications partnership discussion

NOTE: The “Roadmap” is a work in progress, not a NIOSH position or recommendation
Background

- Substantial expectation for mine operators to begin implementing wireless systems
- WV statutory mandate
- Challenge is to find a way for the operators to begin installing something to improve safety without:
  - Jeopardizing operators ability to implement upcoming technology developments
  - Requiring mine operators to replace or radically modify the installation to comply with future federal regulatory guidance

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Communications “Road Map”

- Provide a systems architecture that provides maximum survivability and a framework for success for the NIOSH development efforts.
- Provide a “universal language” that can be used for future documentation and implementation guidelines.
- Provide a path to improve emergency communications capabilities in the short term, while enabling significant functionality advances
Radio Frequency & Underground Mines

- A relatively small portion of the electromagnetic spectrum works underground, even less works well
  - That spectrum should be used efficiently

- There are three different ways that radio waves travel underground
  - Through the Earth (TTE)
  - Parasitic Coupling to Metal Structures (MF)
  - Mine Entry acts as a “wave guide” (UHF)
THE ELECTROMAGNETIC SPECTRUM

Wavelength (in meters)

- 10^3
- 10^2
- 10^1
- 1
- 10^-1
- 10^-2
- 10^-3
- 10^-4
- 10^-5
- 10^-6
- 10^-7
- 10^-8
- 10^-9
- 10^-10
- 10^-11
- 10^-12

Size of a wavelength
- Soccer Field
- House
- Baseball
- This Period
- Cell
- Bacteria
- Virus
- Protein
- Water Molecule

Common name of wave
- Radio Waves
- Infrared
- Visible
- Ultraviolet
- "Hard" X Rays
- "Soft" X Rays
- Gamma Rays

Sources
- AM Radio
- FM Radio
- Microwave Oven
- Radar
- Light Bulb
- The ALS
- X-Ray Machines
- Radioactive Elements

Frequency (waves per second)
- Lower
- 10^6
- 10^7
- 10^8
- 10^9
- 10^10
- 10^11
- 10^12
- 10^13
- 10^14
- 10^15
- 10^16
- 10^17
- 10^18
- 10^19
- 10^20

Energy of one photon (electron volts)
- Lower
- 10^-9
- 10^-8
- 10^-7
- 10^-6
- 10^-5
- 10^-4
- 10^-3
- 10^-2
- 10^-1
- 1
- 10^1
- 10^2
- 10^3
- 10^4
- 10^5
- 10^6

TTE (ELF – LF)
MF "Parasitic Propagation"
VHF/UHF Mine Entry Waveguide Prop.

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Through the Earth Communications

Limitations:
- Interference Sources
- Antenna Size
- Knowledge Base
- Safety Understanding
- Bandwidth Limitations
- No Market Base
MF Parasitic Coupling and Re-radiation

Local Mine Conductor

Signal Propagating along conductor

MF Signal coupling onto local conductor

MF Signal re-radiating from conductor

Limitations:
- Knowledge Base
- Safety Understanding
- Bandwidth Limitations
- Limited Market Base

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Ultra High Frequency Systems (UHF)

- **UHF advantages:**
  - Large knowledge base and wide spread use of UHF radio for two way communications
  - Large commercial product base
  - Some MSHA approved hardware currently available.
  - Safety aspects relative to personnel and explosive devices are well understood.
  - High bandwidth for multiple voice channels and sensors, monitors, and other safety improvements
  - Large assortment of man wearable and long battery life devices can be adapted for underground use.
UHF Systems (cont.)

- **UHF Disadvantages:**
  - Most widely available commercial product for mine applications are not in the best part of the frequency band for use underground.
  - Solutions require a lot of vulnerable infrastructure inside the mine

- **Proposed methods of UHF signal distribution:**
  - UHF Leaky Feeder
  - UHF Wireless Mesh

Proposal for
Discuss
Radio Coverage considerations

• Miner Act requires “mine-wide coverage”
• Practical implementation of available systems will dictate areas with no coverage as a result of shadowing of the radio signals
• Upcoming developments will provide coverage enhancement mechanisms to allow operators to improve coverage in the longer term
UHF Leaky Feeder Cable systems increases coverage to adjacent entries.
UHF Leaky Feeder w/ Coverage Extension

Base Station

Leaky Feeder

Amplifier 1

Note: Coverage includes implementation of coverage extension approaches

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"Commercially Available" WiFi Mesh nodes at 2.4 GHz (upper UHF)
UHF “Mesh” system ‘adapted’ to underground mining geometry

Node 1

Node 2

Note: Coverage includes implementation of coverage extension approaches

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Survivability Considerations

• Miner Act Requires system to be available post disaster

• Telecommunications systems achieve survivability through design
  – Hardening of system Components
  – Redundancy – power, connectivity, and radio coverage

• Lesson learned – self healing network with true physical route diversity provides maximum survivability
Backhaul Link for Wireless Mesh

Node 1

Node 2

"Backhaul" connection to the surface (every 5 to 10 nodes)
Bi-Directional Communications Redundancy

Common Backhaul Device (CBD)

Alternate Communication Path (ACP)

Bore Hole

Mine Entry

Normal Traffic Flow

Emergency Traffic Flow

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Redundancy Challenges

• Face areas and areas beyond the last opening to the surface do not have the option of an ACP through a borehole

• Even with Bi-directional redundancy the area in the immediate vicinity of damaged nodes and amplifiers will not have radio coverage

• Medium Frequency systems can potentially provide a solution to both challenges
Bi-Directional Communications Challenge

Last Opening to the Surface

CBD

ACP

Face Area

Dual Feed Base Station Radio

Reversible Amplifiers

Base Station Radio

Normal Traffic Flow

Emergency Traffic Flow
Face Area Redundancy — Initial Capability

Medium Frequency Signal — ch. 19 converted to MF

Kenwood UHF Phone set to ch. “19”

Legend
- UHF to MF repeater set to Channel “19”
- Normal Traffic Flow (ch. 2-17)
- Emergency Traffic Flow (ch.19 Converted to Medium Frequency)

Last Opening to the Surface
Mine Wide Redundancy – Final Capability

Digital Dual Mode UHF/MF Mesh Radios

Face Area

Dual Mode UHF/MF radio

Normal Traffic Flow

Emergency Traffic Flow

Medium Frequency
Proposed Phased Approach for Discussion

- Phase 1 – Non-redundant Wireless Coverage
- Phase 2 – Bi-directional communication path redundancy
- Phase 3 – Redundant radio coverage (one of which is hardened) and coverage enhancements
Phase 1 – Leaky Feeder Implementation

Legend
- Green: Entry with Radio Coverage
- Red: Radio Coverage Hole

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No Coverage
Phase 1 – Mesh Implementation

Nodes

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Phase 2 - Face Area Redundancy

Medium Frequency Signal – ch. 19 converted to MF

Legend
- UHF to MF repeater set to Channel "19"
- Normal Traffic Flow (ch. 2-17)
- Emergency Traffic Flow (ch. 19 Converted to Medium Frequency)

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Summary

• The proposed communications “road map”
  – Provides a path to improve emergency communications capabilities in the short term, while enabling significant functionality advances over the long term
  – Will require flexibility of regulators in their current positions for the approach to be successful

• Further discussions and industry input are required to encouraged to arrive at specific recommendations

NOTE: The “Roadmap” is a work in progress, not a NIOSH position or recommendation

Proposal for Partnership
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Next Steps

• Solicit input from stakeholders on proposed phased implementation plan
• Arrive at government agreement on specific recommendations if possible
• Translate phasing plans into technical guidelines and regulatory recommendations as information becomes available