IMPROVING THE MINING WORK ENVIRONMENT THROUGH HUMAN FACTORS AND ERGONOMICS RESEARCH

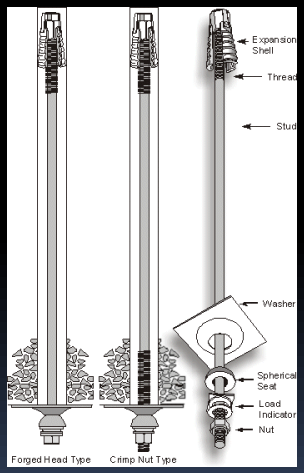
Sean Gallagher, PhD
Auburn University
Industrial and Systems Engineering

100+ years of mining research

- Bureau of Mines created in 1910
- In 1910, 3000+ fatalities
- 52 fatalities in 2008
- Despite decrease miners still 6 times more likely to die than those in general industry

Bureau of Mines Technologies

- Dust suppression through water jet sprays
- Methane control through proper mine ventilation
- Roof bolting for ground control
- Automated temporary roof supports (ATRS)



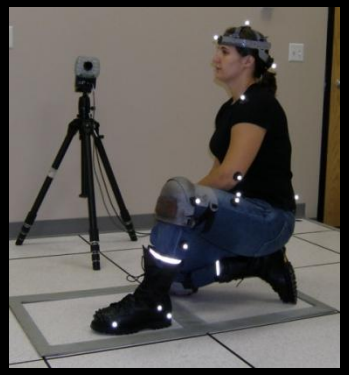
Bureau of Mines Contributions to Other Areas/Industries

- Holland Tunnel – ventilation requirements for CO
- Safer anesthetic gas handling in hospitals
- Safer fuels for aviation
- Apollo attitude control engines

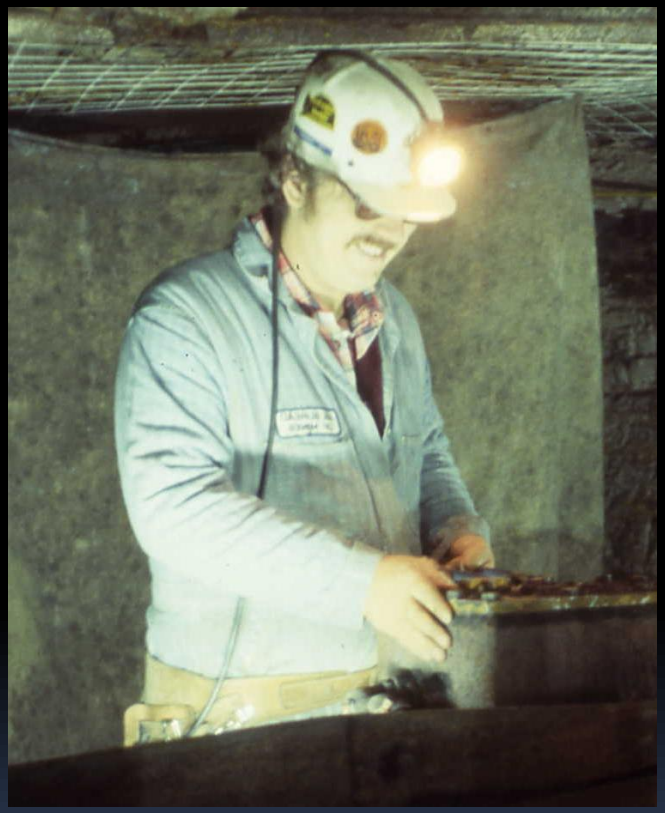
100 years of impact, but what about the future?

A look to the future

- New illumination systems
- Proximity detection
- Musculoskeletal disorder prevention
  - Novel kneepad
  - Ergo Audit tools
- Refuge chambers
- Real-time exposure monitoring



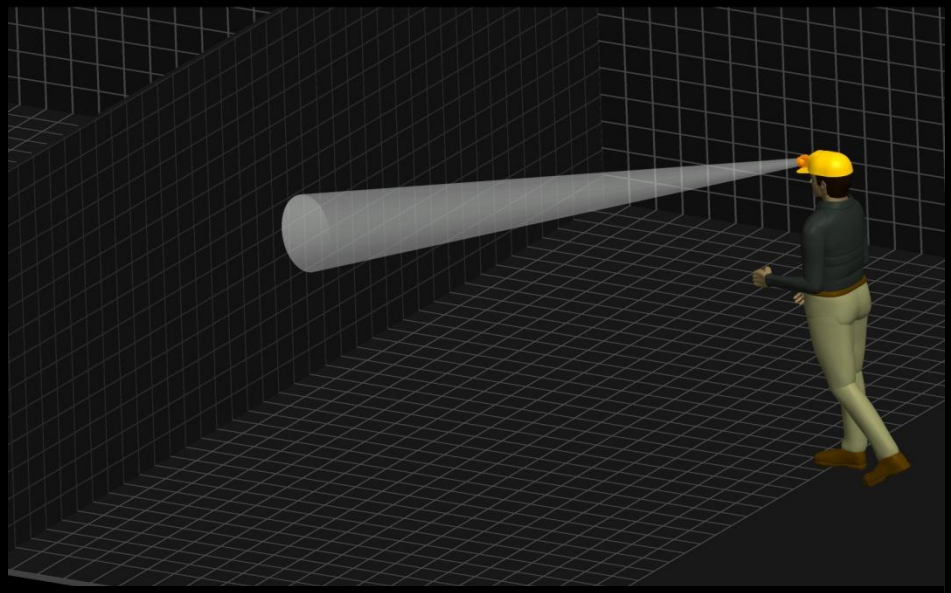
NIOSH Cap Lamp Research



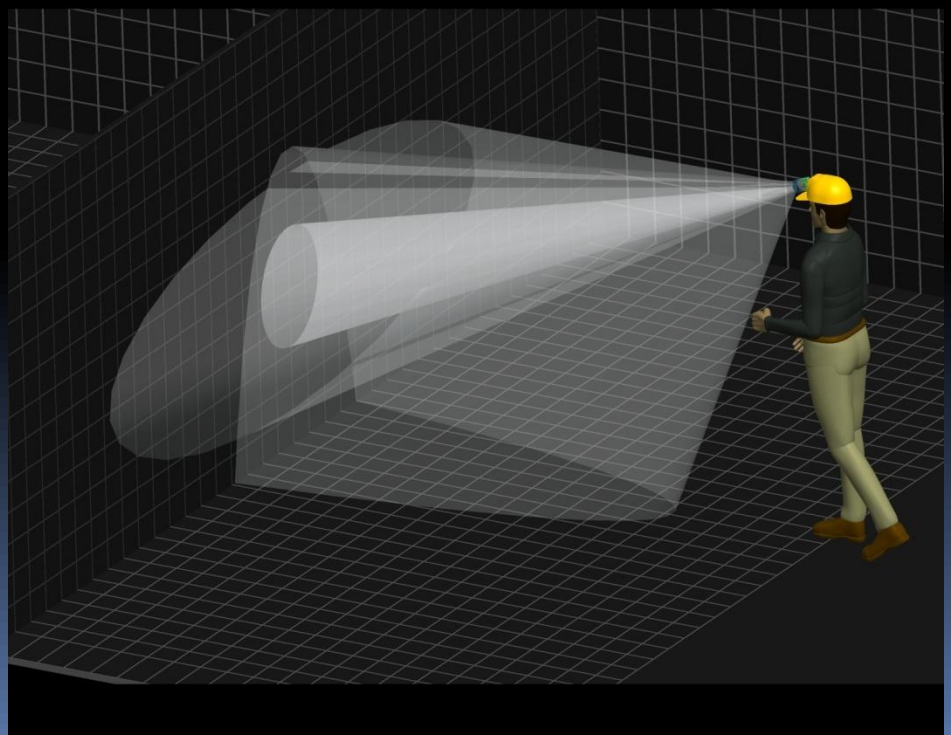
- Cap lamps are a vital component of miner's safety gear
- Industry standard is incandescent
- Heavy battery worn on miner's belt

NIOSH Prototype LED Caplamp

- In collaboration with RPI, NIOSH developed an LED cap lamp
- Greatly reduced energy demands
- Allows for lighter, more compact battery

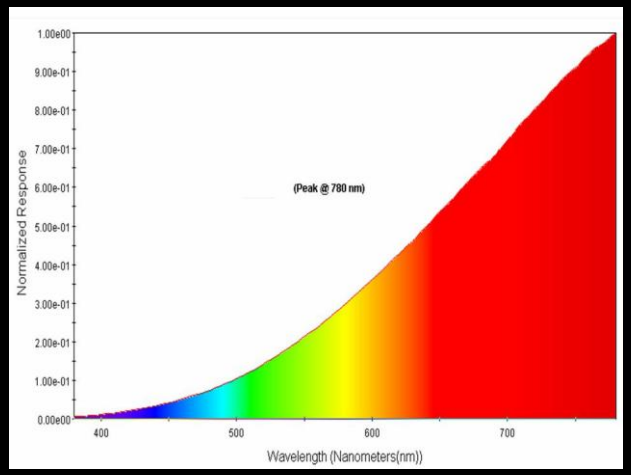


Traditional incandescent cap lamp

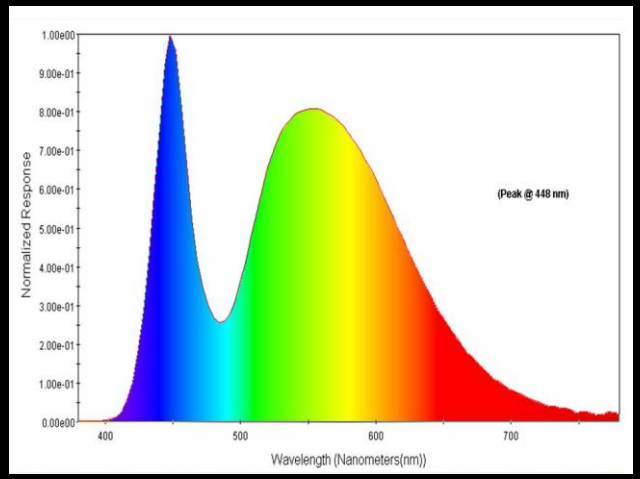


Prototype NIOSH LED cap lamp

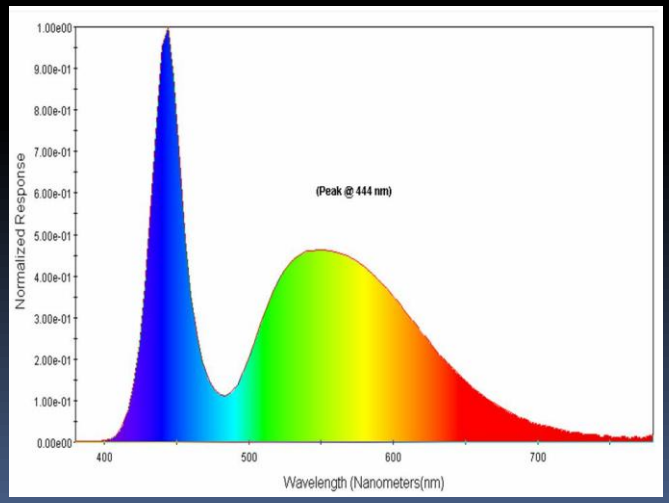
Spectral Power Densities



Incandescent Cap Lamp

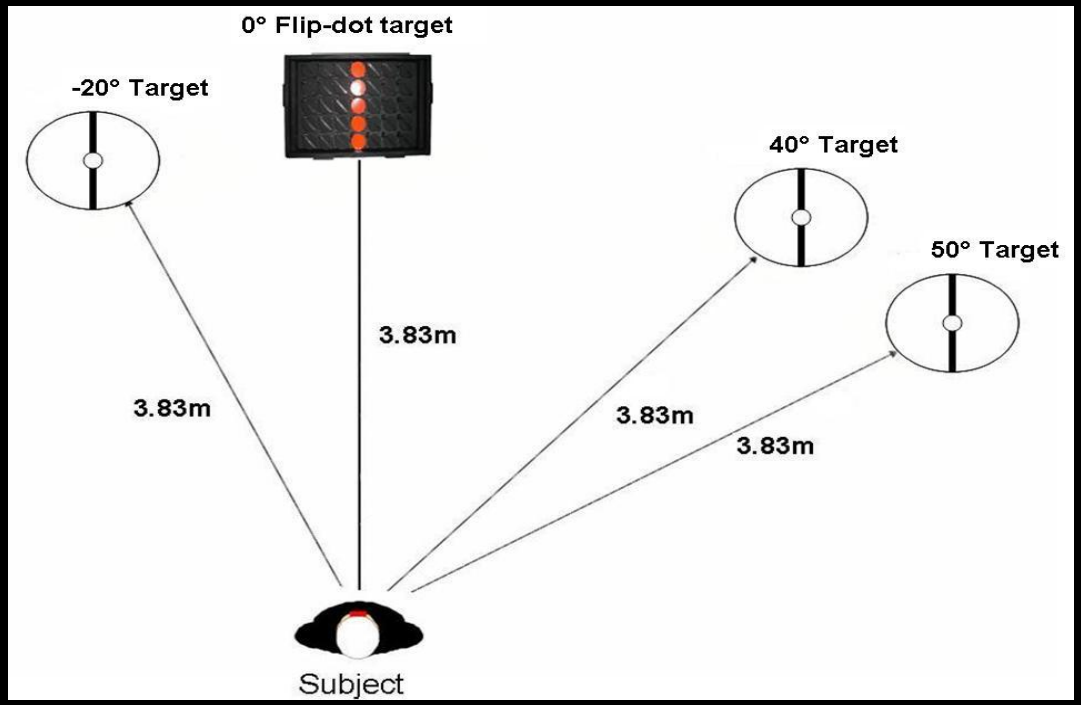


Commercial LED Cap Lamp



NIOSH LED Cap Lamp

Peripheral Motion Detection



Commercial LED	Incandescent	NIOSH LED
2.008 sec	1.951 sec	1.672 sec
A	A	B

Middle age and Older Subjects showed particular improvement!

Detecting Slip Trip Hazards

- Objects placed in pattern on floor
- Subject had to shine laser on object when identified
- NIOSH LED resulted in quickest detection times

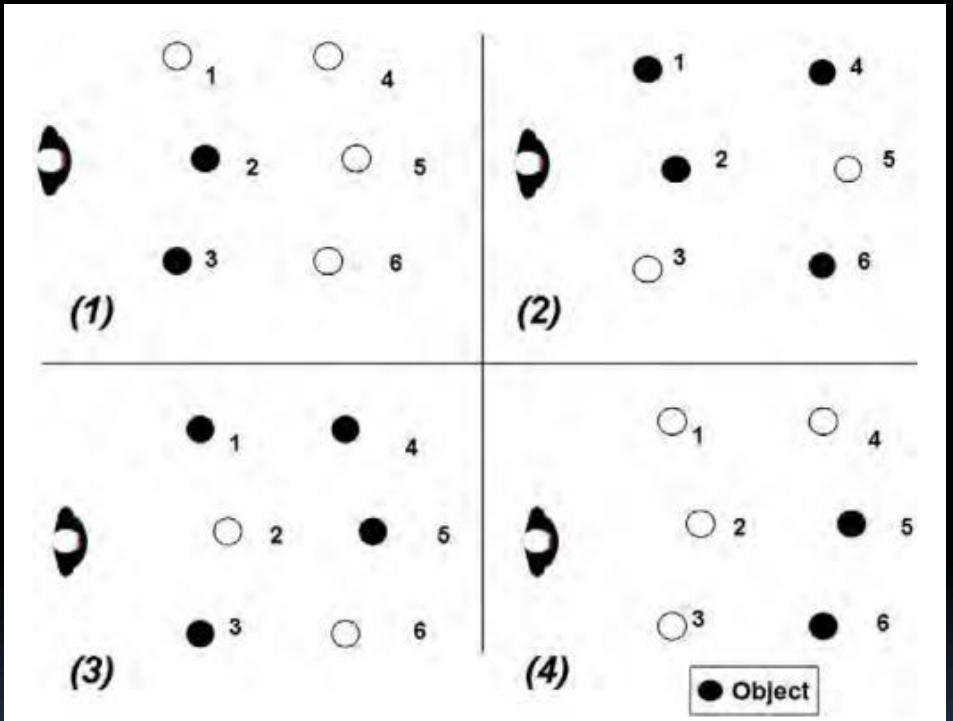


Fig. 1. The four object patterns: (1) near field; (2) mixed; (3) mixed; (4) far field.

NIOSH LED cap lamp results

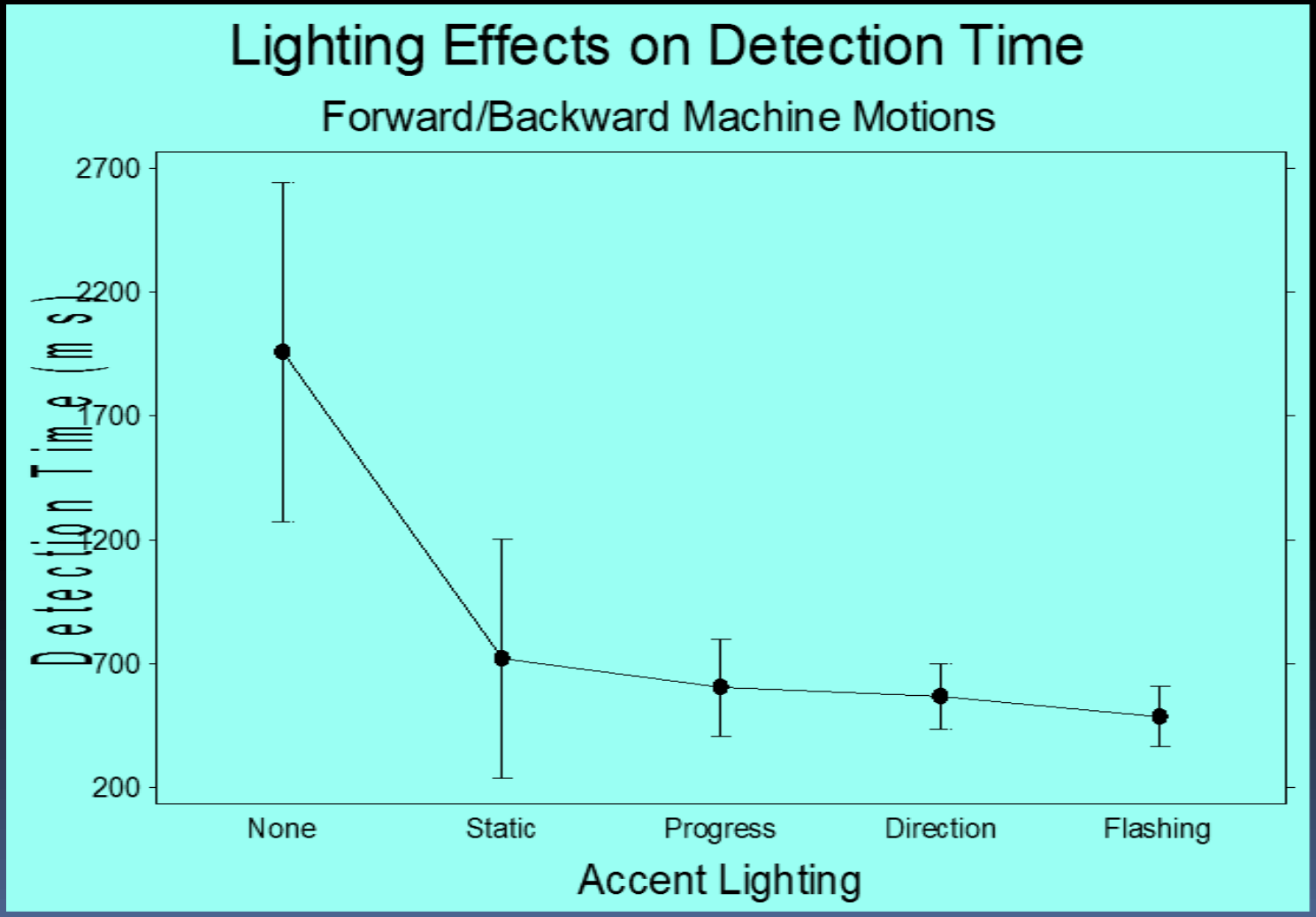
- Better illumination
- Programmable
- Improved spectrum for the mining environment
- Floor hazard detection increased
- Peripheral motion detection increased
- Battery much lighter
- Changes in intl. standards have resulted from this research
- HHS Innovates Award

Reducing struck-by or pinning accidents

Visual Warning System

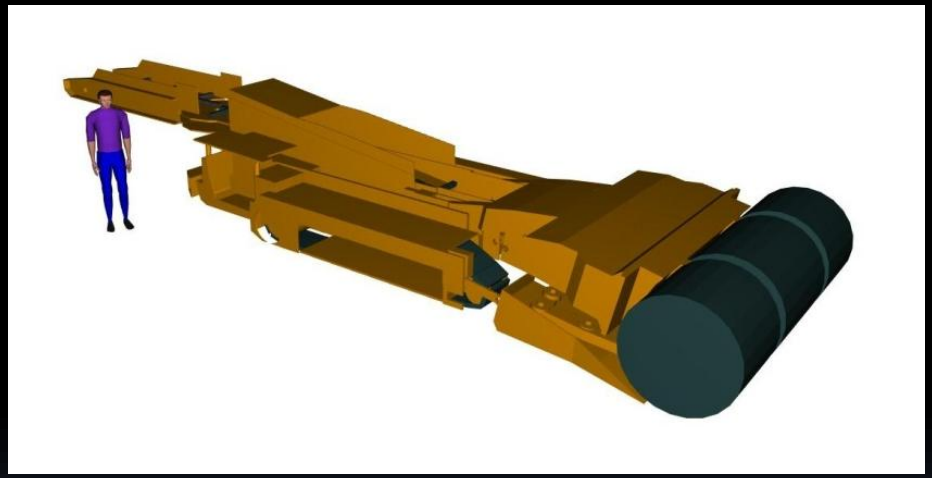
- LEDs mounted at various positions on machines
- Static or flashing (different patterns)
- Subjects were asked to determine when machine started moving (with or without lighting)

Visual warning system results



Proximity detection system

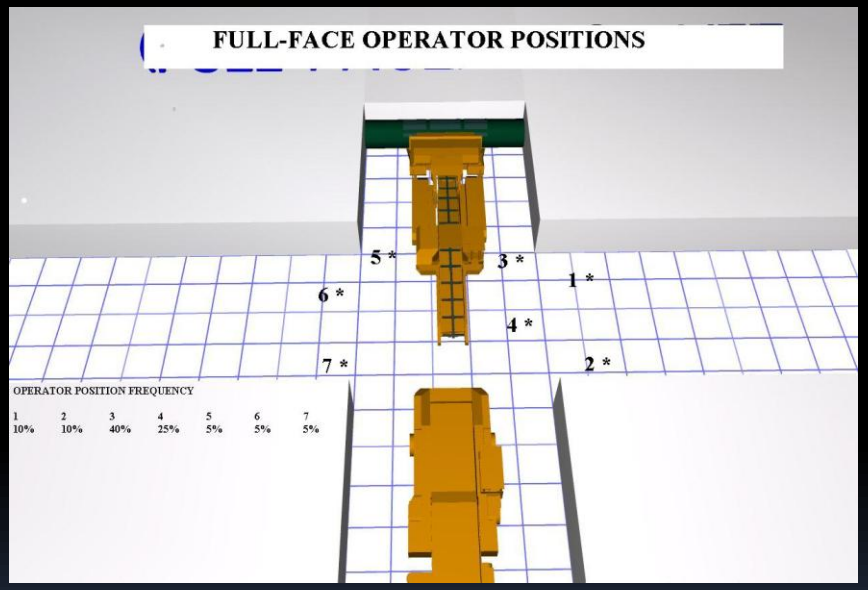
- Miners wear a RFID sensor
- EM Field generated around the machine permitting calculation of the miners position
- Machine would be prevented from moving in a direction that would contact the miner



Proximity Detection Video

Proximity Detection Goals

- Determine location in 3-D space of up to 3 workers in close proximity to the miner
- Analyze the risk to workers based on their job coded RFID and their location
- Warn workers if they are approaching a danger zone
- Prevent particular machine functions if action could injure workers
- Avoid frequent nuisance warnings and function interruptions



Kneepad research

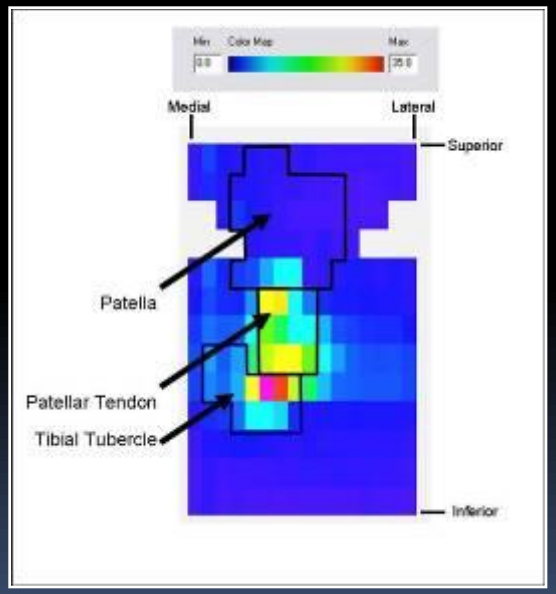
Meniscal injuries in Knee Flexion

- Deep knee flexion reduces muscle activity saves energy
- However, condyles of femur can pinch, tear meniscus in deep flexion
- Desire to save energy in the short term may lead to disabling injuries in long-term

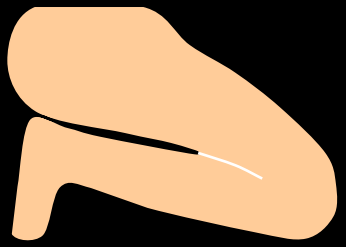
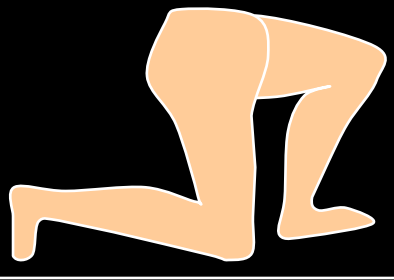
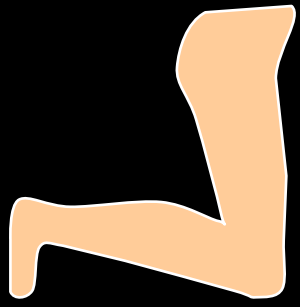
Kneepad research

Pressure Measurement

- Custom pressure sensor
  - Flexible, pre-shaped to knee



Forces at Right Knee

	Full Flexion 	One Knee 	2 knees 
Force at toe (lbs)	37	8	9
Force at knee (lbs)	44	104	69

Base of Support and Muscle Activity

Greatest Base of Support
Lowest Quad, Hamstring Muscle Activity

Intermediate Base of Support
Increased Quad, Hamstring Muscle Activity

Smallest Base of Support
Highest Quad , Hamstring Muscle Activity

Trade-off

- Kneeling in full flexion saves energy
- Provides stable base of support
- However, meniscus will get damaged over time
- Short term energy savings could lead to long-term disability

Project Goal

Develop a prototype kneepad to be used in low-seam mining that:

- Redistributes forces at the knee compared to current kneepads
- Gel insert to reduce forces on tibial tuberosity and patellar tendon

Ergonomics Audit

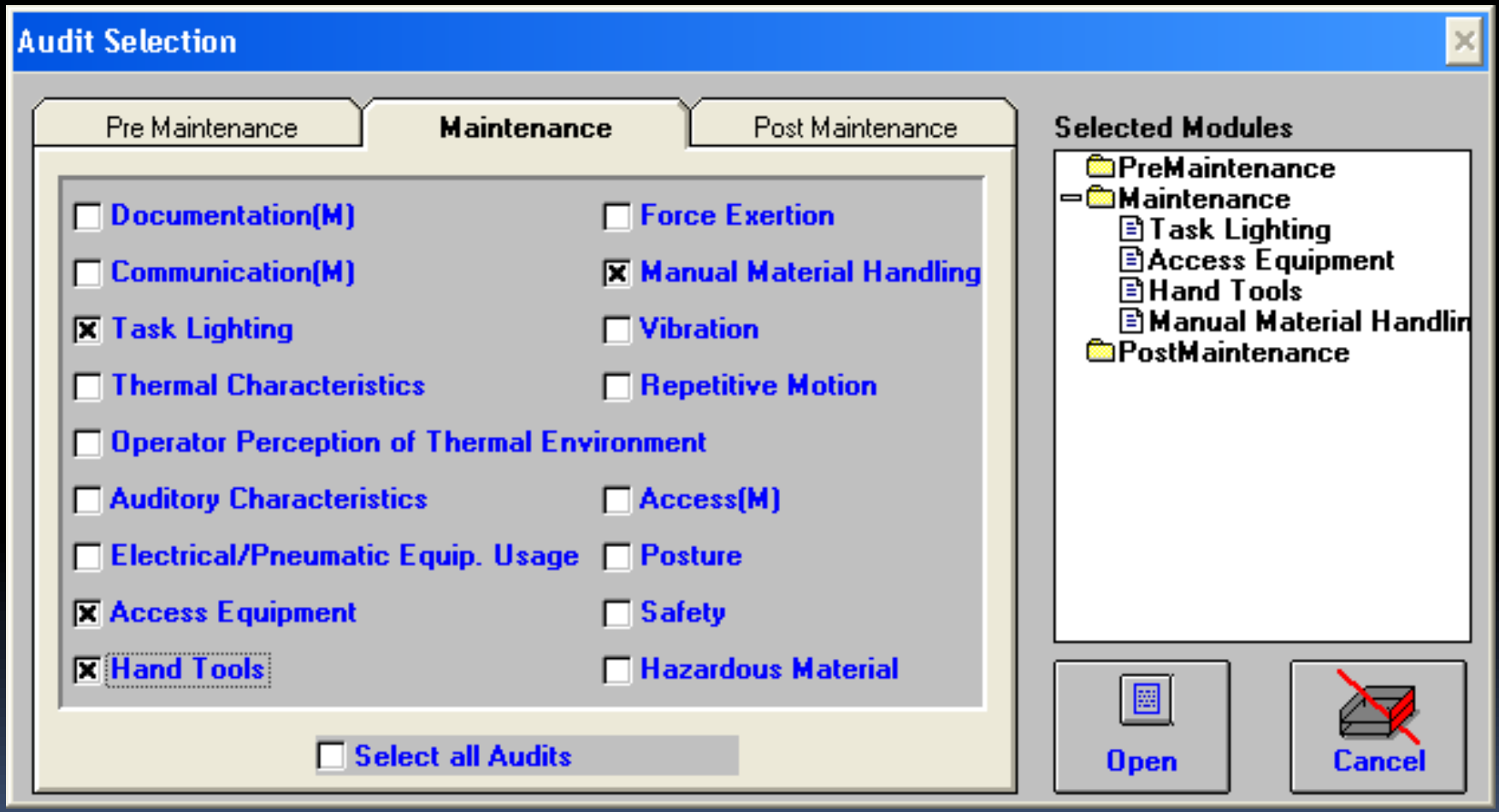
To develop and evaluate ergonomics audits for three types of operations in the mining sector

Small and Bulk Bagging Operations

Haul Trucks

Preparation/Minerals Processing Plant Maintenance and Repair

Ergonomics Audit

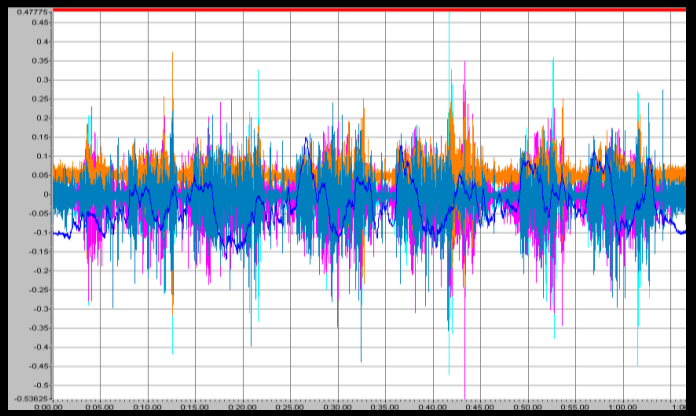


Bagging – Areas of Interest

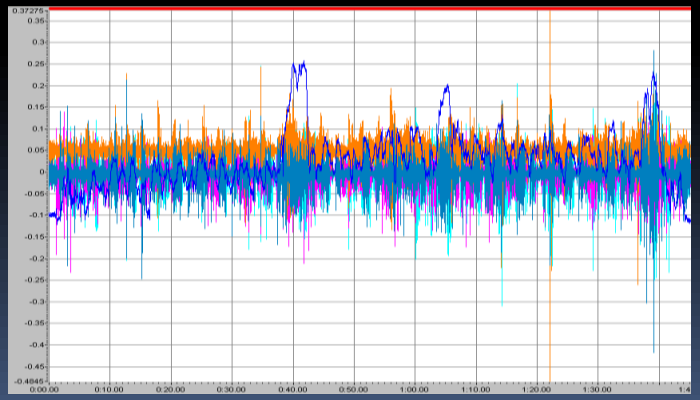
- Small bags
  - Bagging filling stations
  - Bag stacking on pallets
  - Weighing of bags
  - Shrink wrapping of pallets
- Bulk bags
  - Bag closure techniques
- Bagging Audit Tool
  - Assesses bagging operations
  - Provides feedback

Field Data from Bagging Study

Manual Stacking (75 pound bags)



Using Vacuum Hoist (75 pound bags)



Maint/Repair – Areas of Interest

- Identified tasks of interest:
  - Rollers
  - Belts
  - Motors
  - Screens
  - Greasing

Haul Trucks – Areas of Interest

- Areas of interest:
  - Operating/driving truck
  - Loading/unloading truck
  - Getting on/off truck
- Current study
  - Measuring whole-body and hand arm vibration loading
  - Examining effects on balance and touch sensitivity

Issues regarding Self-contained self-rescuers(SCSRs)

- In a mine fire or explosion, atmosphere quickly becomes toxic
- Carbon monoxide can kill you quickly
- Miners use SCSRs to isolate lungs

Human Factors Issues with SCSRs

- Donning the SCSR
- Communication
- Resistance breathing
- Hot air
- How much oxygen is left?
- Switching units

Donning the SCSR

- Miners had trouble donning correctly
- 3+3 method developed
- First three step rapidly isolate lungs
- Second three steps adjust straps, put on goggles

Communication

HF Problem

- Emergency situation
- Can't communicate verbally

Potential Solutions

- Sign language
- Radio transmission via bone conduction

Sign language examples:

- Yes/Good Idea (thumbs up)
- No/Bad Idea (thumbs down)
- We/Us (point finger up, move in circular motion)
- Stop/Stay Here (arm straight out, angled toward floor, palm facing forward)
- Go This Way (arm at side, extend outward from waist indicating direction, palm facing out)
- Refuge Chamber/Barricade (touch fingertips to make triangle in front of chest)

How much O2 is left?

- Units are designed to supply 100 L/oxygen (1-hour units)
- How long does 100 L/O2 last?
- Depends on what you're doing!
- Future designs are working on methods to give feedback on O2 remaining

Refuge Alternatives

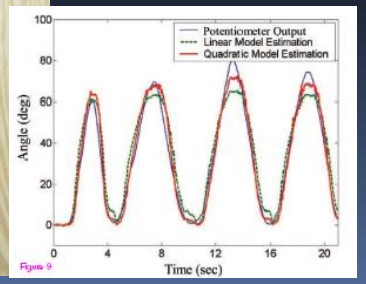
- Coal mines required to have refuge chamber close to working face
- Will miners be able to use in emergency situations?
- Human Factors/Ergonomics Issues
  - Can they deploy chamber under SCSR?
  - Tolerability over a number of days?

Real-time exposure monitoring

- Personal dust monitor

- B-Alert EEG helmet
  - Driver fatigue
  - Task engagement

- Suit to detect ergonomics hazards?



Summary

- The mining workplace is changing, as are the demands placed upon mineworkers
- Many of the historical mining hazards have now been well-controlled (not perfectly)
- New technologies hold great promise in reducing injuries heretofore difficult to control
- Human factors and ergonomics will have an increasing role to play with advances in technology