Human Factors and Lighting for Underground Mining

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Why conduct lighting research?

It's fundamental for health & safety

80% of our perception is visual

Workers depend on lighting to see hazards and work safely

Underground mines are considered one of the most difficult places to light

Underground mines present unique challenges that need to be addressed

Low ceilings and very low reflectivity

Constantly changing environment

Strict lighting regulations

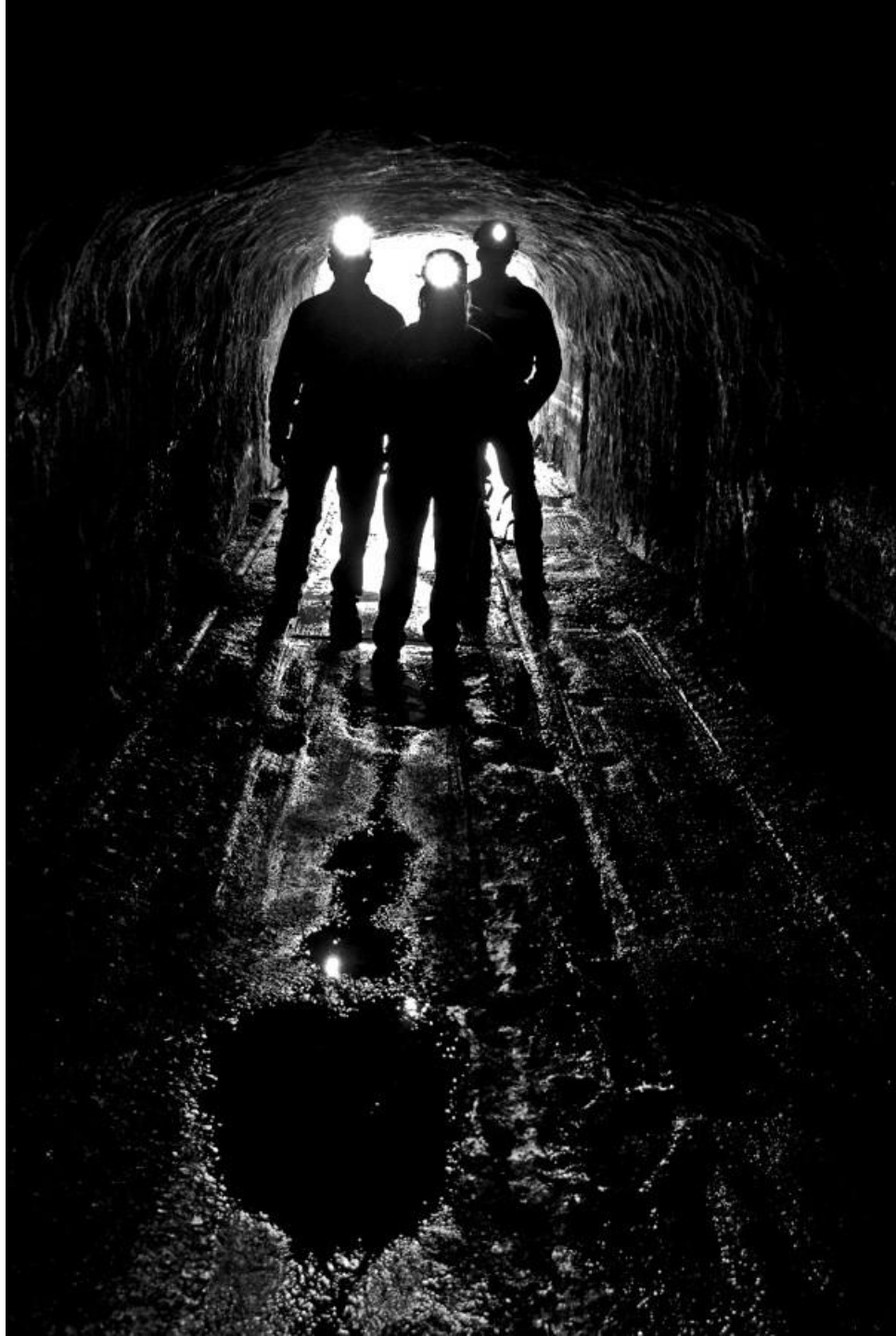
Some areas not lit at all

Shift work and darkness can increase fatigue

Aging of the mining workforce

Topics for discussion:

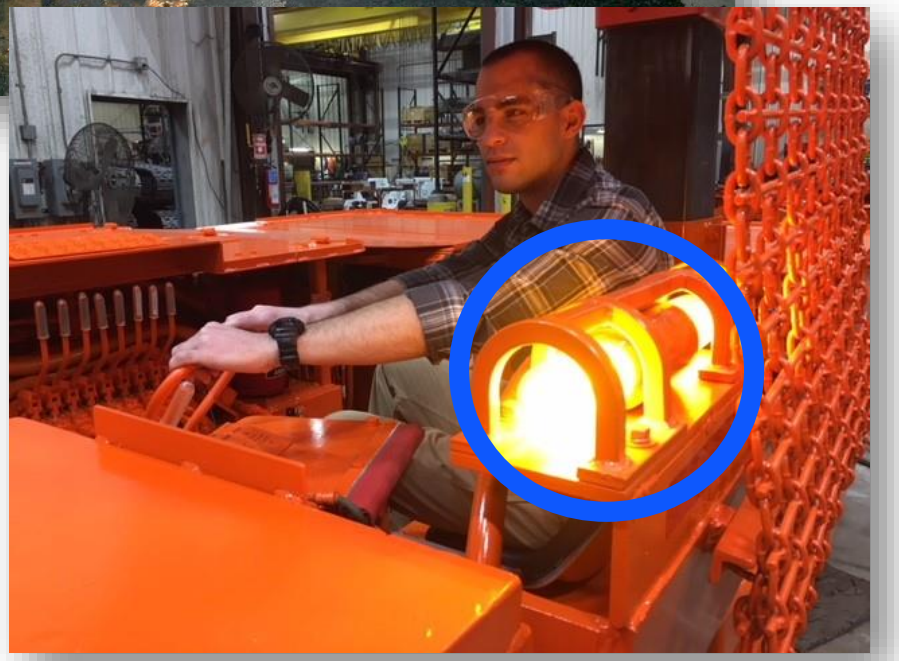
1. **Visibility**
    a. **Saturn light**
    b. **NIOSH LED cap lamp**
2. Visual cues
    a. Escapeway markers
    b. Lighted Lifeline
3. Light and fatigue



Roof bolter illumination

- One of the most dangerous machines to operate
- Drills bolts to secure roof
- Federal requirements for lighting

- Problems:
  - Excessive glare
  - Poor lighting of interior workspaces
  - Confined spaces difficult to illuminate
  - Hazardous environment requires explosion-proof lights



Saturn LED Area Light

- Reduces glare and improves hazard detection
- Replaces two existing CFLs
- Improvements:
  - 37% less glare
  - 112% increased reaction time
  - 2303% more floor illumination
  - 875% less weight
  - 675% less electrical power
  - 598% less volume

Saturn area light increases illumination while decreasing glare

Cap Lamps

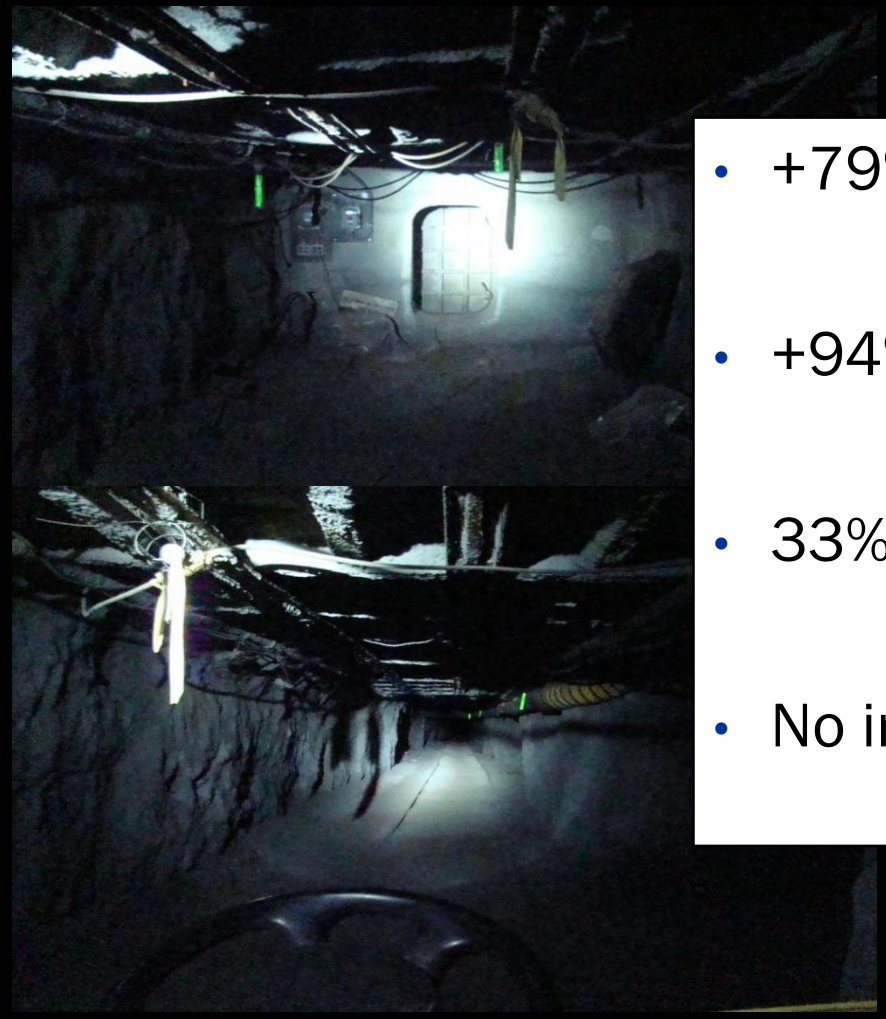
- Problem:
  - Current cap lamps provide poor visibility
  - No peripheral vision from tunnel vision effect
  - Causes glare from spot beam

NIOSH LED Cap Lamp

- 3 angled LEDs with optics
- Programmable intensity & light pattern
- Uses less power
- Reduces glare and tunnel vision effect

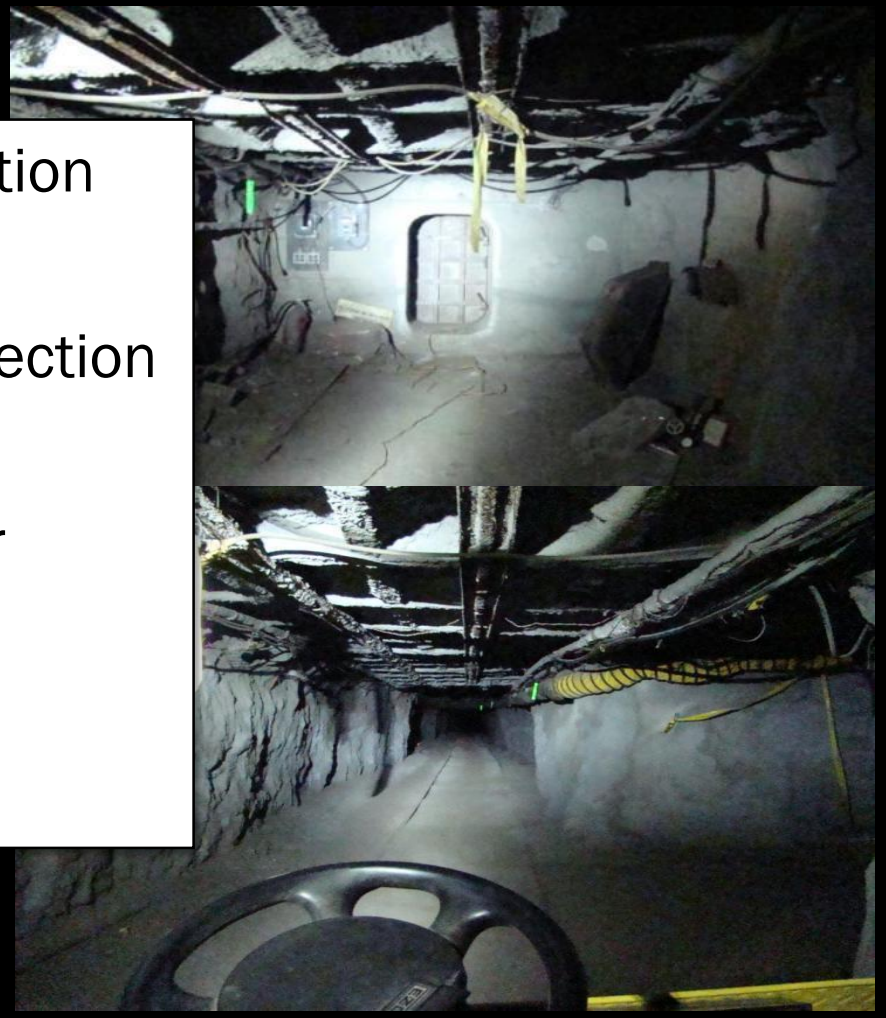
The NIOSH LED Cap Lamp improves visibility without causing glare

Traditional
LED cap lamp



- +79% peripheral detection
- +94% floor hazard detection
- 33% to 50% less power
- No increase in glare

NIOSH
LED cap lamp



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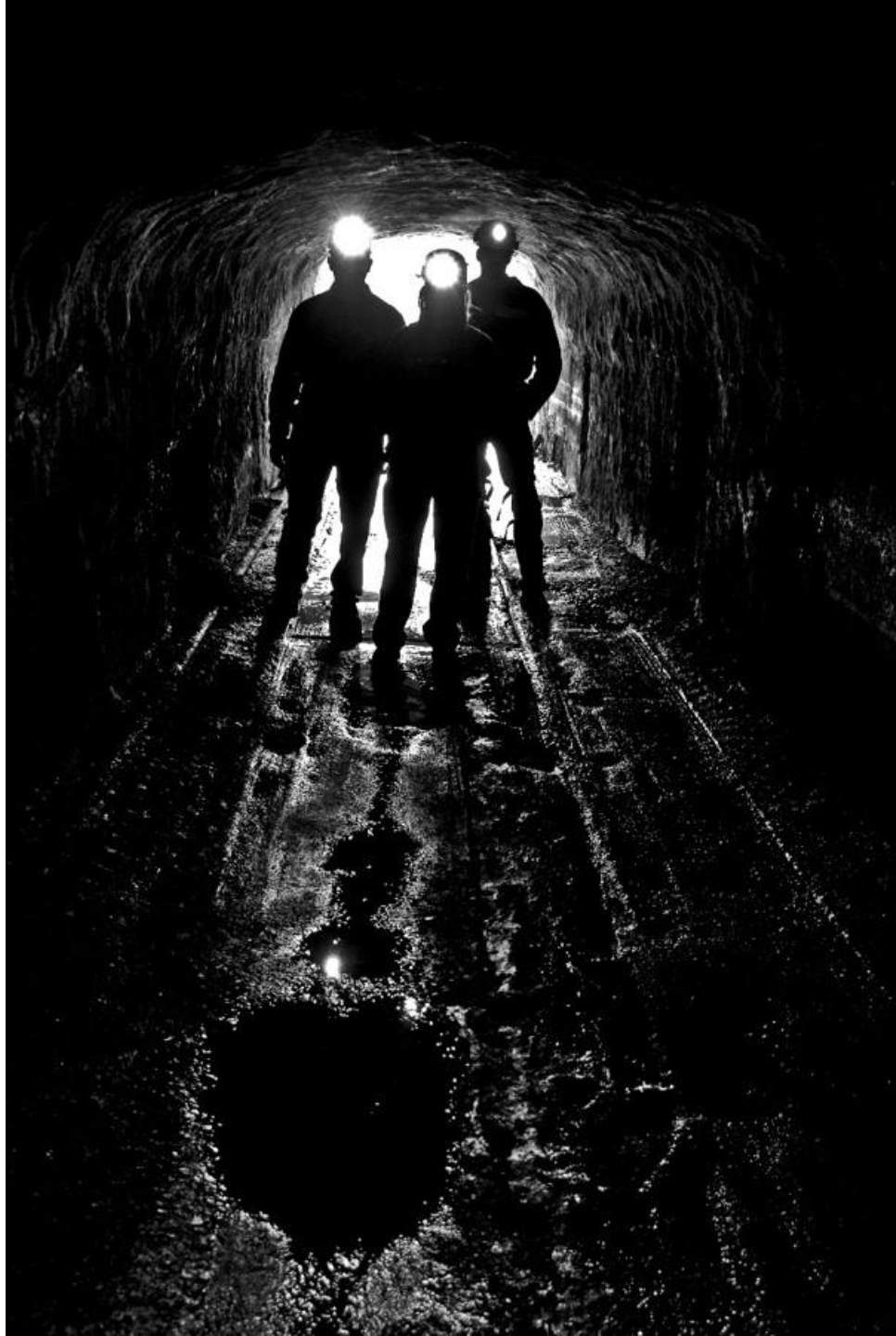


Escapeway markers: Passive beacons

- Federal law requires marking primary and secondary escapeways
- Problems:
  - No color code
  - Various colors, sizes, and shapes
  - Various retroreflective materials
- Tested red, green, and blue markers for detectability in smoke
- Tested FYG, white, yellow, and green markers for differentiation

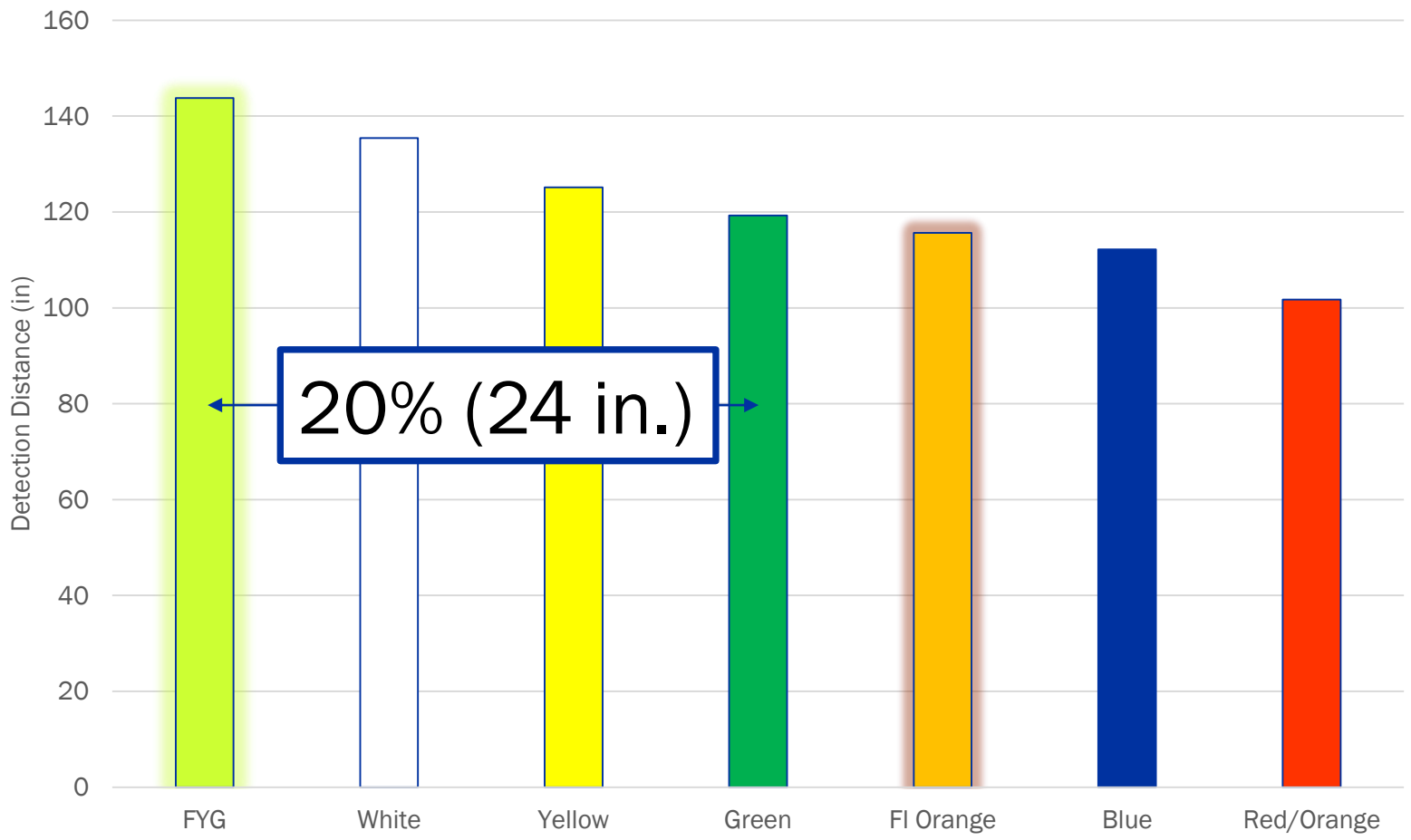
Escapeway marker color is critical for visibility in smoke

Green Marker

Red Marker

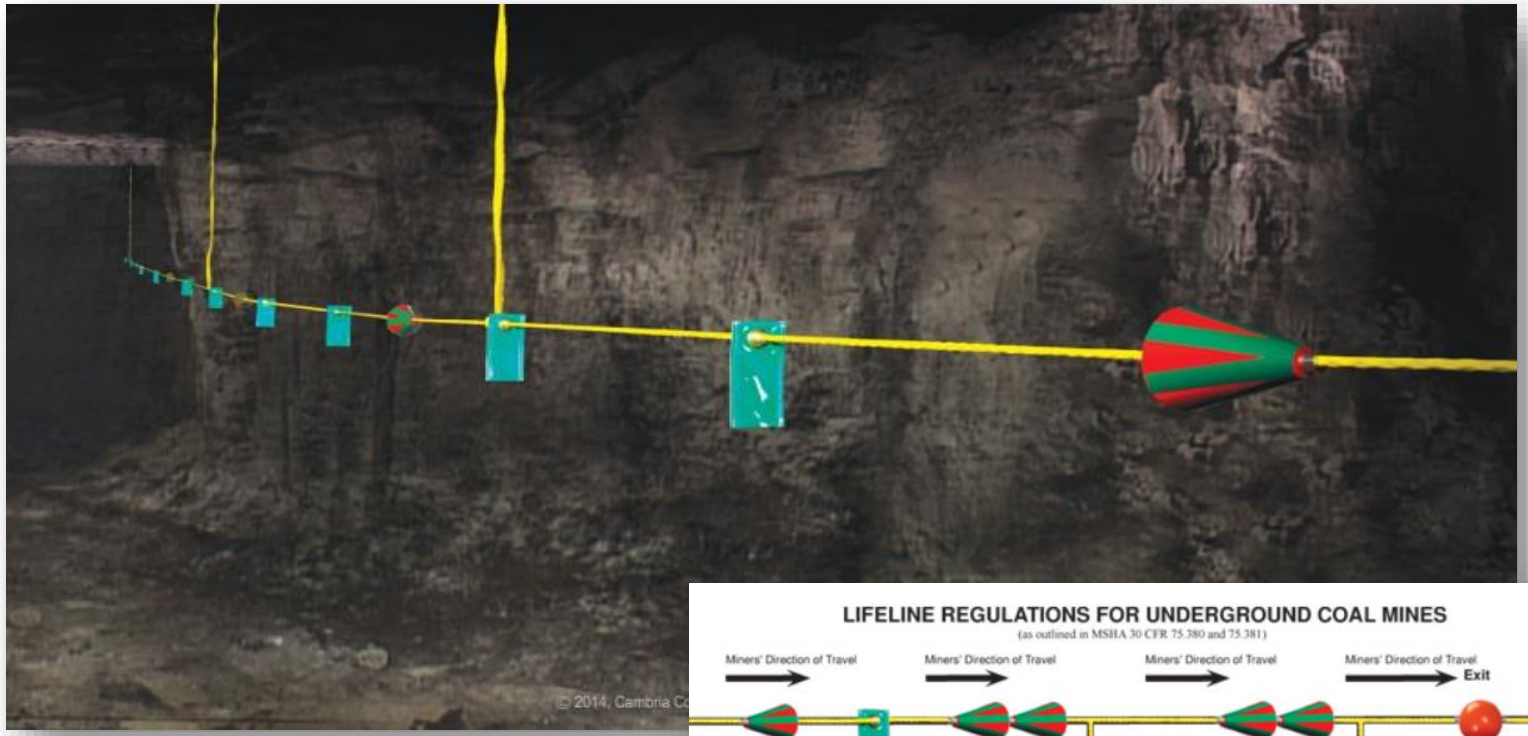
Blue Marker

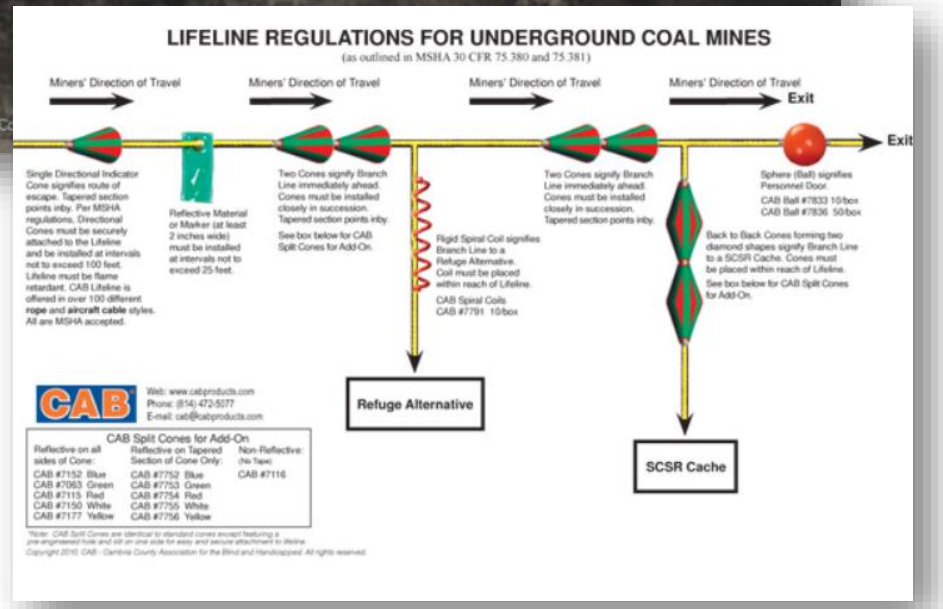
Escapeway marker detection improved 20% for FYG vs. Green



Lifelines for emergency self-escape

- Required by law for underground coal mines
- Tactile objects indicate:
  - Escape direction
  - Locations of safety resources



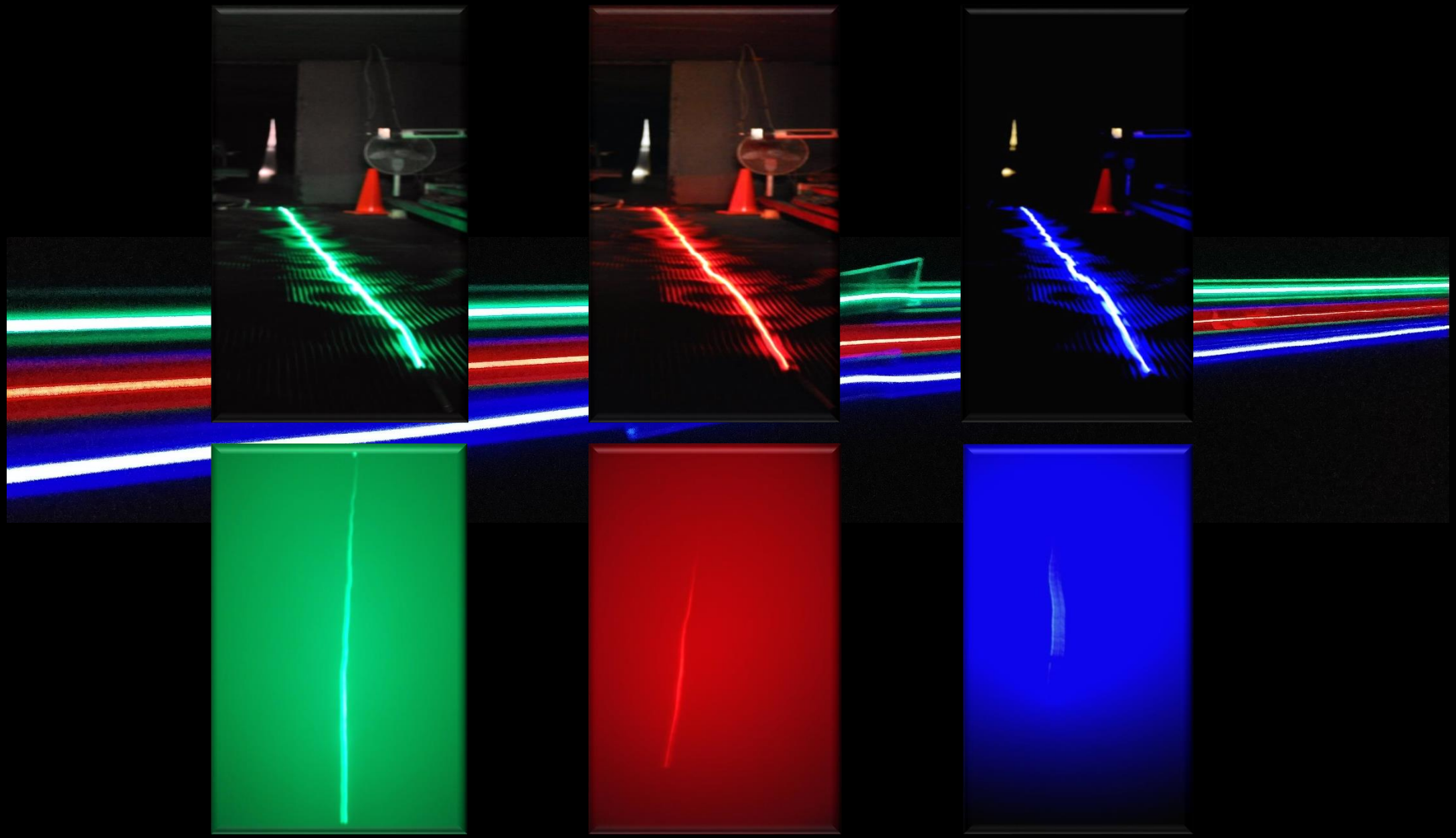


- Problem:
  - Mine disasters typically produce smoke
  - How can miners find the lifeline?

The Lighted Lifeline increases detectability in smoke for miner self-escape

- Fiber optic cable illuminated by lasers
- Greatly increases lifeline visibility in smoke
- Other potential uses:
  - Communications
  - Distributed sensing
    - Temperature
    - Sound
    - Strain

Lighted Lifeline colors for emergency self-escape in smoke



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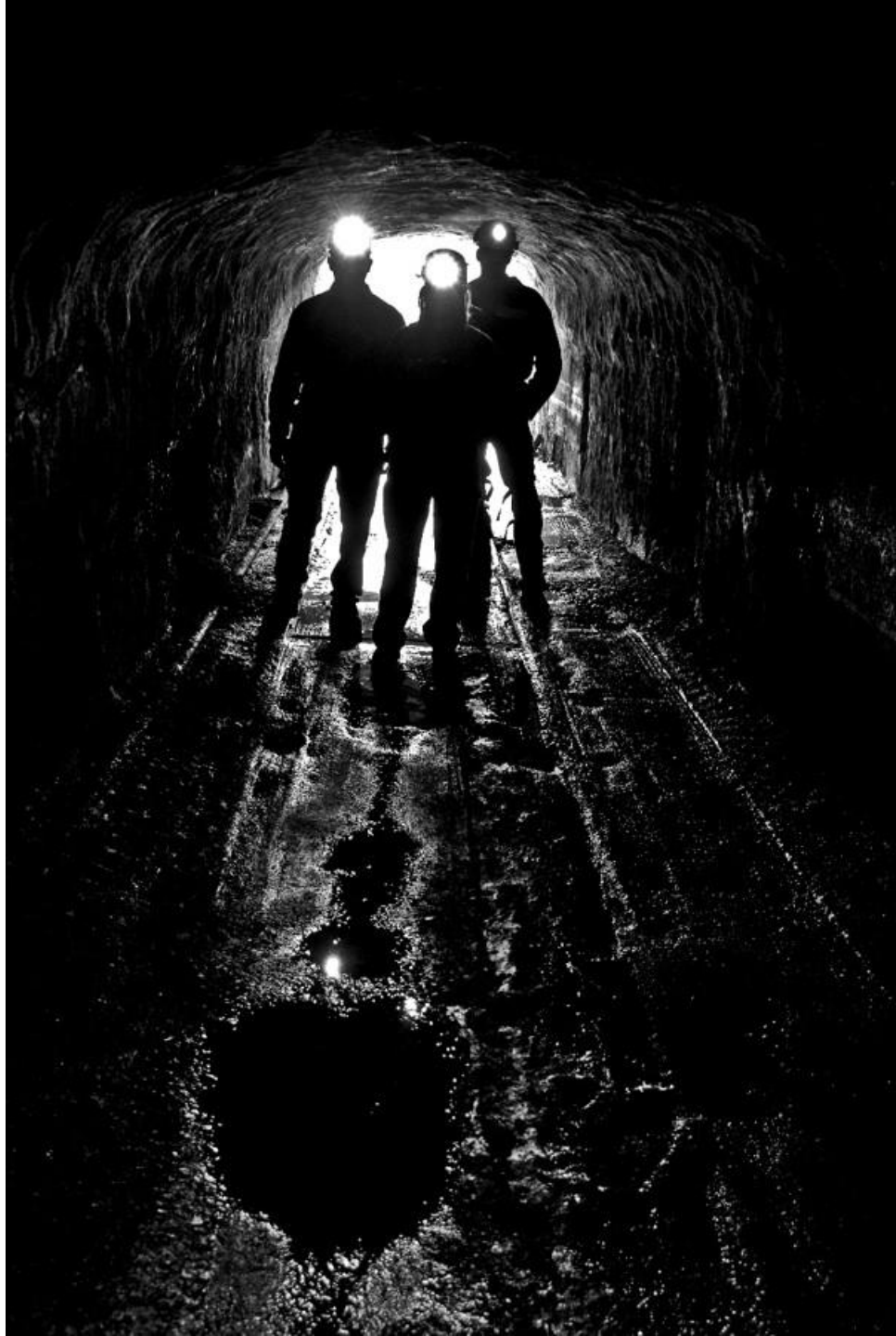
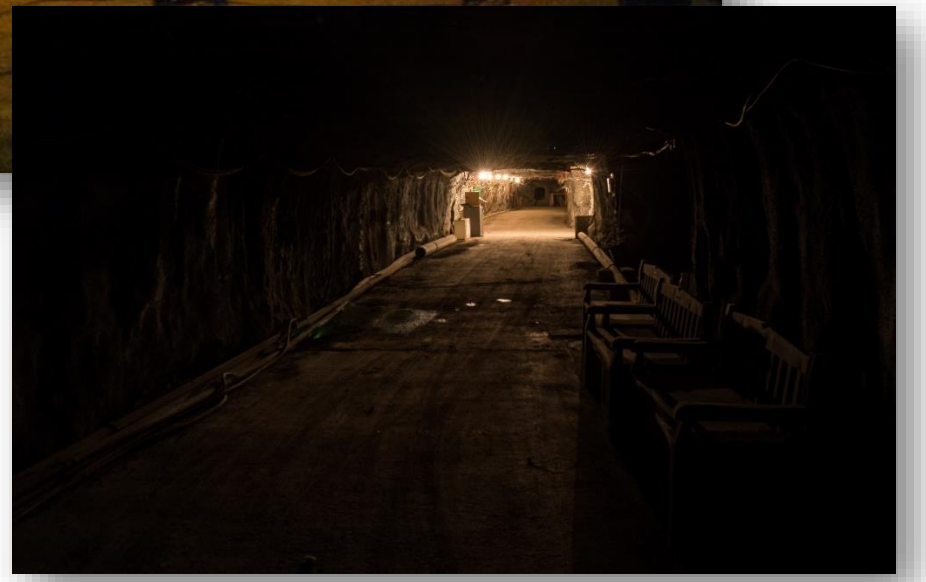


Insufficient light can disrupt circadian rhythms and lead to fatigue

- Highly dependent on the day/night cycle of light
- Underground miners work in darkness for large portions of the day making them especially vulnerable
- Majority of miners shiftwork
- Some areas and machines use “yellow” light



Insufficient light has numerous impacts on safety, including:

Decreased:

- alertness
- productivity
- reaction time
- cognitive function

Increased:

- accidents
- health impacts
- sensitivity to light
- fatigue

Circadian disruption can lead to severe consequences for health

Short-term:

- Loss of sleep
- Weak immune system
- Depression

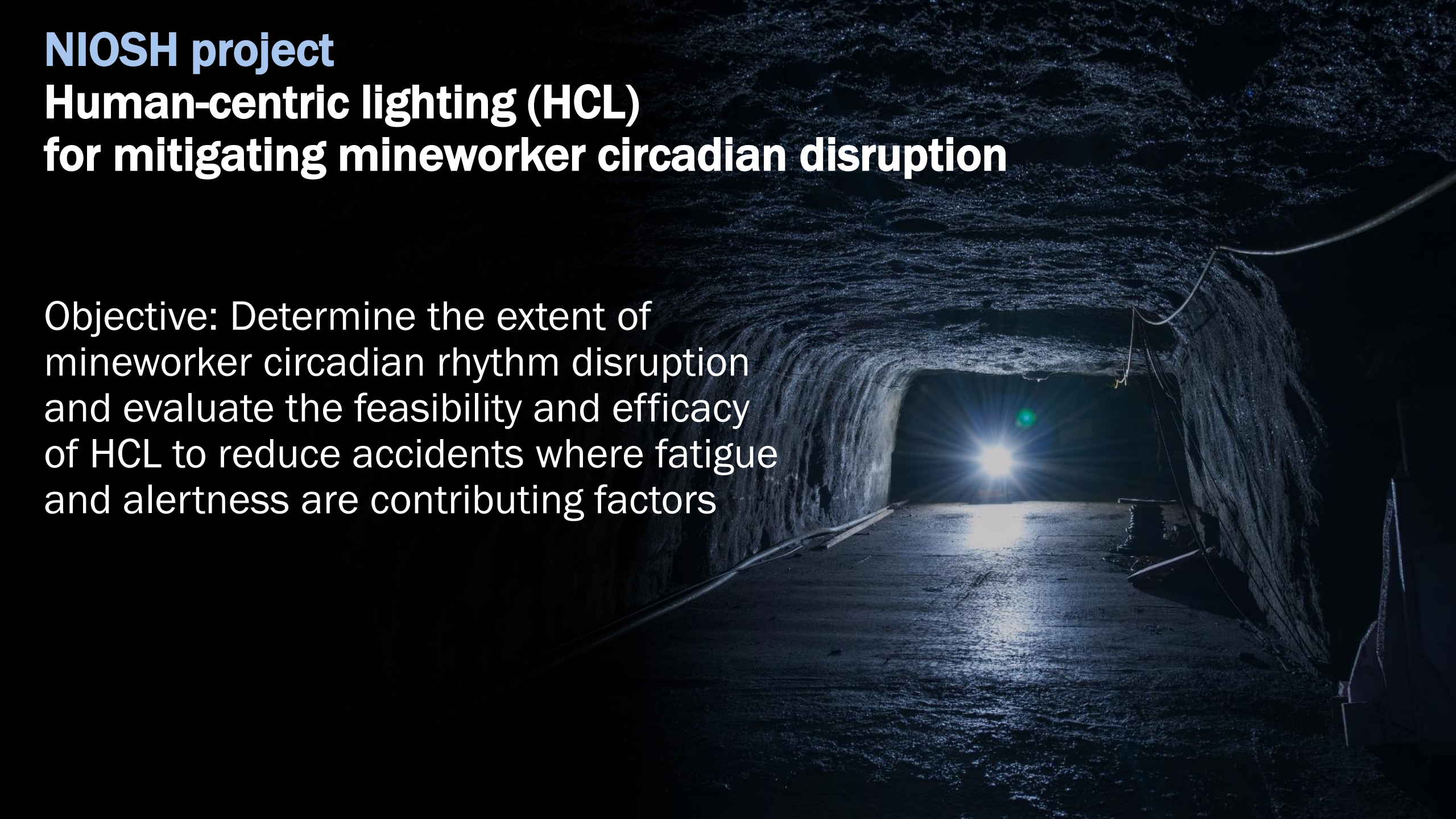
Long-term:

- Obesity
- Diabetes
- Cancer

NIOSH project

Human-centric lighting (HCL) for mitigating mineworker circadian disruption

Objective: Determine the extent of mineworker circadian rhythm disruption and evaluate the feasibility and efficacy of HCL to reduce accidents where fatigue and alertness are contributing factors



Project challenges for underground mines

- Considered one of the most challenging places to light
- Coal mines require “approved” lighting
    - Intrinsically safe, XP housings, etc.
- Unlikely actigraphy devices would be “approved”
- Difficult data collection
- Hardhat & safety glasses limit retinal illumination
- Aging of the mining workforce

Lighting is fundamental for the health & safety of underground miners

NIOSH Mining Program
www.cdc.gov/niosh/mining