A Critical Review of Best Practices, Barriers and Policy Insights

Advancements and Challenges in Fatigue Risk Management in the Mining Industry

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PRESENTATION OVERVIEW

& Your Presenter

- Fatigue
- Causes of Fatigue
- Fatigue at Work
- Fatigue Risk Management
- Hazard Identification
- Wearable Fatigue Technologies
- Wearable EEG Technology
- Implementation
  - Early Challenges
  - Modern Day Realities
  - Best Practices
- Critical Policy Considerations

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FATIGUE

Cognitive fatigue is a state of mental exhaustion that can impair cognitive function.

Fatigue can lead to symptoms such as

- **difficulty concentrating,**
- **forgetfulness, and**
- **decreased motivation.**

It often occurs after prolonged mental activity, particularly when working on difficult tasks or experiencing high levels of stress.

Cognitive fatigue (also called exhaustion, tiredness, lethargy, languidness, languor, lassitude, and listlessness) is <u>medically recognized</u> as a state usually associated with a weakening or depletion of one's mental resources.

CAUSES OF FATIGUE

There are many causes related to fatigue, including conditions, disorders, medications, and lifestyle factors. Causes of fatigue include:

- Situational events (i.e., shift work, and extended work hours such as overtime)
- Disorders or conditions such as insomnia, sleep apnea, or narcolepsy
- Use of certain medications or treatments, such as benzodiazepines, antipsychotics, opioids, anticonvulsants, or beta-blockers, over-the-counter drugs (including antihistamines).
- Infections such as mononucleosis, influenza, pneumonia, Lyme disease, etc.
- Heart and lung conditions such as heart disease, chronic obstructive pulmonary disease, emphysema, congestive heart failure, etc.
- Mental health conditions including depression, anxiety, and post traumatic stress disorder, etc.
- Autoimmune disorders including type 1 diabetes, lupus, multiple sclerosis, rheumatoid arthritis, etc.

FATIGUE AT WORK

A more alert workforce is more productive, less distractable, more focused, and kinder on equipment.

FATIGUED WORKER

- increase in distraction incidents
- increase in human-error incidents
- less efficient task performance
- increase in fuel consumption
- harsher acceleration and breaking
- more steering overcorrection
- poor situational awareness and hazard identification
- increase in spotting time
- reduced ability to personally detect their increasing deficits
- **poor** ability to self-manage and mitigate their fatigue at the moment
- higher likelihood of failure to resolve errors (i.e., reliance on dispatch, supervisor)

ALERT WORKER

- reduction in distraction incidents
- reduction in human-error incidents
- more efficient task performance
- reduction in fuel consumption
- smoother acceleration and breaking
- less steering overcorrection
- greater situational awareness and hazard avoidance
- reduction in spotting time
- greater self-awareness

FATIGUE AT WORK

Fatigued workers are at risk of experiencing microsleeps - during microsleeps the brain disengages from the environment and stops processing visual information and sounds.

FATIGUE RISK MANAGEMENT

Fatigue Risk Management System (FRMS) is data-driven means of continuously monitoring and managing fatigue-related safety risks, based upon scientific principles and knowledge as well as operational experience that aims to ensure relevant personnel are performing at adequate levels of alertness.

Industrial Revolution

1760

Prescribe limits on maximum working hours, and require minimum breaks within and between duty periods.

The approach reflects early understanding that long unbroken periods of work could produce fatigue, and that sufficient time is needed to recover from work demands and to attend to non-work aspects of life.

2nd Half of the 20th Century

1950

Scientific evidence began accumulating that implicated other causes of fatigue in addition to time-on-task, particularly in 24/7 operations. The most significant new understanding concerns:

- Importance of adequate sleep for restoring and maintaining all aspects of waking function; and
- Daily rhythms in the ability to perform mental and physical work, and in sleep propensity

Understanding of human error and its role in accident causation increased

21st Century

2000

Innovation of detection technologies and approaches that avoid a one-size-fits-all approach and account for operational differences or differences among workers.

Data-driven, ongoing adaptive processes that can identify fatigue hazards and then develop, implement and evaluate controls and mitigation strategies.

FATIGUE RISK MANAGEMENT

The approach is designed to apply this knowledge from fatigue science and safety science. It is intended to provide an equivalent, or enhanced, level of safety, while also offering greater operational flexibility. Best approach to mitigate fatigue related risks is through a comprehensive fatigue risk management system (FRMS) comprehensive FRMS includes:

PRESCRIPTIVE APPROACH

Prescribed limits that do not consider aspects specific to the organization or operating environment

PERFORMANCE-BASED APPROACH

Define requirements for operators to manage fatigue risk

MONITOR

Methods to monitor potential causes of fatigue and devise action plans to minimize their effects

IDENTIFY

Identifying personal warning signs of fatigue and appropriate counter-measures to ensure that effective work capability and alertness are maintained

MITIGATE

Adopting and applying effective practices and countermeasures for combatting fatigue

COMMUNICATE

Communicating these fatigue management strategies to all levels of operation

FATIGUE IDENTIFICATION

There are three types of processes for fatigue hazard identification:

PREDICTIVE PROCESSES

Focus on establishing crew schedules and conditions that consider factors known to affect sleep and fatigue in order to minimise their potential future effects.

- Previous Experience
- Evidence-Based Scheduling Practices
- Bio-Mathematical Models

PROACTIVE PROCESSES

Focus on monitoring fatigue levels in an operation. Multiple sources can be considered based on the expected level of fatigue risk.

- Self-Reporting of Fatigue Risks
- Crew Fatigue Surveys
- Relevant Performance Data
- Safety Databases and Scientific Studies
- Planned Vs Actual Time Worked

REACTIVE PROCESSES

Focus on identifying the contribution of worker fatigue to safety reports and events to reduce the likelihood of similar occurrences.

- Fatigue Reports
- Confidential Reports
- Audit Reports
- Incidents
- Task Data Analysis

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- Evidence-Based Scheduling Practices
- Bio-Mathematical Models

Previous Experience

The collective experience of managers, schedulers, and workers is an important source for identifying aspects of a proposed schedule associated with increased fatigue.

Evidence-Based Scheduling Practices

Use of fatigue science in the building of schedules; considering factors such as sleep loss, the circadian biological clock, and the impact of workload on fatigue.

Bio-Mathematical Models

Use of modelling to predict relative fatigue levels based on sleep loss and recovery or the circadian biological clock to influence scheduling and advanced roster planning.

CHALLENGES

When operational demands are changing, reliance on previous experience can have some limitations.

Not the most robust or innovative solution for new situations.

Predict group average fatigue levels, not the fatigue levels of individual workers.

Do not take into account the impact of workload or personal and work-related stressors that may affect fatigue levels

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Self-Reporting of Fatigue Risks
Workers' reports about high fatigue levels or fatigue-related performance issues.

Crew Fatigue Surveys
Retrospective or prospective surveys about sleep and fatigue using validated, standardized scales.

Relevant Performance Data
Reaction time, vigilance testing, short term memory function, fleet management data analysis or trained observers.

Safety Databases and Scientific Studies
More general guidance about fatigue hazards available from external safety databases.

Planned Vs Actual Time Worked
Analyze actual schedules and rosters for factors such as performance, crew time limits or exceedances.

CHALLENGES

Time requirement to complete repeat iterations of performance testing.

A multitude of factors contribute to deviations from planned parameters.

Having an observer present may also have an alerting effect and place additional demands on workers.

Some tools are affected by the "learning" process, which can reduce sensitivity over time.

Inability to detection source of impairment (i.e., fatigue vs. alcohol, drug impairment).

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- Fatigue Reports
- Confidential Reports
- Audit Reports
- Incidents
- Task Data Analysis

Fatigue Reports
Periodic site-level reports collating findings from multiple data sources.

Confidential Reports
Individual reports made by front-line workers to supervisors or safety personnel.

Audit Reports
External fatigue expert conducts a site-level review.

Incidents
Accident investigation seeks to identify if fatigue was a factor.

Task Data Analysis
Trend level analysis of fatigue levels with productivity data.

CHALLENGES

There is no simple test for fatigue-related impairment.

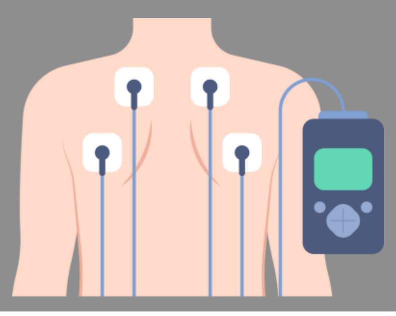
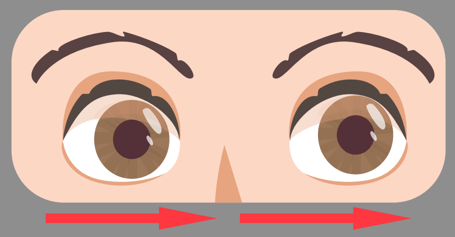
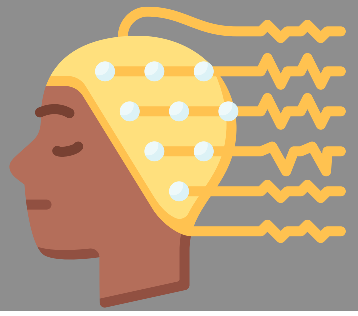
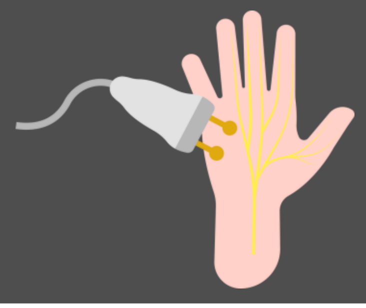
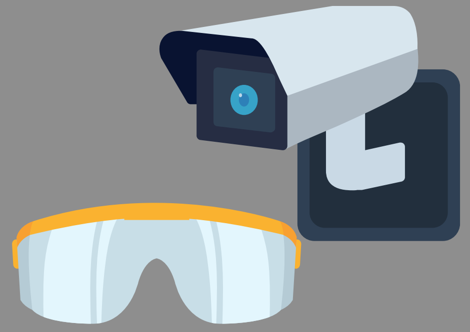
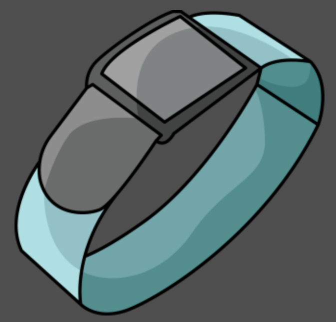
Information gathered after the event, based on the recall of the people involved.

No simple rules for interpreting fatigue related accident investigation information.

No validated methods for fatigue investigation.

WEARABLE FATIGUE MONITORING

There are various methods of measuring biopotentials (electrical output) associated with operator fatigue.

	Cognitive Fatigue			Physical Fatigue
	For measuring heart activity	For monitoring eye movement	For monitoring brain activity	For measuring muscle activity
Clinical Setting	**electrocardiogram (ECG)** 	**electrooculogram (EOG)** 	**electroencephalogram (EEG)** 	**electromyogram (EMG)** 
Other Setting	smart watches 	cameras & glasses 	headband 	arm band 

WEARABLE FATIGUE MONITORING

Smart Watches

PORTABILITY

Portable devices offer constant and convenient monitoring.

PREDICTIVE ANALYTICS

Algorithms enable proactive fatigue alerts.

REAL-TIME INTEGRATION

Can be combined with tools like EEG devices to detect and manage sleep quality contributing to fatigue.

HEALTH APPLICATIONS

Beyond fatigue, it allows for monitoring sleep health, heart health, etc.

CHALLENGES

Limited Action Capacity:
Fatigue predictions are difficult to implement in an operational environment.

Precision:
Predictive algorithms are inherently less accurate.

Not Real-Time: Cannot detect risks occurring during a shift; only provides predictions.

Union Resistance:
Requires use 24/7, including non-working hours.

Privacy Concerns:
Data privacy issues and potential misuse that could undermine trust.

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WEARABLE FATIGUE MONITORING

Cameras & Glasses

MULTIFUNCTIONALITY

Designed to detect microsleeps and distractions.

VISUAL CONFIRMATION

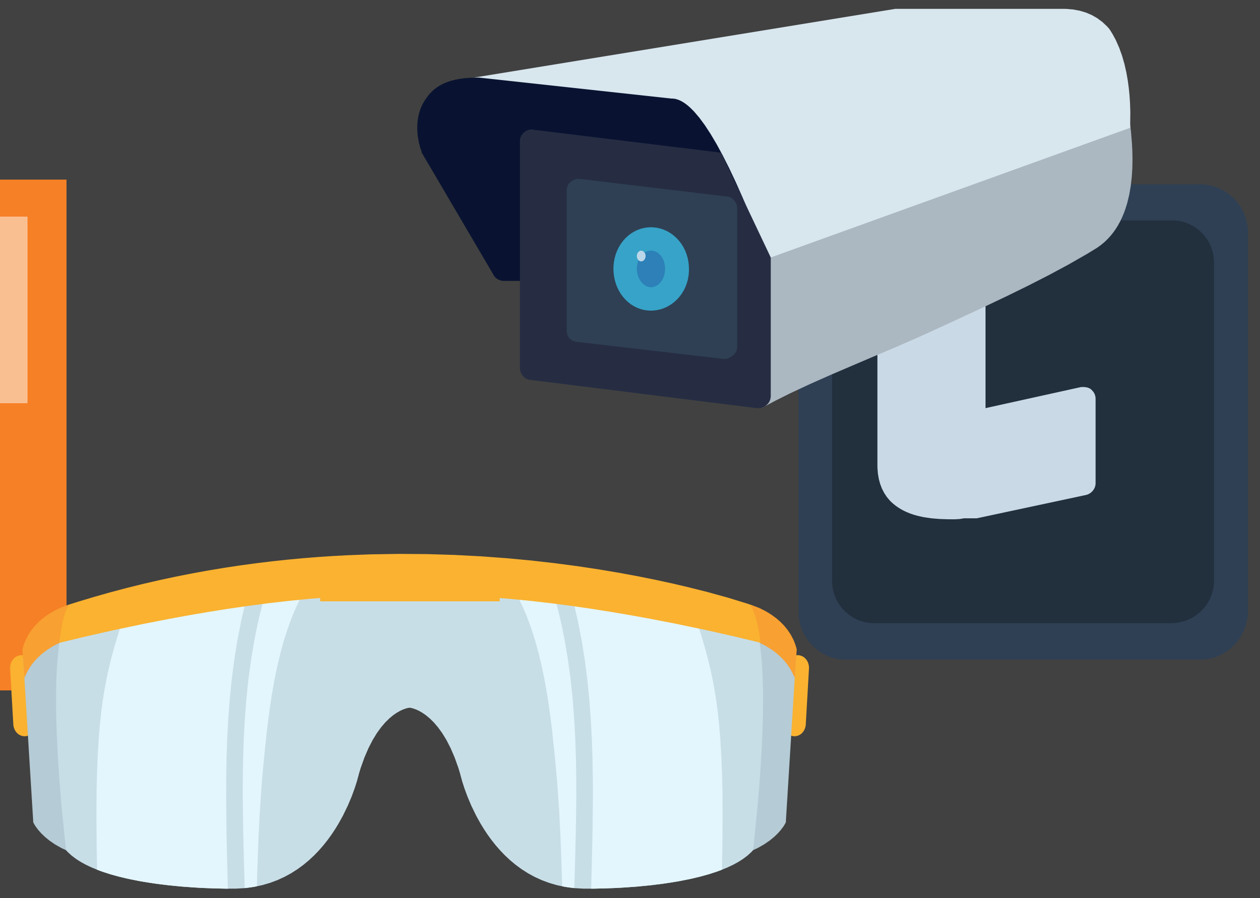
Provides visual evidence for analysis and alerts.

AI INTEGRATION

Advanced algorithms to improve accuracy (depending on the brand).

REGULATORY COMPLIANCE

Alignment with safety standards for greater adoption.



CHALLENGES

Privacy Concerns:
Continuous monitoring may raise privacy issues.

Environmental Limitations:
Not suitable for auxiliary equipment and non-driving applications.

Precision:
Prone to a higher rate of false alarms.

Implementation Resistance:
Employees and unions may resist constant supervision.

Technological Limitations:
Performance affected by vibrations, poor lighting, or adverse conditions.

WEARABLE FATIGUE MONITORING

Headbands

SELF-MANAGEMENT

Promotes early warnings and fatigue alarms before microsleep.

PRECISION

The only DIRECT source of real-time fatigue; measurement at the source provides greater accuracy, minimizing false alarms.

VERSATILITY

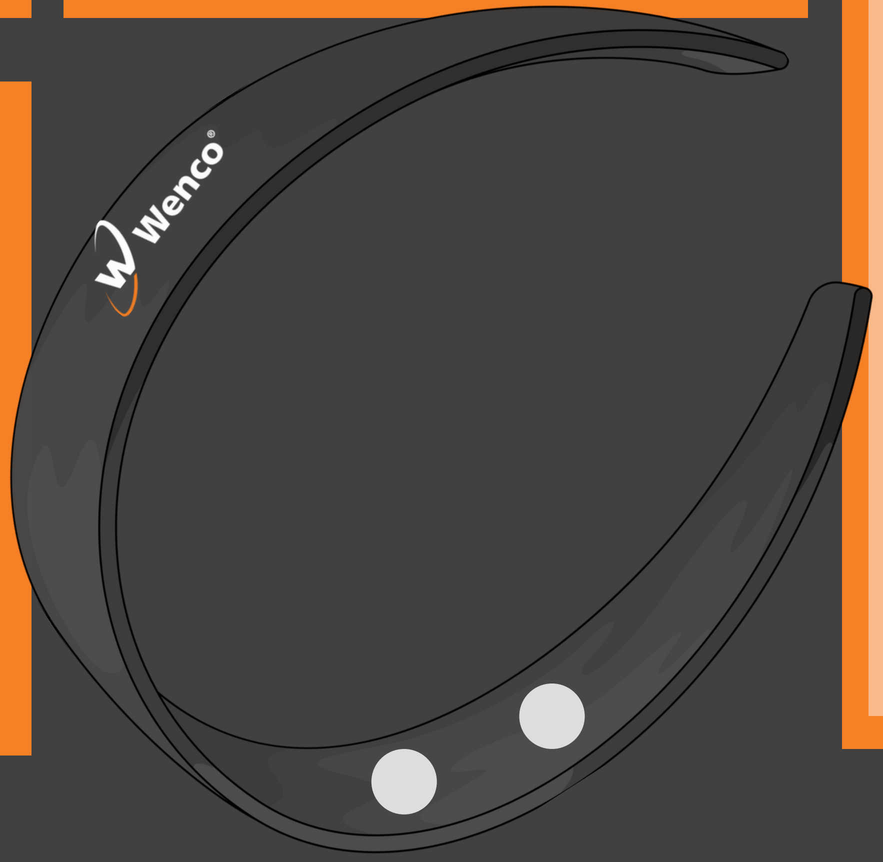
Functions in all driving environments and equipment operations.

OPERATIONAL IMPROVEMENTS

Data insights, including alert profiles, allow for improvements in road design, lighting, rosters, and travel management.

INITIATIVE EXPANSION

Opportunity to expand the fatigue initiative to roles outside traditional operations (office-based roles) and even off-site applications.



CHALLENGES

Intrusiveness
Requires users to wear the device.

Complexity
Microsleep risk may not align with the sensation of fatigue, requiring education/training.

Hardware Dependency
Needs specific hardware for its functionality.

Single Vendor
Unique solution with no direct competitor.

Privacy Concerns
Data privacy issues and potential misuse that could undermine trust.

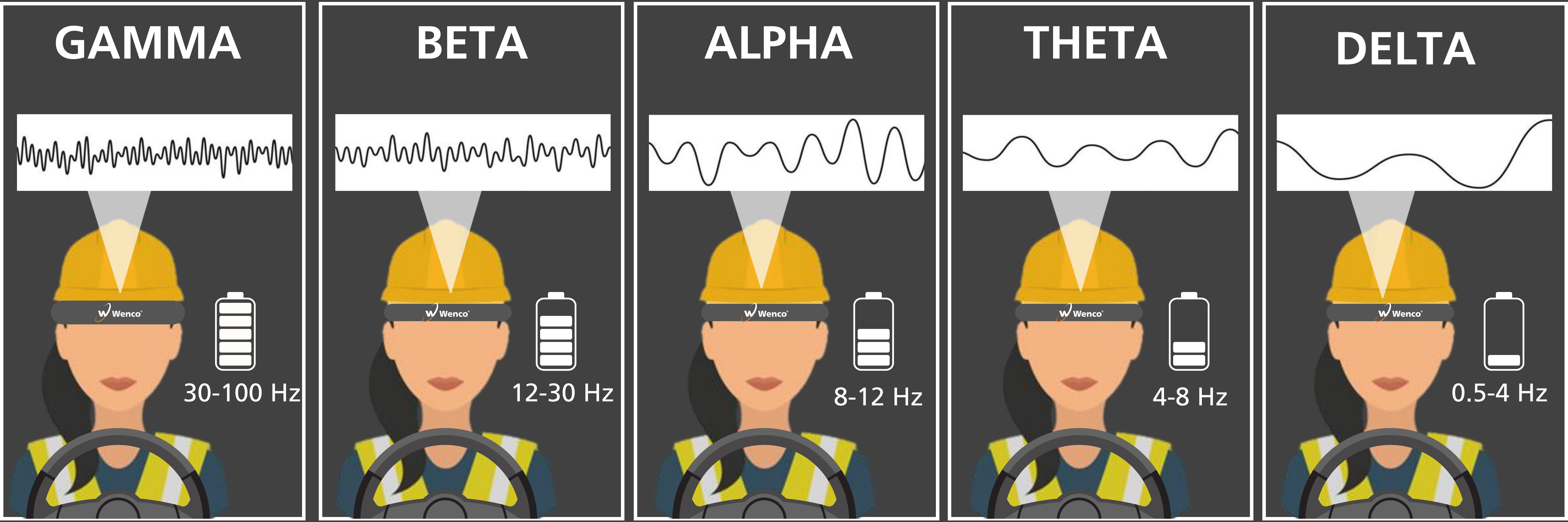
WEARABLE FATIGUE MONITORING

SUMMARY

	Headbands (EEG)	Cameras (EOG)	**Wristbands (ECG)**	**Predictive Analytics**
Real-time early warning alerts	✓	✓	-	-
Gold standard in fatigue science	✓	X	X	X
Prevent eyes-closed microsleeps	✓	X	X	X
Prevent eyes-open microsleeps	✓	**sometimes**	X	X
False Alarm Rate	**Low**	moderate	-	-
No Calibration Required	✓	X	✓	X
Fatigue Risk Profiling	✓	✓	✓	✓
Individual Reporting	✓	sometimes	✓	✓
Heavy Industry Applicable	✓	✓	✓	✓
Personal Use (car, home)	✓	X	✓	✓
Multi-Purpose (sleep, heart health detecting other risks; seat belt use)	X	✓	✓	X

WEARABLE EEG TECHNOLOGY

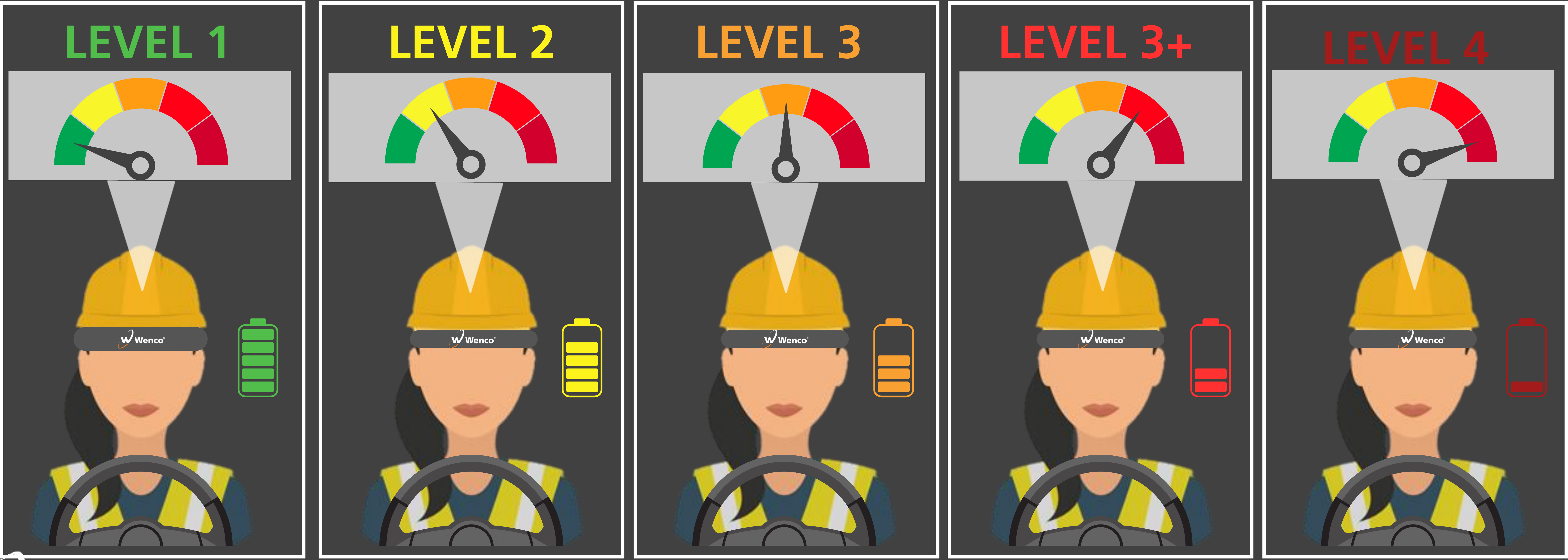
We use field wearable electroencephalography (EEG) - the gold standard in sleep science - to measure electrical activity in the brain using small, electrodes. The electrical impulses fluctuate rhythmically in distinct patterns based on the level of wakefulness/alertness.



WEARABLE EEG TECHNOLOGY

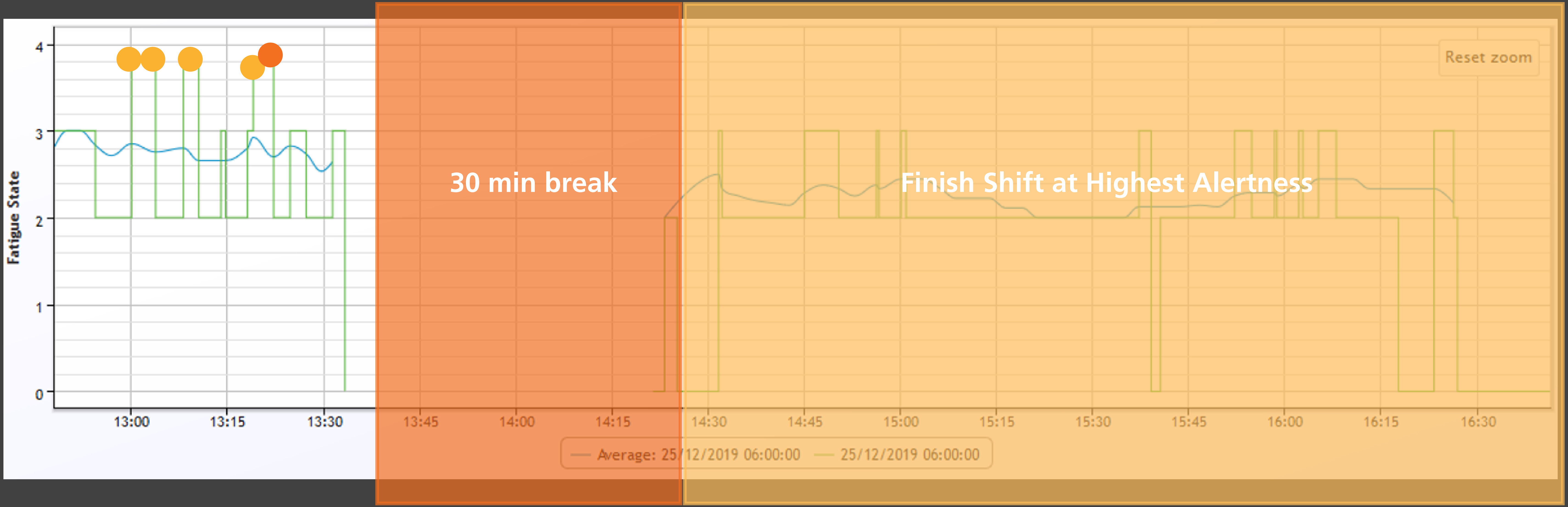
Using sophisticated AI methods (machine learning), these algorithms capture variations in electrical activity and translate the information into a representative measure of the operator’s ability to resist sleep.

No Action Required → Immediate Action



SOLUTIONS THAT DRIVE AUTONOMY

Look for solutions that provide a proactive, leading indicator of fatigue, that enables positive change in operator behavior to reduce organizational risk.



- **Operators can self-manage via early warning alerts and fatigue alarms directly.**
- **Only if they are unable to self-manage will alarms be escalated for support.**

EARLY IMPLEMENTATION CHALLENGES

TECHNICAL ISSUES

- Prototype-level reliability
- Harsh mining environment demands
- Calibration and maintenance needs
- Limited vendor experience in mining

WORKFORCE RESISTANCE

- Privacy concerns
- Union opposition
- Fear of punitive measures

MANAGEMENT HESITATION

- Operational impact concerns
- "Can of worms" mentality
- Fleet shutdown fears

ECONOMIC BARRIERS

- High implementation costs
- Difficult ROI justification
- Under-reported incidents

SUPPORT CHALLENGES

- Limited vendor experience
- Inadequate deployment support
- High maintenance requirements

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MODERN IMPLEMENTATION REALITIES

MYTH VS. REALITY

- Fleet shutdown fears overblown
- One alarm per 22 operator hours
- Manageable intervention rates

VENDOR EVOLUTION

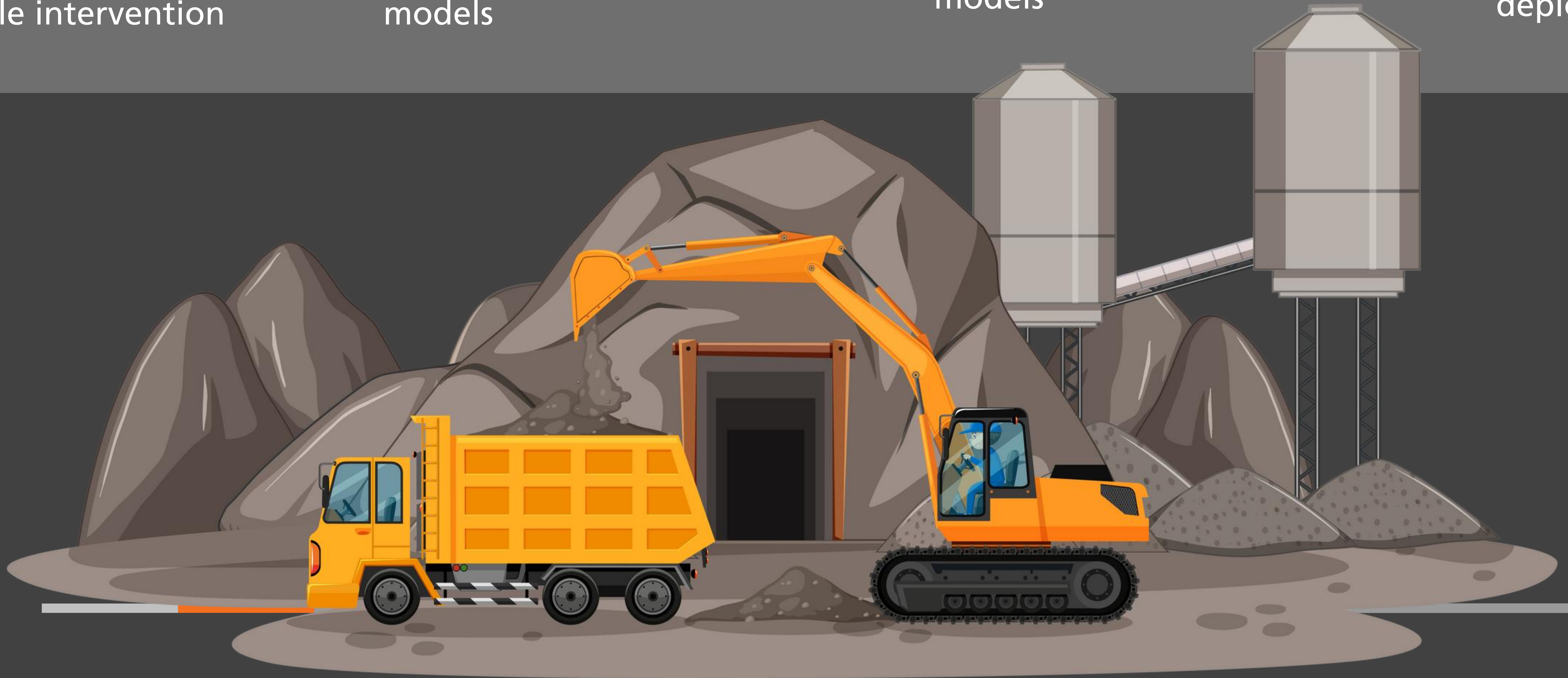
- Improved support structures
- More mining experience
- Better deployment models

HISTORICAL LESSONS

- "Silver bullet" mentality
- Unrealistic expectations
- Unsustainable usage models

SUSTAINABLE APPROACHES

- Balanced implementation
- Realistic expectations
- Progressive deployment



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BEST PRACTICE IMPLEMENTATION

1 CHANGE MANAGEMENT FUNDAMENTALS

- Early workforce communication
- Clear trial criteria
- Regular progress updates

2 SUPERVISOR ENGAGEMENT

- Critical role recognition
- Support and training
- Resource allocation

3 TECHNOLOGY INTEGRATION

- Beyond alarm systems
- Identifying chronic issues
- Support program integration

4 IMPLEMENTATION BALANCE

- Self-management emphasis
- Appropriate oversight
- Avoiding micromanagement

5 VALIDATION IMPORTANCE

- Independent verification
- Scientific backing
- Workforce confidence

CRITICAL POLICY CONSIDERATIONS

Zero-Discipline Approach

- Written policy commitment
- Management buy-in
- Consistent application

Legislative Alignment

- Reporting requirements
- Equipment standards
- Operator responsibilities

Privacy Protection

- Data access controls
- Usage guidelines
- Camera footage policies

Equipment Policies

- Non-functioning equipment rules
- Maintenance timeframes
- Alternative controls

Standardized Procedures

- Clear escalation protocols
- Multiple alarm handling
- Pattern recognition response

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CLOSING THOUGHTS

Product innovation from mining, for mining

You can't manage what you don't measure

There is only one DIRECT source of real-time fatigue

Ability to proactively assess the presence of risk on an individual-level

Prevent the incident, not record it

A tool is just a tool - must be supported by a well designed system

Productive and protective

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