



# A "SYSTEMS" APPROACH FOR MANAGING FATIGUE IN MINING OPERATIONS



*Presented by:*  
*Circadian Technologies*  
*Stoneham, MA*

[www.circadian.com](http://www.circadian.com)



# Circadian Technologies, Inc.

- International research and consulting firm for 24-hour operations
- Based in Stoneham, Massachusetts (North of Boston)
- Outgrowth of Harvard Medical School and the discovery of human biological clocks
- Utilizes objective, scientific approach to scheduling and shiftwork issues
- Assist companies improve operating efficiency and overall health, safety & employee work/life balance through development of Fatigue Risk Management Programs (FRMP)



# CIRCADIAN's ® Experience

CTI has been privileged to work in all types of round-the-clock businesses world-wide, where scheduling and shiftwork problems significantly impact productivity, quality, safety, and quality of life, including:

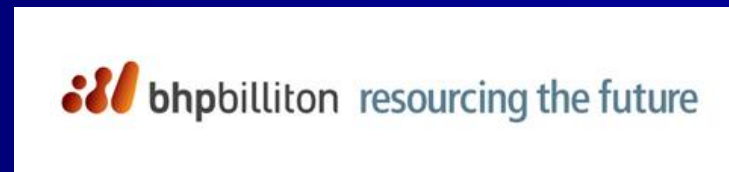
- Mining
- Oil/Chemicals
- Utilities
- Pulp & Paper
- Manufacturing
- Food & Beverage
- Call Centres
- Hospitals
- Police/Fire
- Pharmaceuticals
- Primary Metals
- Railroads
- Aviation
- Marine
- Trucking/Bus
- Mass Transit
- Insurance
- Government
- Banking
- Biopharmaceuticals



# Some of CIRCADIAN's ® Clients



RioTinto







# FATIGUE RISK MANAGEMENT: The Challenge

**Global economy and modern equipment efficiently runs 24/7**



**But human design specs are not**



# INHERENT FATIGUE RISK MANAGEMENT CHALLENGE IN MINING OPERATIONS



MODERN EQUIPMENT AND TECHNOLOGY RUNS  
EFFICIENTLY 24/7...



WE HUMANS DO NOT...



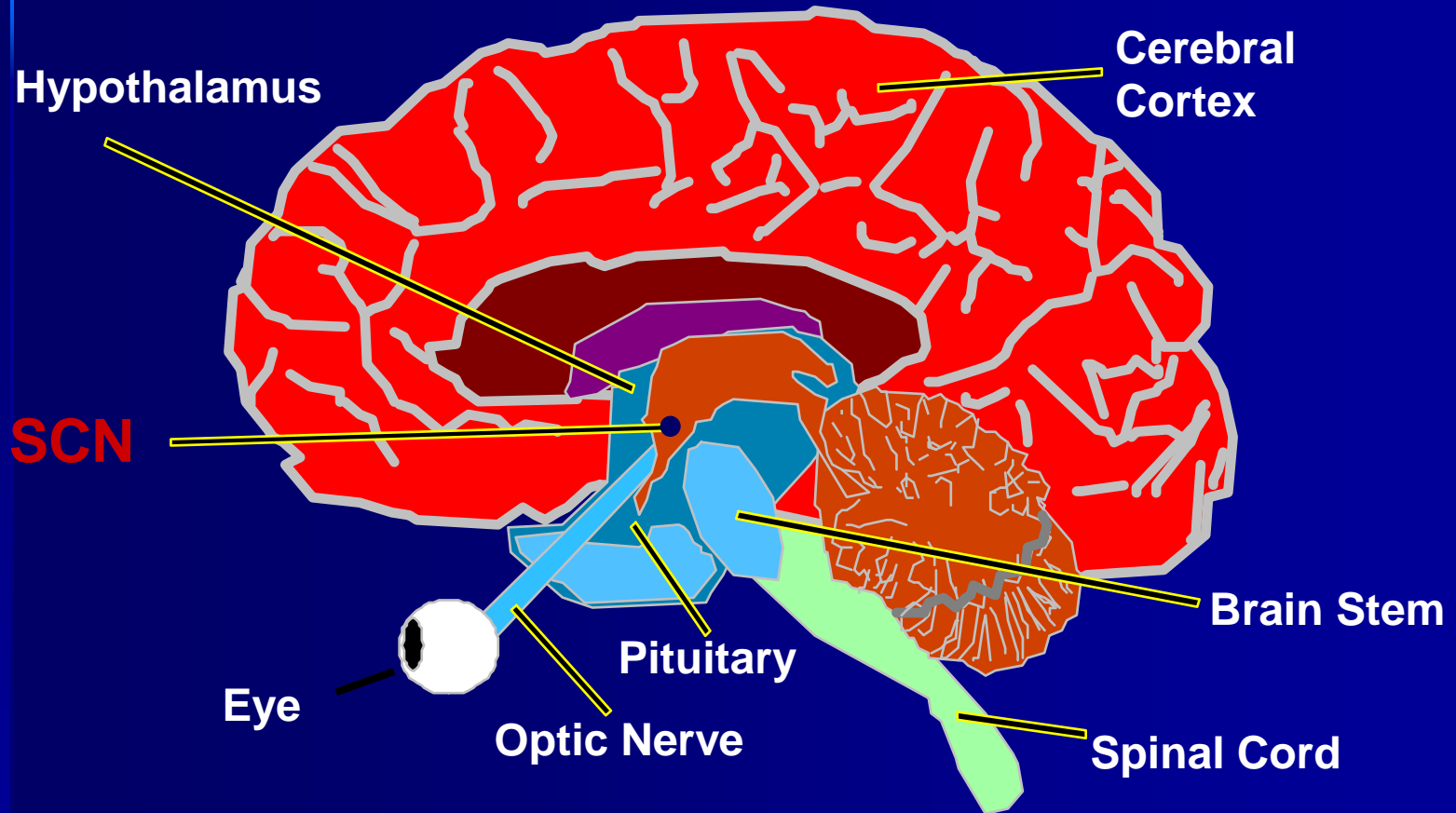
# Design Specs of the Human Body

Humans were not designed for peak performance at night.





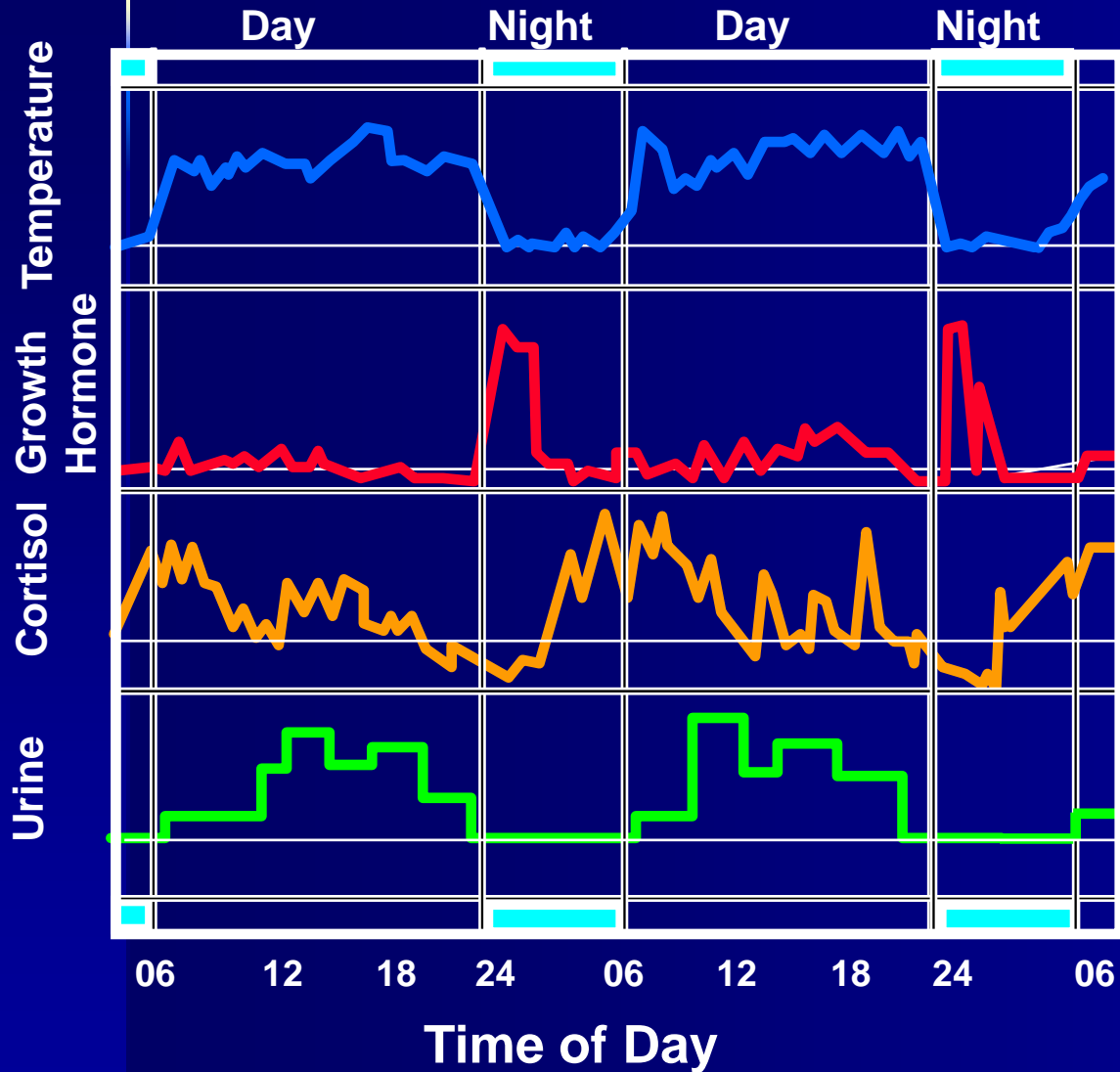
# Suprachiasmatic Nucleus (SCN)







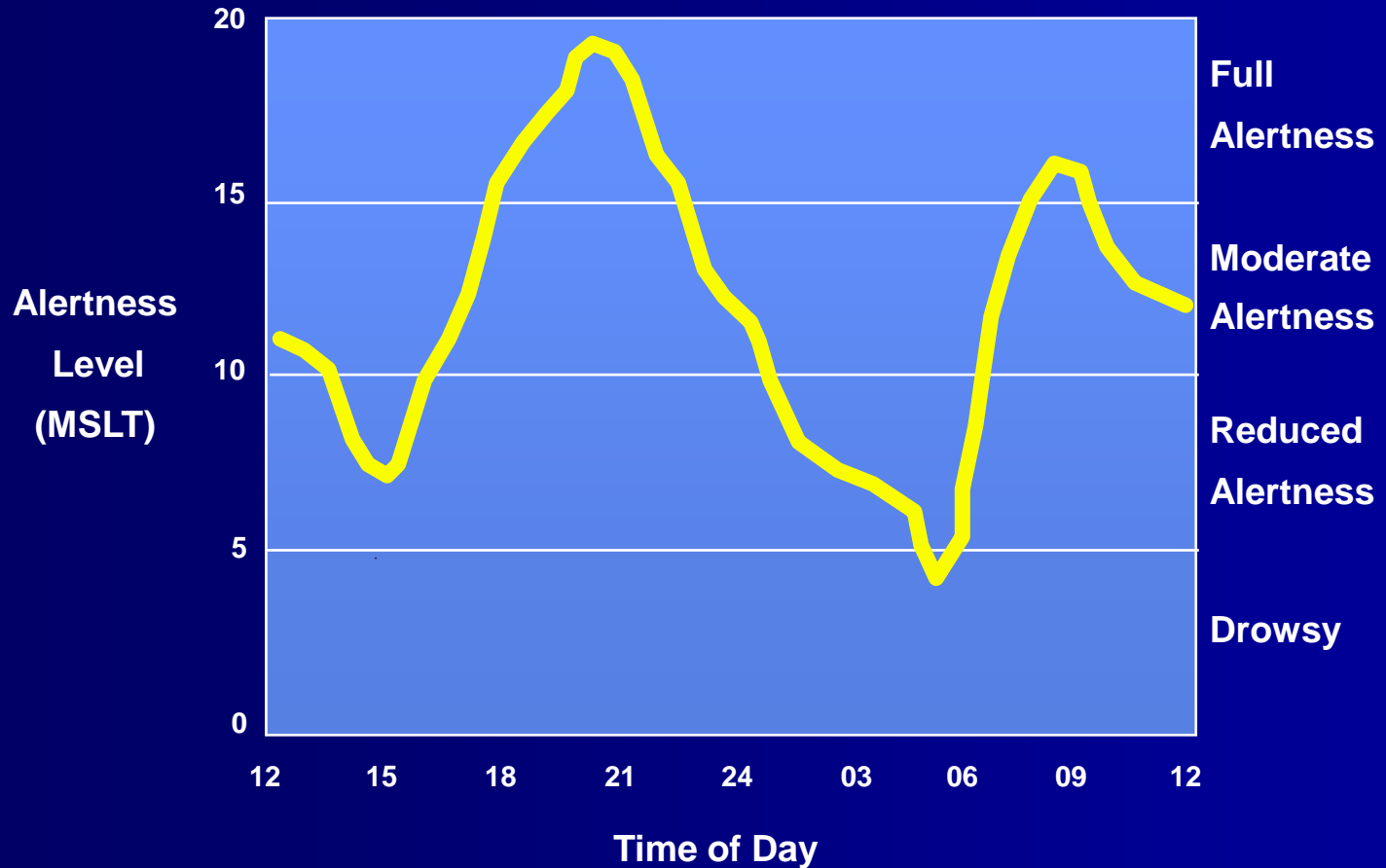
# Daily Rhythms



The body has many circadian rhythms. This chart shows a few of the many bodily functions which exhibit a normal daily rhythm, including (1) core body temperature, (2 & 3) secretion of hormones such as growth hormones and stress hormones like cortisol, and (4) levels of electrolytes such as potassium in the blood and urine.



# Alertness Variability Over 24-Hour Period

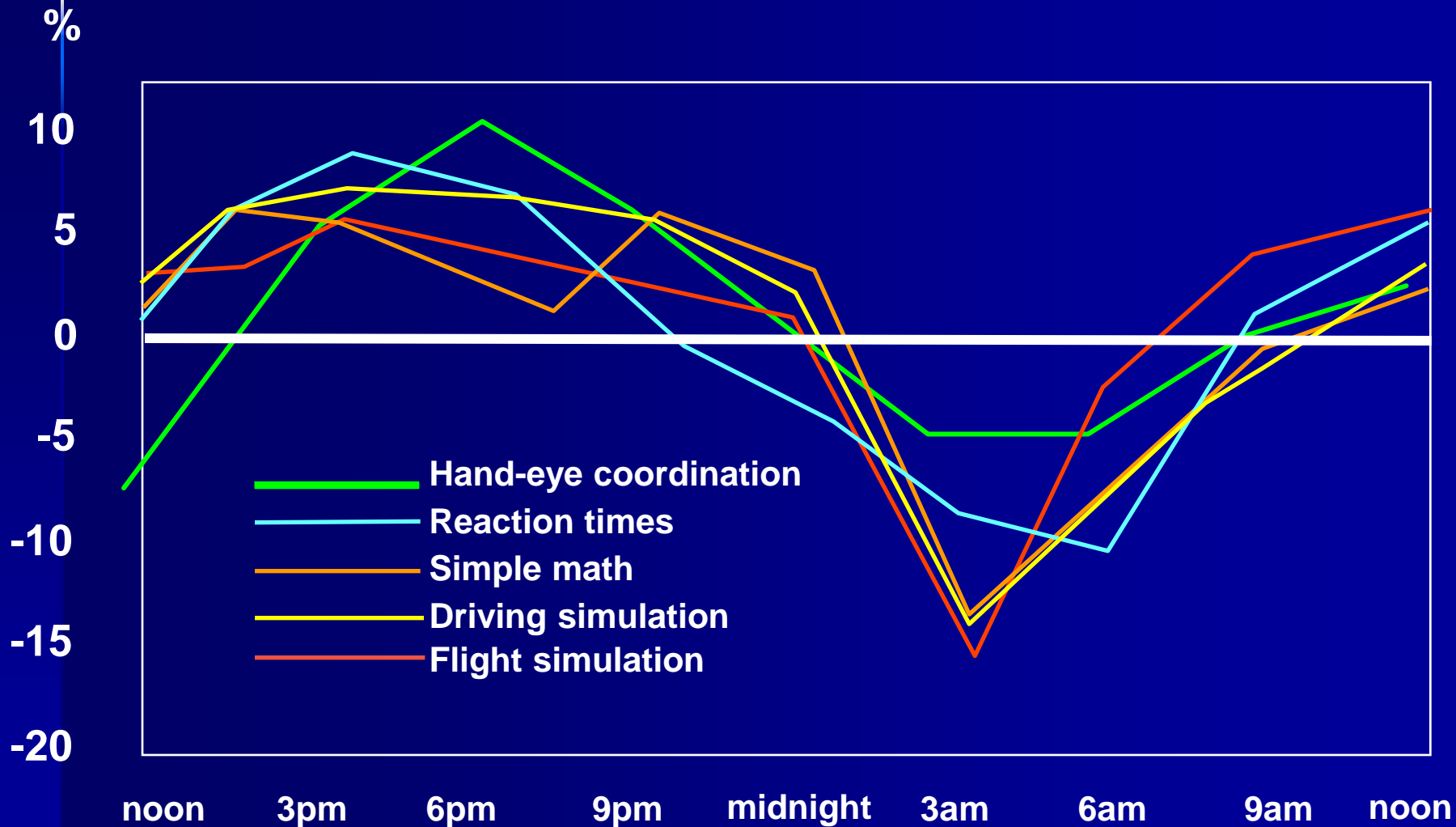


Source: Circadian Technologies, Inc. (1993)



# LAWS OF CIRCADIAN SLEEP PHYSIOLOGY

## Circadian Rhythms in Human Performance



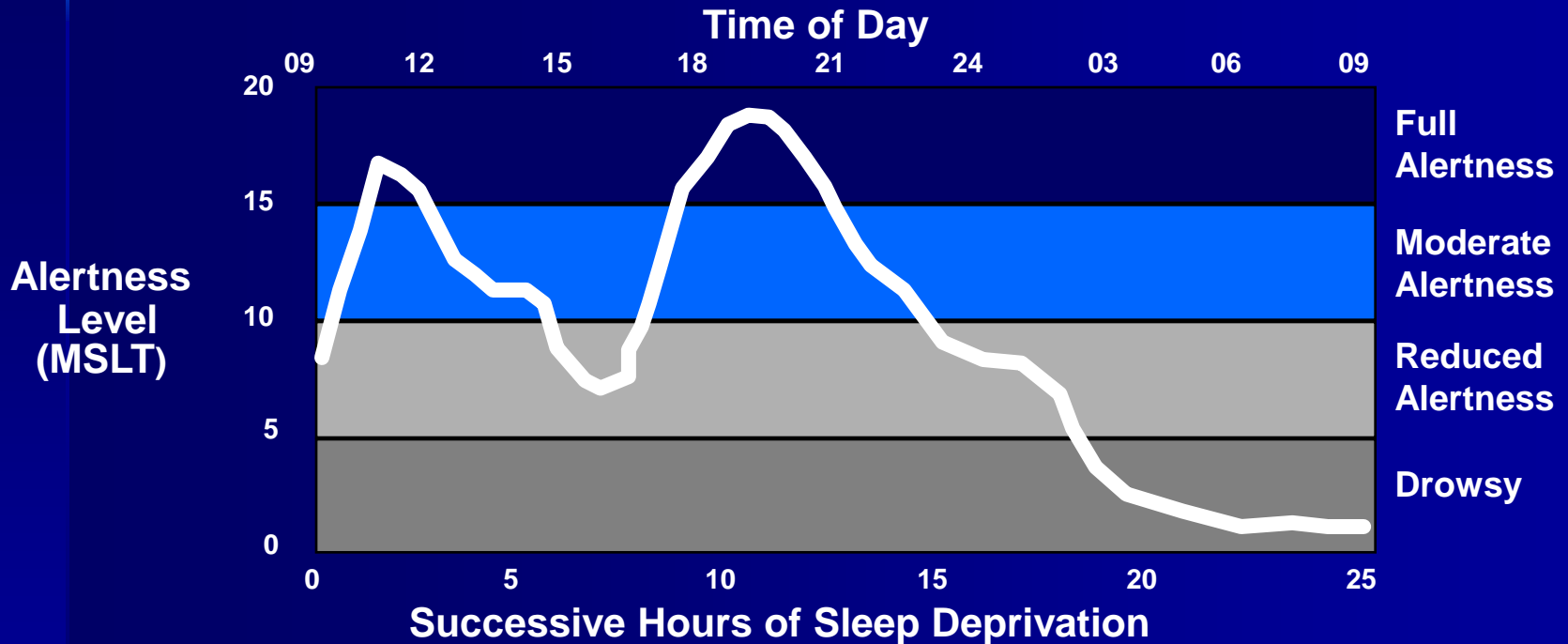
WOCL = Window of Circadian Low

**Time of Day**

Source: Moore-Ede 1993



# DETERMINANTS OF HUMAN ALERTNESS: Extended Hours Without Sleep



Source: Circadian Technologies, Inc. (1993)



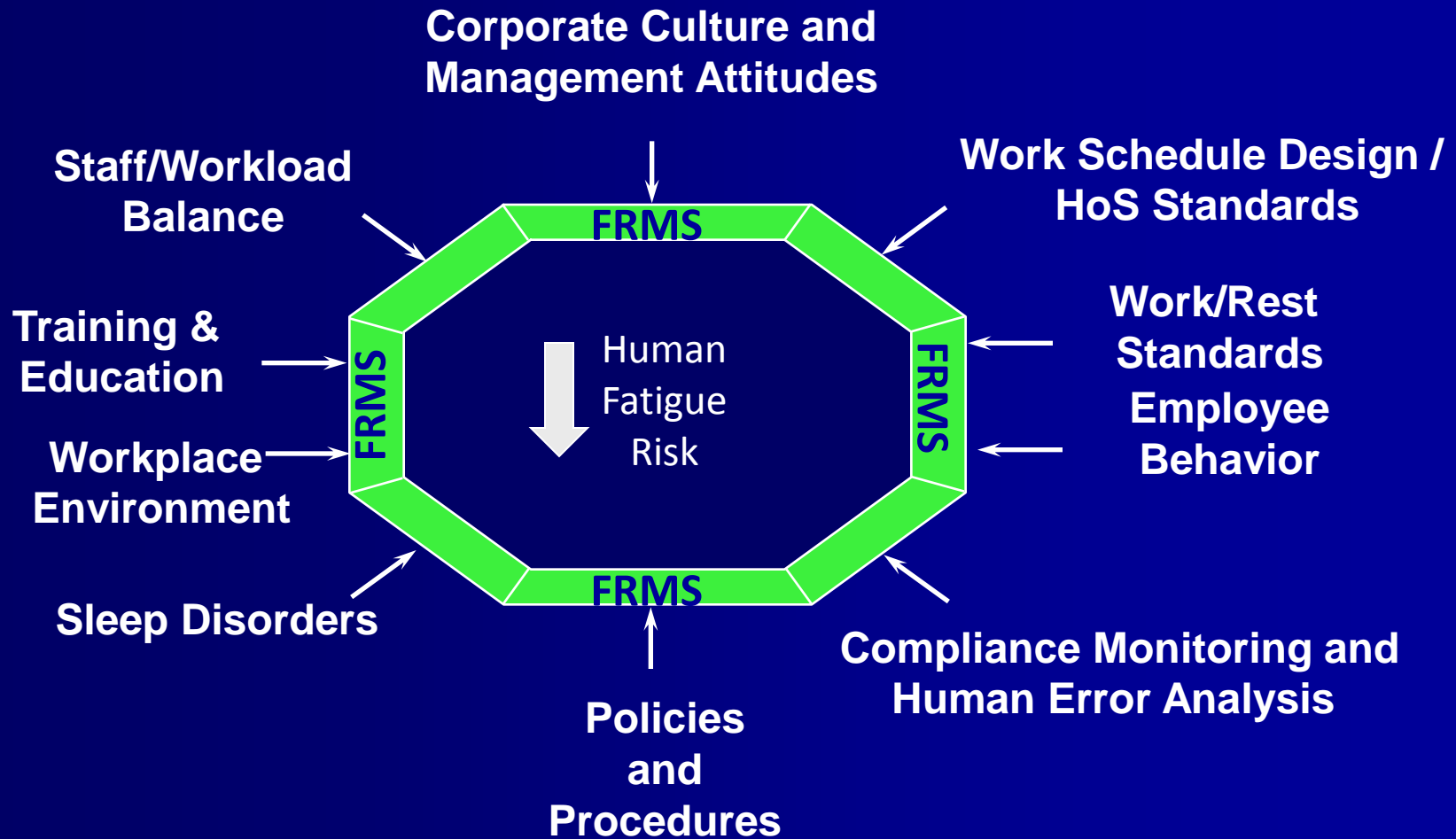


# ***APPLYING FATIGUE MANAGEMENT STANDARDS TO IMPROVE OCCUPATIONAL HEALTH AND SAFETY***

*A cooperative (win-win) effort between management and labor to reduce shiftworker fatigue and its costs for the company and its employees.*



# FATIGUE RISK MANAGEMENT "SYSTEMS" (FRMS) IS A HOLISTIC APPROACH THAT ADDRESSES MULTIPLE SOURCES OF FATIGUE

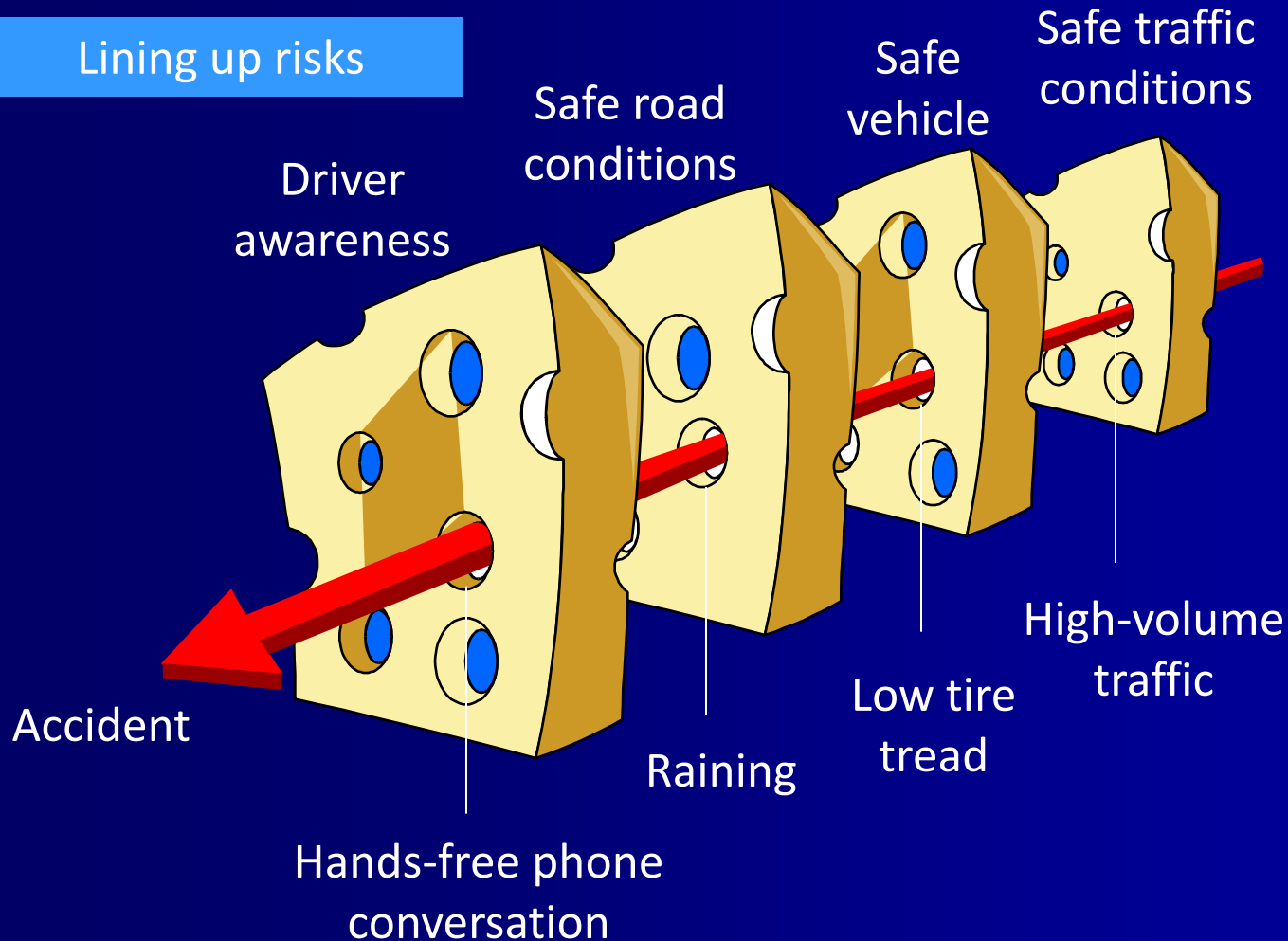




# JAMES REASON'S Multiple Causation Theory



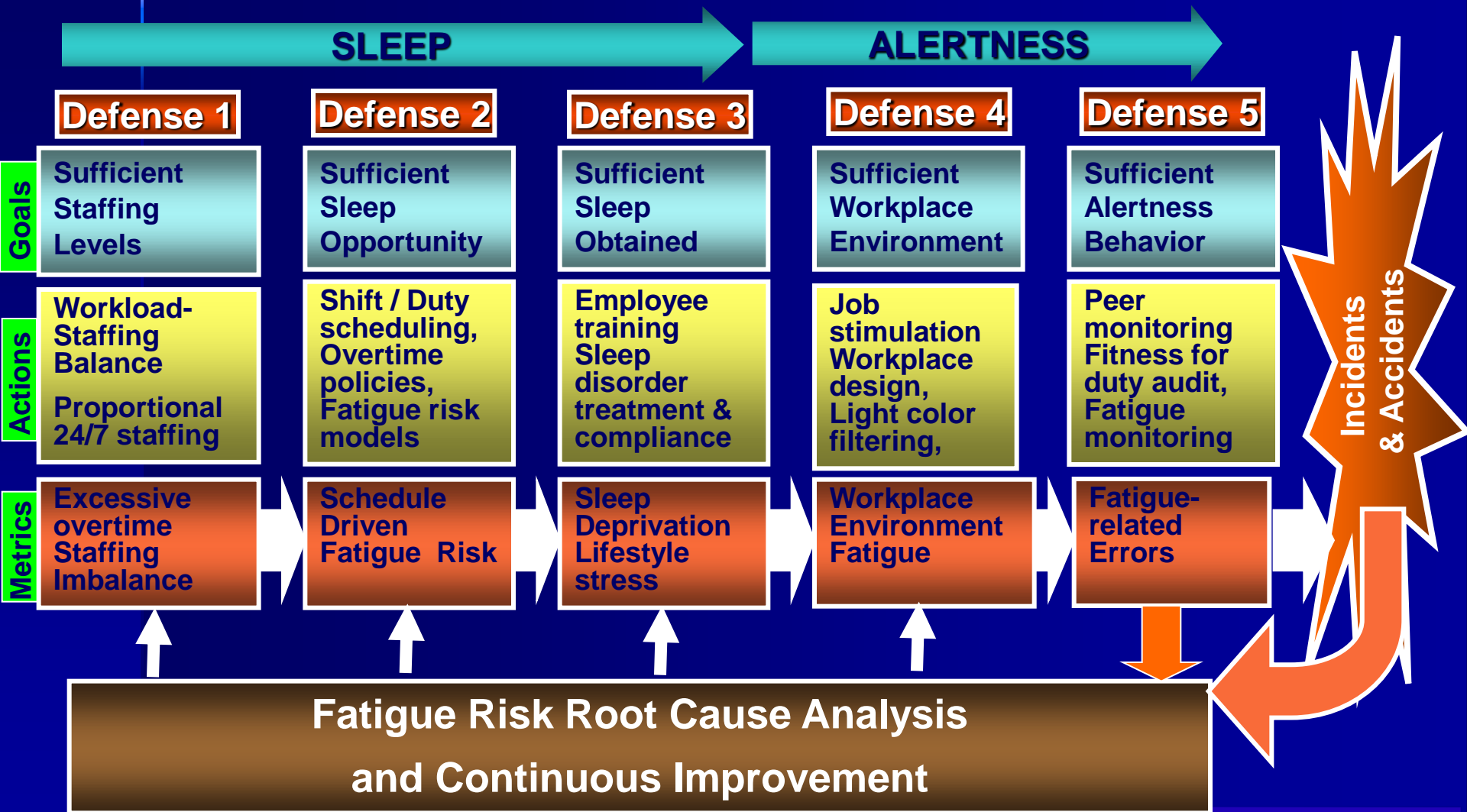
Lining up risks



**Successive layers of defences, barriers, & safeguards**



# INTEGRATED FRMS MODEL







# FRMS Defenses in Depth

## #1. Sufficient Staffing



*Premise: Fatigue can be generated by excessive work hours & lack of rest due to inadequate staffing levels*

### Defense 1

**Goals**  
Sufficient Staffing Levels

**Actions**  
Workload-Staffing Balance  
Proportional 24/7 staffing

**Metrics**  
Excessive overtime Staffing Imbalance

Provide an adequate staffing level to:

- Maintain overtime at or below 10% of an average 40-42 hour work week
- Consistently work within recognized Hours of Service Guidelines
  - Consecutive & total workdays
  - Time off between consecutive shifts and worksets
- Account for and provide coverage for anticipated levels of training, vacations, sickness and other absences



# FRMS Defenses in Depth

## #2. Core Schedule Design:



*Premise: Excessive fatigue can be generated by excessive work hours or lack of rest caused by the core schedule*

### Defense 2

Goals

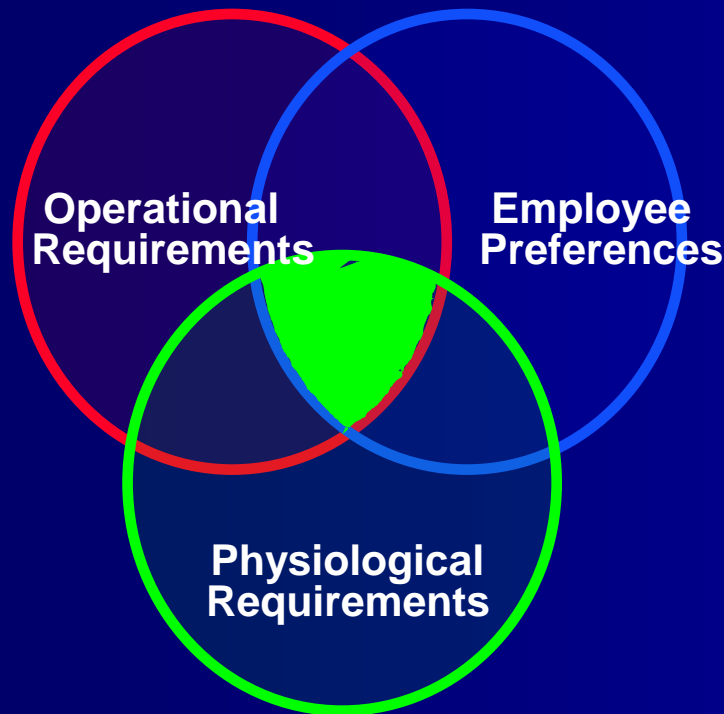
Sufficient  
Sleep  
Opportunity

Actions

Shift / Duty  
scheduling,  
Overtime  
policies,  
Fatigue risk  
models

Metrics

Schedule  
Driven  
Fatigue Risk



Design Biocompatible  
Shift Schedules focused  
On Three Main Criteria

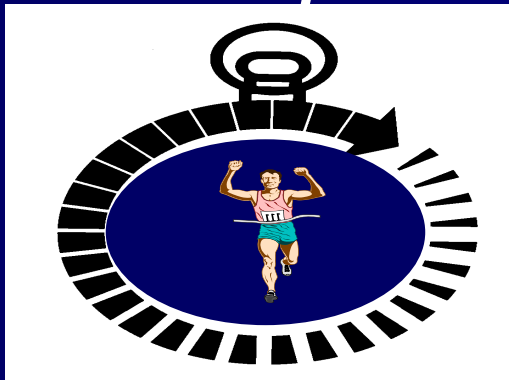


# FRMS Defenses in Depth

## #2. Core Schedule Design:



***Biocompatible***



***Schedules***

**Max Shift Length**  
Routinely:  $\leq 12$  hrs

**Consecutive Workdays**  
7 with 8-hour shifts  
4-5 with 12-hour shifts

**No Start Time Between**  
Midnight - 5:59 a.m.

**Time Off Between Work**  
**Blocks -- No Less than 48**  
**Hours**

**Slow Rotation**  
(easier on body)



# FRMS Defenses in Depth

## #2. Schedule Design: Outer Limits



Operational Situation	12-Hour Shift	10-Hour Shift	8-Hour Shift
<b>Maximum Consecutive Shifts (Day or Night)</b>			
<b>In a Work set</b>			
a) Normal Operations	7 shifts	9 shifts	10 shifts
b) Outages	14 shifts	14 shifts	19 shifts
<b>Minimum time off after a work set</b>			
a) Normal Operations	36 hours	36 hours	36 hours
• Work set of 4 or more night shifts	48 hours	48 hours	48 hours
• After 84 hours or more regardless of day or night	48 hours	48 hours	48 hours
b) Outages	36 hours	36 hours	36 hours
<b>Extended Shifts</b>			
a) Unscheduled maximum shift	18 hours	16 hours	16 hours
b) Time off after shift			
• 10 to 16 hour shift	N/A	N/A	8 hours
• 12 to 16 hour shift	N/A	8 hours	N/A
• 14 to 16 hour shift	8 hours	8 hours	N/A
• >16 to 18 hour shift	10 hours	N/A	N/A
<b>Maximum Number of Extended Shifts per Work set</b>	1	1 for 14 hour shift or 2 for 12 hour shifts or for 3 or more 12 hour shifts, follow 12 hour normal operations guidelines above	2 if greater than 12 hours in duration; extended shifts must be non-consecutive. If >2, follow 12 hour normal operations above





# FRMS DEFENSES IN DEPTH

## #3: SHIFTWORK LIFESTYLE TRAINING



*Premise: Fatigue can be minimized by providing employees and managers with training on how to improve sleep and minimize unique stress factors that comes with shift work*

### Defense 3

**Goals**  
Sufficient  
Sleep  
Obtained

**Actions**  
Employee  
training  
Sleep  
disorder  
treatment &  
compliance

**Metrics**  
Sleep  
Deprivation  
Lifestyle  
stress

- Basic sleep, circadian, and fatigue physiology
- Strategies for achieving good quality, restorative sleep including sleeping quarters design
- Recognizing symptoms of sleep disorders
- **Managing an alert and healthy lifestyle**
- Understanding risks of fatigue impairment
- Recognizing the signs of fatigue impairment and ways to mitigate them



# FRMS DEFENSES IN DEPTH

## #3: SHIFTWORK LIFESTYLE TRAINING



Most of the digestive problems for shiftworkers can be summed up in one phrase:

**“Eating the Wrong Food at the Wrong Time”**





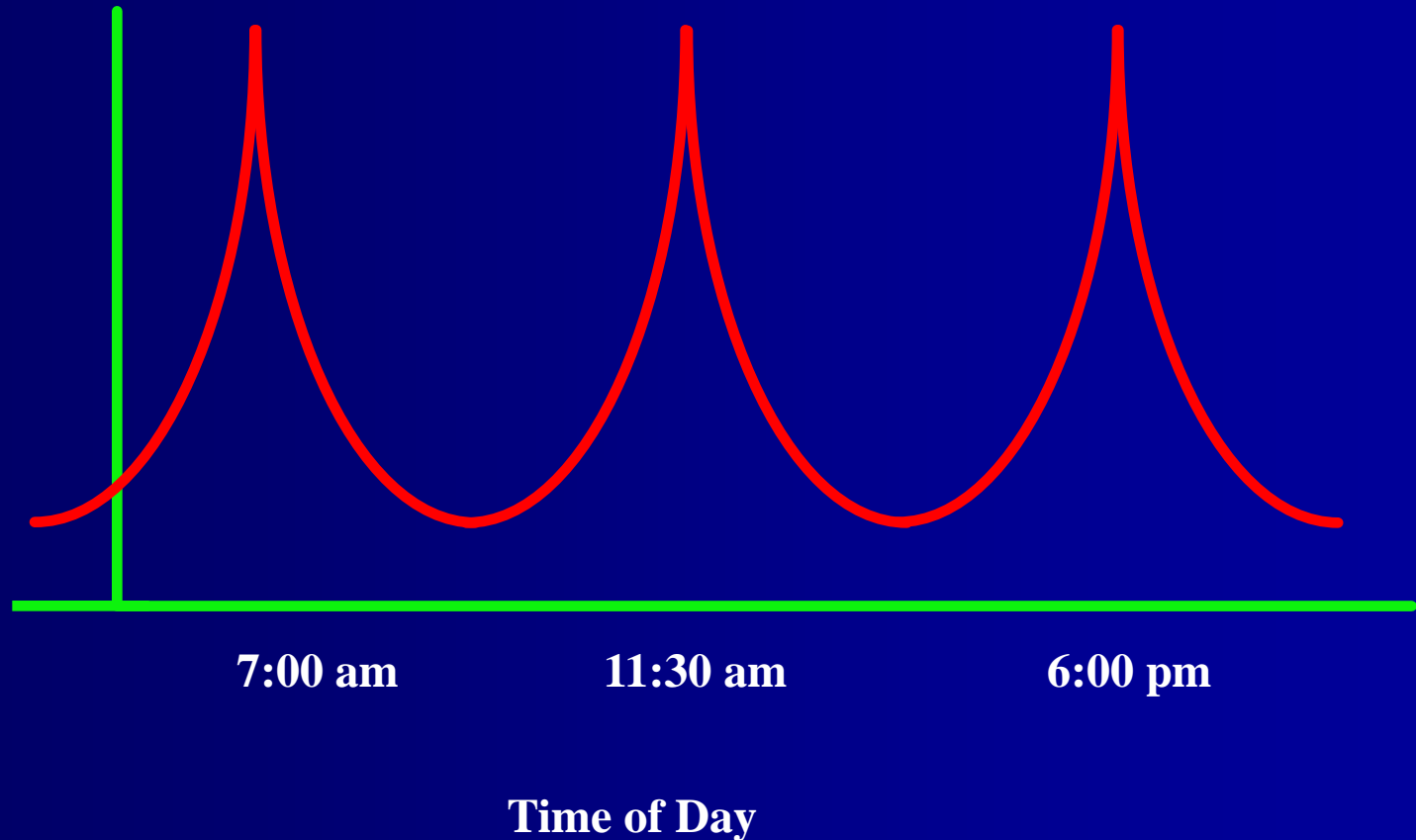
# FRMS DEFENSES IN DEPTH

## #3: SHIFTWORK LIFESTYLE TRAINING



### Your Biological Clock and Your Stomach

Typical  
Daytime  
Schedule



**Your stomach anticipates meal times in the day**



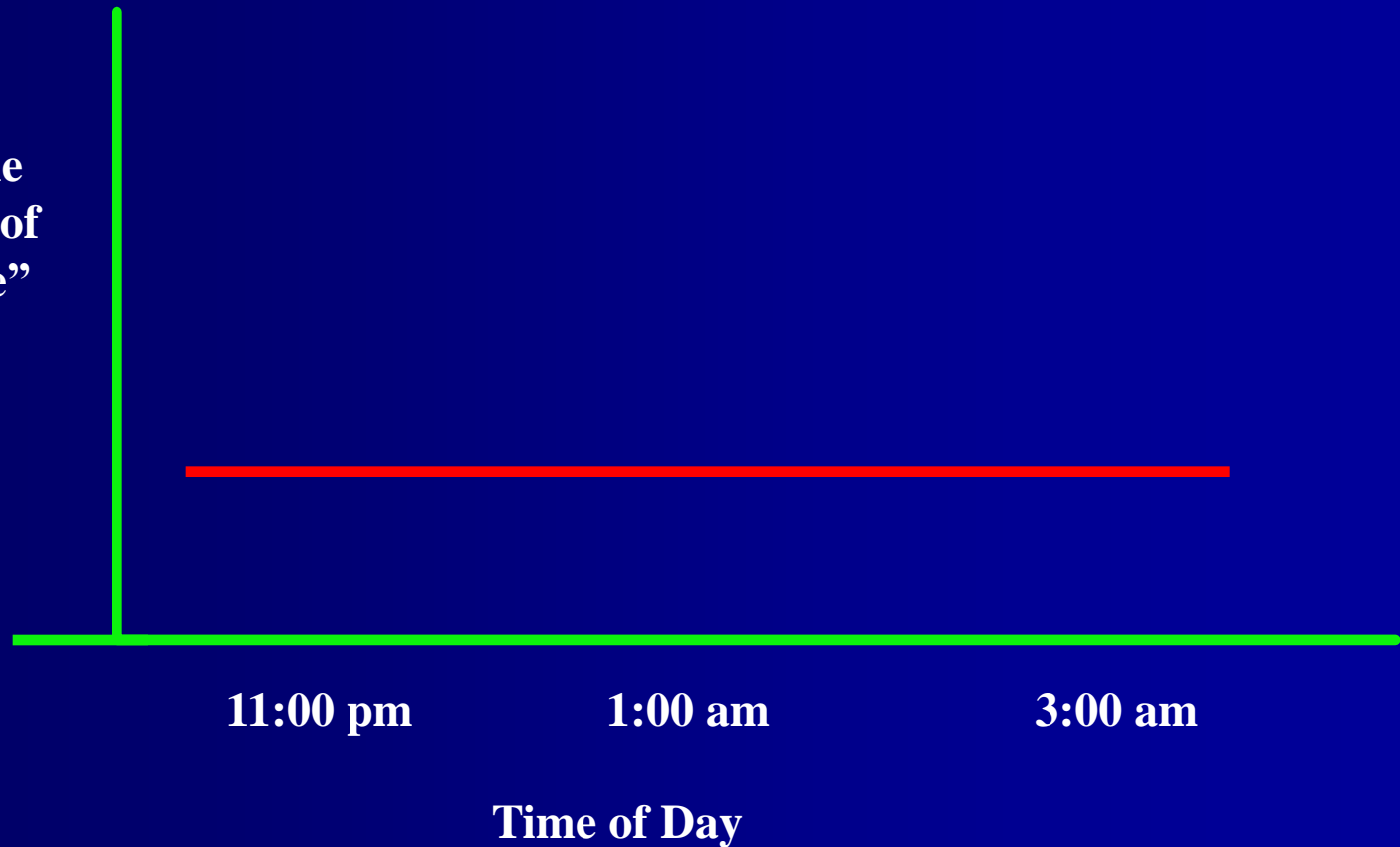
# FRMS DEFENSES IN DEPTH

## #3: SHIFTWORK LIFESTYLE TRAINING



### Nighttime Rhythms of Stomach Enzymes

Typical  
Nighttime  
Schedule of  
“Daytime”  
Person



**At night, your stomach does not expect to digest food**



# FRMS DEFENSES IN DEPTH

## #3: SHIFTWORK LIFESTYLE TRAINING



### Caffeine...The Pro's:

- Can increase alertness
- Can improve reaction time
- Can improve performance
- Can improve overall energy
- Works quickly (in about 30 minutes)
- The effects last for 3-5 hours in most people





# FRMS DEFENSES IN DEPTH

## #3: SHIFTWORK LIFESTYLE TRAINING



### The Cons:

- Can cause gastrointestinal problems
- Stays in the body for several hours
- Caffeine is addictive; a dependence can develop
- May worsen some sleep disorders
- High levels promote stress, anxiety and irritation
- Coffee is a mild diuretic (increases urine production)
- Cutting back can cause withdrawal symptoms



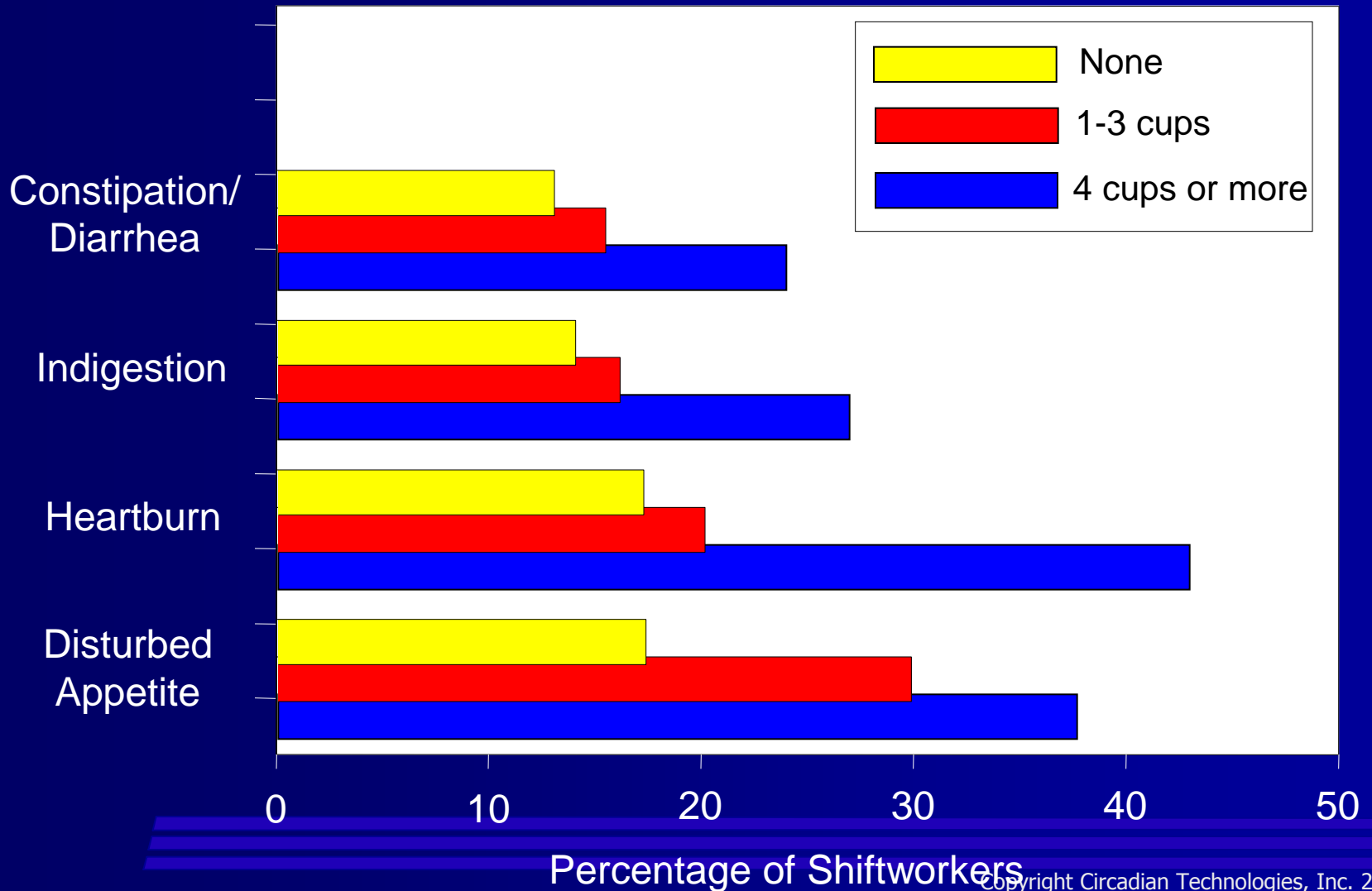


# FRMS DEFENSES IN DEPTH

## #3: SHIFTWORK LIFESTYLE TRAINING



Relationship between caffeine use (cups/day) and frequency of gastrointestinal problems. Source: Circadian employee database





# FRMS DEFENSES IN DEPTH

## #3: SHIFTWORK LIFESTYLE TRAINING



### Energy Drinks

- **Becoming ever more popular**
- U.S. sales were \$10 billion+ in 2012
  - Especially among younger shiftworkers (prefer over coffee)
- **Where does “energy” come from?**
  - Caffeine
  - Sugar
  - Vitamins (e.g. B12, B6, B3)
  - Amino Acids (e.g. Taurine, L-Carnitine)
  - Herbs and other natural (e.g., Ginseng, Guarana)
- **Classified as “Dietary Supplements” by FDA**
  - Energy claims do not have to be proven scientifically
  - Do not need to disclose amount of each ingredient
  - Soda classified as a “functional food” – must list precise ingredients



# 5-Hour Energy



- 4 calories
- caffeine based
- sugar free
- contains B vitamins and amino acids
- fruit flavored
- called a "dietary supplement"
- touted as a "pick me up" to increase alertness and energy
- company claims it "significantly" outperforms placebos in attention and alertness tests
- company tests haven't been published or peer reviewed to screen biases
- independent tests show that it contains about 207 mg of caffeine, compared to an 8 ounce serving of Starbucks coffee, which has 180 mg
- no research to suggest that B vitamins or amino acids provide any boost





# FRMS DEFENSES IN DEPTH

## #4: Sufficient Workplace Environment



### Defense 4

**Goals**  
Sufficient Workplace Environment

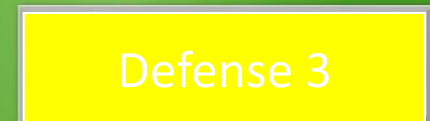
**Actions**  
Job stimulation  
Workplace design,  
Light color filtering,

**Metrics**  
Workplace Environment  
Fatigue

Premise:  
Fatigue can be significantly impacted by work environment



Six of the nine switches of alertness are influenced by job design and workplace environment





# FRMS DEFENSES IN DEPTH

## #5 FATIGUE MONITORING AND RISK MITIGATION.



*Premise: Even when staffing levels, schedules, training and work environmental have been optimized, fatigue can still be present and means to detect fatigue and intervene prior to incident are necessary.*

**Policies and Procedures**  
**Technologies**

### Defense 5

**Goals**  
Sufficient  
Alertness  
Behavior

**Actions**  
Peer  
monitoring  
Fitness for  
duty audit,  
Fatigue  
monitoring

**Metrics**  
Fatigue-  
related  
Errors



# FRMS DEFENSES IN DEPTH

## #5 FATIGUE MONITORING AND RISK MITIGATION.



### Technology

- Camera based, non-contact, non-intrusive sensor observing the driver
- Measures eyelid closure
- Measures head orientation

### Event Types Detected

- Fatigue events characterised by extended eye closure duration > 1.5sec / speed > 4mph
- Distraction events characterised by glances away from the road duration > 4.5sec / speed > 10mph



*Technology alone is not the “silver bullet”*





# FRMS Defenses in Depth

## # 6 Fatigue: Root Cause Analysis



Investigations of incidents should be conducted in a manner that facilitates the determination of the role of fatigue as a root or contributing cause

Information collected should include:

- Time of the incident
- Shift pattern, including the number of consecutive shifts worked
- The number of hours awake
- The number of hours of sleep in the past 24-72 hours by the individuals involved
- Shift duration and any overtime worked
- Operational condition: normal operation, extended shift, call out, outage

Since it is common that no definitive conclusion can be reached on the role of fatigue in an individual incident investigation, a periodic aggregate analysis of incidents should be conducted to look for patterns suggestive of fatigue





# FRMS Defenses in Depth

## # 6 Fatigue: Root Cause Analysis



### Fatigue Accident / Incident Causation Testing System (FACTS)

FACTS HOME    ENTER NEW CASE    CHANGE PASSWORD    ADMIN    LOGOUT

#### ENTER A NEW CASE

Your Incident/Accident ID (optional)

Facility / Region ID

#### Timing of the Incident

What was the Date of the incident ?

02/13/2011

What time of the day did the incident occur?

4 AM

How many hours prior to the time of the incident, did his/her last sleep episode end?

5

At the time of the incident, what kind of activity was the individual performing?

Operating a Vehicle(as part of job)

At the time of the incident, how many hours had the individual been on duty?

3

#### Sleep during the nights/days prior to the incident

The following set of questions tries to collect information about how much and how well the individual sleep in the last 3 days/nights.

How many hours of sleep did the individual get in the 24 hours prior to the incident? (include main sleep and naps)

2

### Fatigue Accident / Incident Causation Testing System (FACTS)

FACTS HOME    ENTER NEW CASE    CHANGE PASSWORD    ADMIN    LOGOUT

#### FACTS CASE RESULTS

Thank you for filling out the FACTS questionnaire.  
Based on the information you provided, FACTS determined the following result:

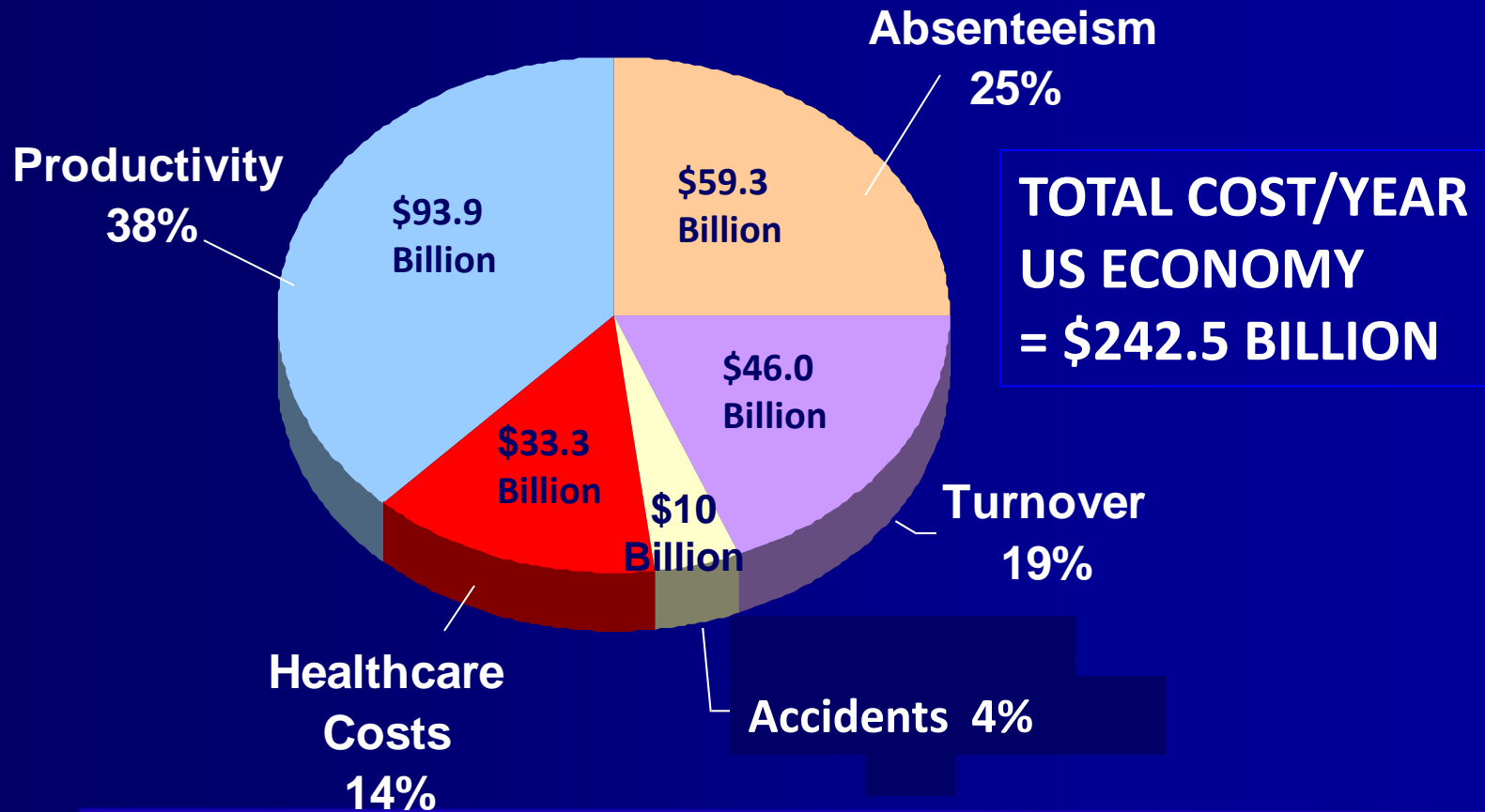




# EXCESS COSTS OF FATIGUE IN SHIFTWORK OPERATIONS



Total excess cost of increased absenteeism, turnover, health care, incidents & accidents and productivity loss averages **\$10,100 per shiftworker per year**





# Safety Costs: Haulage Truck Accidents



- 77% of serious injuries occurred at strip or open pit mines (3 times higher than other mining operations)
- **Driving over the edge resulted in 37% of serious injuries and 85% of fatalities.**
- 93% of surface mine haulage truck accidents due to **human error**
- 60-70% of **human error** accidents are **fatigue-related**



Source: "Safety Analysis of Surface Mining Accidents," MSHA, 1998 and "Haulage Truck Dump Site Safety," MSHA & NIOSH, 2001



# CONCLUSION:



- Fatigue is inherent in all shiftwork operations
- Fatigue directly correlates with human error and accidents
- Costs, risks and liabilities of fatigue are substantial (minimum \$10,100 per 24/7 employee, excluding collateral costs, productivity loss, and litigation costs)
- New analytics provide ability to quantify costs of fatigue, justify FRMS, and monitor/control ROI results
- New standards provide guidelines / roadmaps for FRMS development
- FRMS DOES PROVIDE A PATHWAY TO THE NEXT STEP CHANGE IN HSEQ AND HUMAN PERFORMANCE



**CIRCADIAN®**

**24/7 WORKFORCE SOLUTIONS**

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