Crew Endurance Management Practices

CREW ENDURANCE MANAGEMENT
USCG R&D CENTER

A Guide for Maritime Operations

United States Coast Guard

U. S. Coast Guard Research and Development Center

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CREW ENDURANCE MANAGEMENT PRACTICES
A Guide for Maritime Operations

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16. Abstract (MAXIMUM 200 WORDS)

This guide presents a formal program of practices (the Crew Endurance Management System) for controlling risk factors that affect crewmember performance and shipboard safety in the commercial maritime industry. The CEMS program is overviewed; a real-world example is provided; techniques for managing crewmember energy and performance levels are provided; operational risk factors affecting crewmember energy and performance levels are addressed; procedures for implementing a CEMS program are described; and supplementary materials are provided.

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FOREWORD

In maritime operations, professional mariners are exposed to a variety of operational risk factors, including erratic work schedules, extreme temperatures, frequent separation from loved ones, and heavy workloads. These risk factors can have a negative impact on productivity and safety.

The ability of crewmembers to cope with operational risk factors depends on their level of endurance. The responsibility for maintaining a high level of crew endurance rests with company officers, operation managers, safety and human resource managers, vessel captains, department heads, mates, as well as with crewmembers.

This guide is specifically designed to help maritime companies ensure the highest possible levels of performance and safety. Users of this guide will be able to (1) identify specific factors affecting crew endurance in their particular operations, and (2) manage these factors toward optimizing crewmember endurance.

CAPT Jeffery G. Lantz, Chief
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EXECUTIVE SUMMARY

Normal maritime operations expose crewmembers to a variety of operational risk factors, such as irregular work periods, temperature extremes, heavy workloads, and extended separations from family members. Left unmanaged, these risk factors can degrade crewmember endurance, and thereby both performance and safety levels.

In response to this situation, the U. S. Coast Guard has developed the Crew Endurance Management System (CEMS), a set of tools and practices maritime operators can use to manage productivity and safety levels in their operations. CEMS specifically helps operators identify the operational risk factors affecting crew endurance in particular situations, and to control these risk factors by means of proven practices and procedures.

These proven practices and procedures apply to the full scope of endurance management, not simply to sleep management. In other words, crew endurance management encompasses the full range of environmental, physiological, operational, and psychological risk factors affecting performance and safety in normal maritime operations.

Section I introduces the concept of Crew Endurance Management; Section II provides a quick, real-world example of a CEMS implementation; Section III describes how to use light-management techniques to match energy level with time-of-day workload; Section IV provides practical recommendations for controlling operational risk factors such as temperature extremes, stress, and caffeine use; and Section V describes how to design, implement, and evaluate CEM plans aboard maritime vessels.

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GLOSSARY

Biological clock

The ‘mechanism’ within the brain that regulates physiological and cognitive resources throughout the day. See also *Circadian rhythms*.

CEM – see Crew Endurance Management

CEM coach

Person responsible for monitoring crewmember adherence to CEM practices, and for providing guidance and training when necessary.

Circadian desynchronosis

A syndrome characterized by jet lag-like symptoms induced by seeing light (natural or artificial) at inappropriate times of the day.

Circadian dip

A low point in the normal daily rhythm (cycle) of body energy and wakefulness. See also *Circadian rhythm*.

Circadian rhythms

The daily ebb and flow of body energy and alertness over the course of a 24-hour period. See also *Biological clock*.

Coach – see CEM coach

Crew Endurance

The ability to maintain performance within safety limits while enduring job-related physical, psychological, and environmental challenges.

Crew Endurance Management

A system for managing the risk factors that can lead to human error and performance degradation in maritime work environments.

Desynchronosis – see circadian desynchronosis

Endurance risk factors

Factors such as heavy workloads sleep debt, and caffeine addiction that can threaten operational safety and crewmember efficiency in the maritime industry. See also *Performance stressors*.

Endurance – see Crew Endurance

Final Common Path

A CEM deployment strategy in which a team of onboard coaches monitors crewmember adherence to implemented CEM practices, and provided guidance and training when necessary. See also *CEM coach*.

Insomnia

Chronic inability to get to sleep and/or to remain asleep.

Light management

The practice of using a regimen of controlled light exposures to adapt the body clock for a new sleep-work schedule; that is, to shift the Red Zone. See also *Red Zone*.

Lux

Standard measurement for light intensity: one lumen per square meter.

Maladaptation

Shifting into a new sleep-work schedule without adjusting the biological clock.

Performance stressors

Factors such as motion sickness, psychological stress, and caffeine addiction that can individually or collectively have a severe impact on safety and endurance in maritime operations. See also *Endurance risk factors*.

Protocol

The plan or design for a scientific experiment or treatment.

Red Zone

The daily period of lowest energy and alertness, normally occurring between bedtime and sunrise.

Risk factors – see endurance risk factors

Sleep inertia

The tendency, after awakening, to feel sleepy and sluggish.

Synergistic

Characterized by synergism, or the ability of two agents to create an effect neither agent is capable of creating on its own.

Stamina

Synonym for endurance.

Stressors – see performance stressors

Working Group

A committee charged with the responsibility for implementing all aspects of a CEM program.

About This Guide

Purpose

This guide is specifically intended to help maritime operators maximize crew performance and safety by identifying and controlling factors affecting crew endurance in normal operations.

PURPOSE: This guide provides proven practices for managing endurance risk factors (sleep loss, stress, heat, cold, etc.) that affect operational safety and crewmember efficiency in the maritime industry.

Audience

This guide is intended for:

- Boat captains, pilots, engineers, mates, and all crewmembers interested in safety and health
- Dispatchers charged with distributing workload and assignment of personnel to fulfill operational demands
- Trainers charged with teaching crewmembers about: (1) the harmful effects of normal operational risk factors on crewmember performance, and (2) how to control these risk factors
- Company port captains and operations managers charged with maintaining operational safety
- Coast Guard Marine Safety Offices

Contents

Section I of this guide introduces the concept of Crew Endurance Management (CEM) and the factors (including the Red Zone, defined later) that degrade crew endurance.

Section II provides a real-world example of a CEM program implemented on a maritime vessel.

Section III describes and illustrates how to manage the Red Zone (daily period of least energy and alertness) toward optimizing crew endurance in maritime operations.

Section IV provides specific guidance on how to control operational risk factors that can degrade crew performance and compromise shipboard safety.

Section V provides practical recommendations on how to implement crew-endurance management practices.

How to Use This Guide

Key concepts are highlighted in boxes. The information contained in these boxes is supported by the surrounding text. (Additional supporting information is available in the Appendices.)

Of particular interest are the boxes labeled **Management Nuggets**, which contain key concepts for leaders and managers to use toward making immediate improvements in crew endurance.

It is recommended you approach using this guide as follows:

- First, scan the guide and read the key information in the boxes
- Next, read the entirety of Sections I and II (*Overview* and *Quick Example*)
- Finally, read the remainder of the guide

This guide is not intended to replace guidelines currently in Oil Pollution Act of 1990 (OPA 90) or Standards of Training, Certification and Watchkeeping for Seafarers (STCW) regarding hours of work and rest. The fundamental purpose of this guide is to provide managers, captains, department heads, and officers with tools to manage normal operational risk factors that can degrade crew performance and compromise shipboard safety.

Leaders should use this information, along with the guidelines provided in OPA 90 and STCW:

- To identify risk factors affecting crew endurance in specific operations
- To implement proven CEMS practices to control these risk factors

The Crew Endurance Management practices provided in this guide, particularly those involving adaptation to nighttime work hours, work schedules, policy modifications, and vessel environmental improvements, were implemented during normal operations aboard vessels graciously made available to us by our partners in the Inland Towing Industry (refer to Acknowledgments).

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SECTION I

Managing Crew Endurance: A Quick Overview

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I. Managing Crew Endurance: A Quick Overview

This section (I) outlines how maritime operators can optimize performance and safety by managing risk factors affecting Crew Endurance.

Crew Endurance in Maritime Operations

The 24-by-7 nature of the maritime industry exposes crewmembers to a number of risk factors (sustained wakefulness, temperature extremes, and unpredictable workloads, for example) that can degrade crew endurance – that is, the physical stamina and mental alertness of the crew – and thereby performance and safety.

Optimizing crew endurance on a 24-hour basis is a paramount goal within the maritime industry.

BASICS: Crew Endurance refers to the ability to maintain performance within safety limits while enduring job-related physiological, psychological, and environmental challenges.

While vessel endurance is a function of how long a vessel can support operations without replenishment or maintenance, crew endurance is a function of operational risk factors. These factors include the psychological state of crewmembers, their level of physical conditioning, their threshold of motion discomfort, the quality and duration of their sleep, their diet, and the stability of their internal timing system (biological clock).

Each of these factors can degrade crew endurance by depleting crewmember energy stores or by reducing the level of crewmember alertness. The overall level of shipboard productivity and safety, therefore, depends on the overall level of crewmember endurance.

Basics: Ambient temperature, humidity, light, noise, and vibration are examples of environmental risk factors that can degrade stamina and alertness, and thereby both productivity and the safety of operations. Another category of risk factors includes company policies and shipboard practices. A third category includes work-related stress, irregular sleep periods, and adverse working conditions.

The Crew Endurance Management (CEM) practices provided in this guide are intended to help maritime operators optimize crew endurance by helping them identify and manage specific risk factors, such as stress and temperature extremes, affecting their operations (see Section IV).

Crew Endurance Management

Crew Endurance Management is a formal program of proven practices for optimizing crewmember productivity and safety by means of:

- Managing the Red Zone (daily period of lowest energy) of crewmembers
- Controlling endurance risk factors

Managing the Red Zone

The human body is naturally oriented toward expending energy during daylight hours and resting (restoring energy) during nighttime hours. The amount of energy available over a 24-hour period, therefore, normally peaks in daylight and bottoms out in darkness. Because performance tends to correlate with available energy, the human body tends to function most efficiently in daylight, when the energy level is highest, and least efficiently in darkness, when the energy level is lowest.

In this guide, the daily period of lowest energy and performance is referred to as the **Red Zone**. See Figure 1.

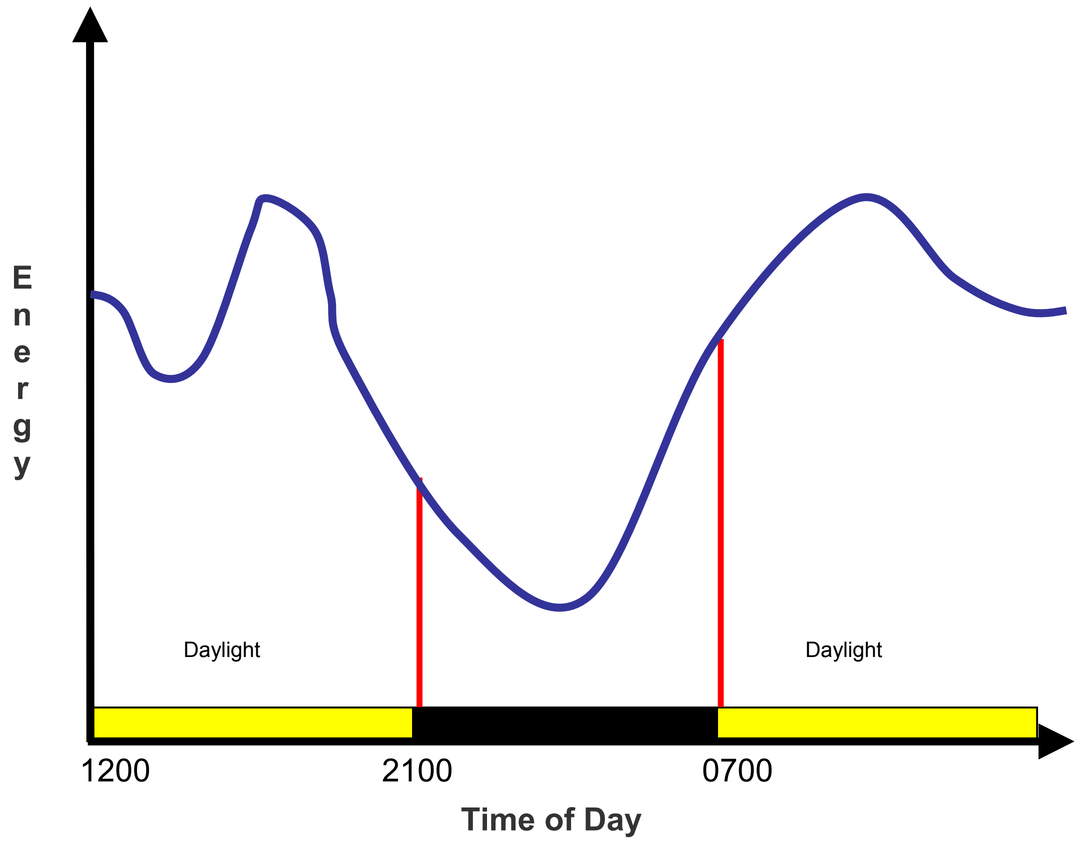

Figure 1. The **Red Zone** of energy and performance

For crewmembers accustomed to sleeping at night (typically 2300-0700), energy and alertness increase steadily throughout the early morning hours, reach a daily peak near mid-morning (1000), dip in the afternoon (1300-1600), increase again to another daily peak in the early evening (around 1800), and then decrease steadily during the night, reaching a daily low in the early morning hours (approximately between 0300 to 0500).

The **Red Zone** is defined as the daily period when energy and alertness are at their lowest levels, typically spanning from bedtime to sunrise, **with the most-critical period spanning from 0300 to sunrise**. In the case illustrated in Figure 1, the full Red Zone spans from 2100 until 0700[1].

Several factors can influence the duration as well as the intensity of individual Red Zones, including crewmember sleep, social, and dietary habits; the current period of sustained wakefulness; and accumulated sleep debt.

[1] Red Zone time frames tend to vary with the chronotype of the individual, with some individuals being prone to sleep late into morning hours; others, to wake up with the birds.

Although nighttime is usually considered a period of increased operational risk, proven light-management techniques can be used to cause crewmember energy and alertness levels to peak during nighttime hours instead of during daylight hours. In other words, the Red Zone of individual crewmembers can be shifted, as needed, to accommodate 24-by-7 watch and workload schedules. See Figure 2.

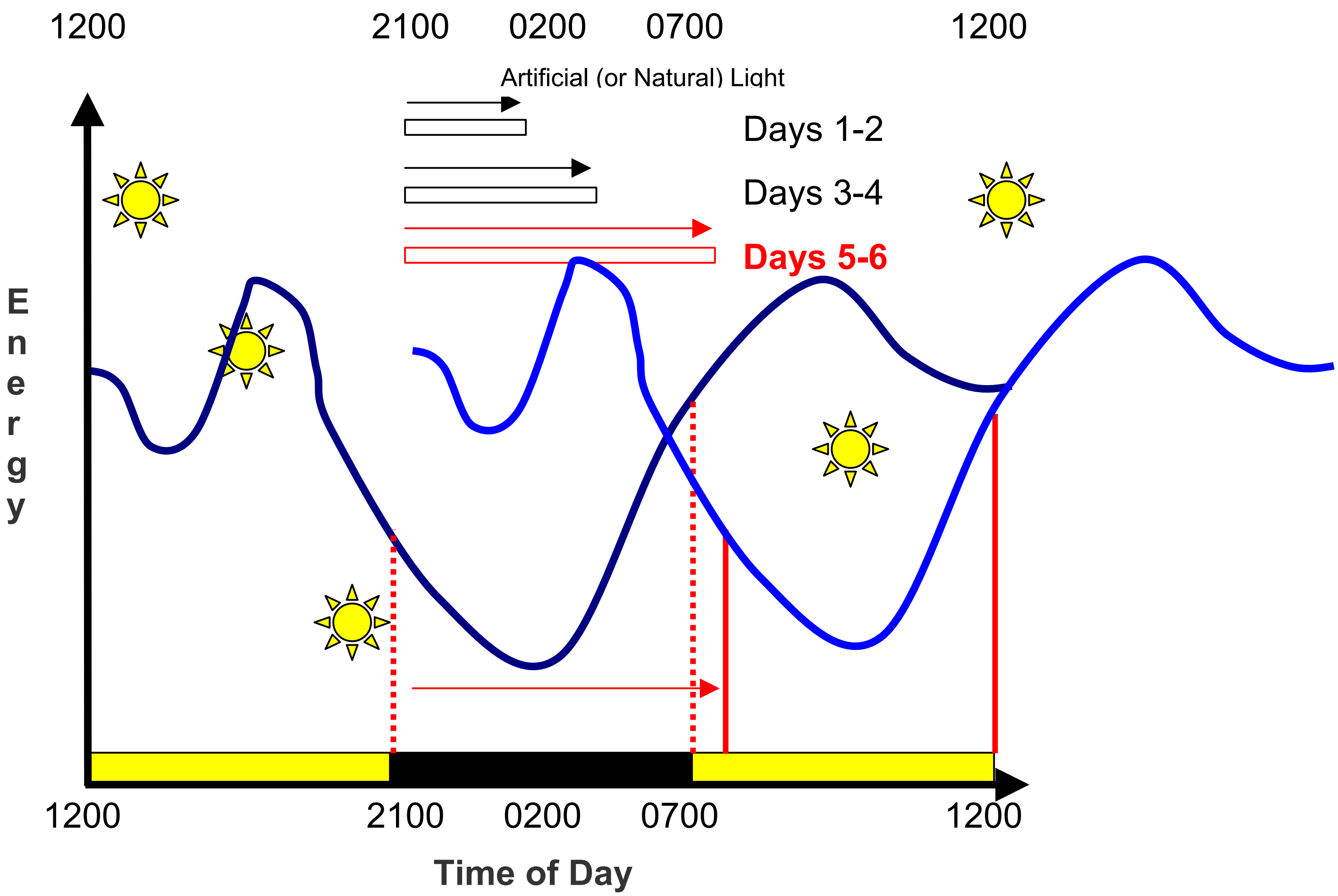

Figure 2. Shifting the Red Zone fully into daylight hours

Figure 2 shows the Red Zone being shifted into full daylight hours to accommodate sleeping during the day versus at night. The three bars/arrows indicate the amount of relative shift realized by applying light-management techniques (discussed in Section III) over three different periods of time. (**Note:** If sunrise occurs prior to 0700, daylight may be used for light management once it is of sufficient intensity.)

CAUTION! Light Management involves being exposed to measured amounts of ambient light of a specific intensity and wavelength (color). Light Management does not involve staring into naked light bulbs.

Managing Endurance Risk Factors

As previously mentioned, risk factors encountered in normal maritime operations can degrade crew endurance. The following endurance risk factors are discussed in detail in Section IV of this guide:

- **Cold-related illness**

  Heat & energy loss, hypothermia, frostbite

- **Heat illness**

  Dehydration, loss of the minerals needed to maintain normal body function

- **Motion sickness**

  Dizziness, performance degradation, headaches, nausea, vomiting, sleep loss, and fatigue

- **Psychological stress**

  Flight-or-fight anxiety, burnout

- **Excessive caffeine use**

  Energy drain, anxiety, sleep loss

- **Improper use of over-the-counter medications**

  Drowsiness, reduced alertness, reduced performance

CEM Implementation

A CEM program can be applied to a particular vessel, a particular operation, or a particular industry. In all cases, however, implementing a CEM program requires:

- Setting up a **Crew Endurance Working Group** (CEWG)
- Setting up and maintaining a crew-management **Final Common Path**

Setting Up a Crew Endurance Working Group

The Crew Endurance Working Group (CEWG) is responsible for all aspects of implementing a CEM program, including:

- Identifying the relevant endurance risk factors
- Creating a collaborative network of participants
- Devising and deploying a specific CEM plan

To be effective, a Crew Endurance Working Group must include or represent all those individuals who stand to be affected by the implementation of a CEM program. A CEWG typically consists of the following individuals:

- One or two company officers
- The company operations manager
- The captain of the vessel
- The pilot, the bridge personnel, or both
- The department chiefs
- The first mate, the engineer, or both
- One or more deckhands

Setting Up and Maintaining a Final Common Path

In order for a CEM program to succeed, a CEM Final Common Path must be established and maintained. A Final Common Path consists of the following key elements:

- Setting up a team of onboard coaches to train crewmembers on the science and practices of CEM, and to serve as program models and monitors

  The team of coaches must include the captain, the pilot or bridge personnel, and the first mate. Where available, it should also include the department chiefs.

- Training the coaches in the science and practices of CEM

  Training for coaches is provided by company management, typically using resources available from the U.S. Coast Guard Human Element and Ship Design Division (202-267-2997).

- The coaches train the crewmembers in the science and practices of CEM, model the required practices, and monitor crew adherence to these practices

Experience has demonstrated that, to implement a CEM program successfully, it is not sufficient simply to add more personnel or to modify watch schedules. **CEM implementation will invariably fail if a crew-management Final Common Path has not been set up and practiced in the prescribed order: (1) to teach crewmembers how to take advantage of working conditions, as well as how to use light-management techniques, and (2) to ensure that appropriate environmental changes have been made (for example, to control noise and light in sleeping quarters)**.

Engrained habits used to cope with work and life aboard a maritime vessel will not change unless individual crewmembers are: (1) given a realistic opportunity to change their habits, and (2) make daily efforts to change their habits and take advantage of improved shipboard working conditions. Old habits die hard!

Section V discusses CEM implementation in detail.

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SECTION II

Quick Example

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II. Quick Example

This section (**II**) provides an example of a Crew Endurance Management (CEM) program implemented on a commercial maritime vessel.

The operators and crew of the example vessel implemented their tailor-made CEM program in three phases:

Phase I: Development

Phase II: Deployment

Phase III: Assessment

This section describes these three phases in detail.

Phase I: Program Development

The process of developing a tailor-made CEM program for the example maritime operation consisted of three critical tasks:

- Setting up and training a Working Group
- Analyzing the current situation
- Drawing up a CEM plan

Setting Up a Working Group

A Working Group was set up: (1) to identify and assess the risk factors currently affecting crew endurance on the example vessel; and (2) to make appropriate recommendations concerning controlling these risk factors.

Members of the Working Group were selected by the operating company and consisted of personnel who would be directly or indirectly affected by a CEM program implemented aboard the example vessel:

- The Company Safety Manager

- The Company Operations Manager
- The Vessel Captain
- The Vessel Pilot
- The Vessel First Mate
- The Vessel Deckhands

Note: Because the Head Cook is likely to be considered unbiased, in being outside the chain of command, he or she is often a good choice for the CEWG, as is the Chief Engineer, who would likely be responsible for implementing any environmental changes decided on.

Training the Working Group

Before beginning their work, the Working Group members received professional training on the following:

- **The science of Crew Endurance Management**: The major environmental, operational, psychological, and physiological factors that affect crew endurance (physical stamina and mental alertness).
- **The process of Crew Endurance Management**: The procedures and tools commonly used for assessment and implementation.

The Science of Crew Endurance Management

The USCG R&D Center CEM team provided the Working Group with training on the following crew endurance topics:

- Sleep and shiftwork
- Light management and the body clock
- The **Red Zone** and its impact on performance
- Stress
- Caffeine and the use of over-the-counter medications

- Diet
- Cold-related illness
- Heat-related illness
- Motion sickness

The process of Crew Endurance Management

The USCG CEM team trained members of the Working Group on how to deal with cultural barriers ('This is the way we've always done it'; 'Don't fix it if it ain't broke'), and how to identify and assess the risk factors affecting crew endurance.

In addition, the CEM team trained crewmembers in the use of risk-assessment tools to determine which endurance risk factors were present in daily operations.

Analyzing the Current Situation

The Working Group studied the example vessel's operational system and broke it down into its major components; identified the relationships between these major components; and isolated specific elements within each component that were currently affecting crewmember endurance. See Figure 3 and the following legend and table.

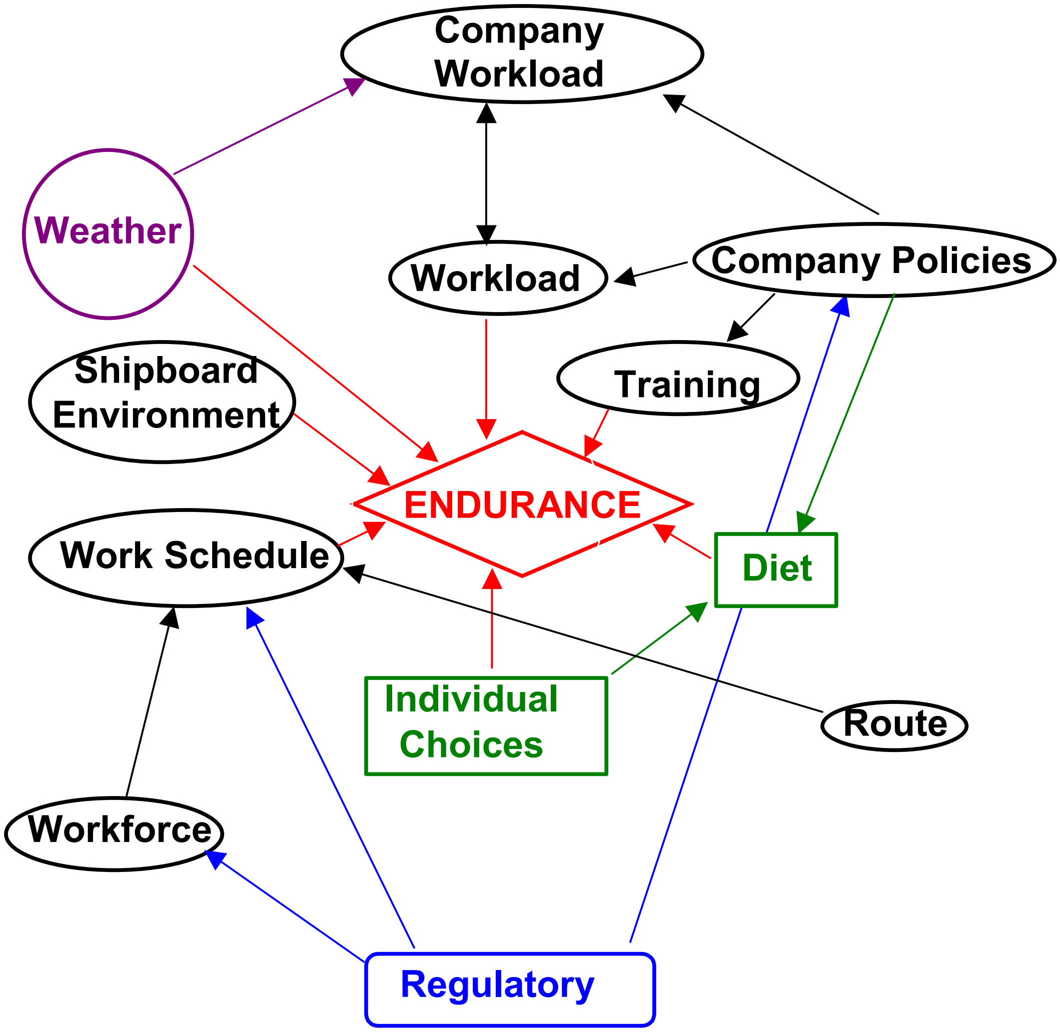

Figure 3. Operational components aboard example vessel

Figure Legend:

Company Workload	The accepted number of jobs at the company level.
Weather	Inclement weather can delay or stop operations.
Workload	Heavy workloads require more energy per hour from crewmembers.

Company Policies	Company policies can affect efforts by crewmembers to maintain endurance.
Shipboard Environment	Factors such as noisy, fumy, and light-porous quarters can disrupt sleep.
Training	The amount and focus of crew training can affect stamina and alertness factors.
Work Schedule	Long or erratic work schedules can leave inadequate time for sufficient sleep.
Diet	How much, what, and when crewmembers eat affects energy, mood, stamina, and sleep.
Individual Choices	Individual choices (for example, watching TV during a sleep period) can affect stamina and alertness.
Route	Routing can determine the type of work and the work schedule.
Workforce	The number of personnel allotted to each vessel can affect the watch regime used.
Regulatory	Coast Guard regulations determine the maximum number of work hours per 24-hour day.

The Working Group identified the following specific factors (grouped by operational component) that appeared to be affecting crew endurance aboard the example vessel:

Work Schedule	The current watch schedule was not allowing crewmembers sufficient opportunity to obtain the 7-8 hours of daily uninterrupted sleep required to maintain endurance.

Diet	Crewmembers were eating large meals immediately before going to bed after watch. Crewmembers were consuming large quantities of caffeine throughout the day, even close to bedtime.
Individual Choices	Crewmembers were consuming coffee throughout watches; staying up to watch TV, play games, or make lengthy phone calls; asking to be awakened an hour or more before a watch change. Crewmembers were being kept awake by noises associated with crews handling rigging near the vessel; slamming doors or banging manhole covers; and using televisions, radios, hand-held VHF radios, etc. at high-volume levels.
Vessel Environment	Crewmembers were being awakened by sudden movements of the vessel. Crewmembers were being kept awake by light entering crew quarters through windows and door louvers, and by engine-room noise. Crew-quarters lights were not sufficiently bright for crewmembers to adapt to day or night work hours or to become alert quickly upon waking. Fumes from the diesel engines were sometimes entering into staterooms, causing discomfort.

Company Policies	Crewmembers were accumulating sleep debt because of the 'no napping' policy. Crewmembers were being delayed from sleep time by not being able to take meals or showers until after watch change.

Drawing Up a Crew Endurance Plan

On the basis of their analysis, the Working Group drew up a list of specific recommendations. These recommendations fell into two major categories:

- **Operational recommendations**
- **Environmental recommendations**

Operational Recommendations

The Working Group recommended the following operational changes:

New watch schedule:

A new watch schedule was designed to meet the following criteria:

- Crewmembers should have enough time off to obtain 7-8 hours of uninterrupted sleep per 24-hour period
- If unable to obtain 7-8 hours of uninterrupted sleep per 24-hour period, crewmembers should have enough time off to obtain at least 6½ hours of uninterrupted sleep, as well as a nap of no less than two hours, per 24-hour period
- Crewmembers working at night should be able to maintain the same work-rest schedule for at least two continuous weeks
- Schedule rotations from day to night, or from night to day, should be minimized in order to avoid body clock and sleep cycle desynchronization (a condition similar to jet lag)

- Work periods should be no greater than eight continuous hours, particularly when prolonged exposures to extreme temperature or humidity levels (see Section IV) are involved
- Environmental light-management techniques should be used to adapt crewmembers to night watch (see Section III)

The major rationale for the new watch schedule was that it allowed crewmembers to get up to 6½ hours of uninterrupted sleep during the long off-periods, plus a 2- to 3-hour nap during the short off-periods.

The Working Group members had learned in their CEM training that the average adult requires approximately 7 to 8 hours of uninterrupted sleep per 24-hour period, and that overall sleep quality is best when the daily sleep periods are uninterrupted and extended over long stretches.

> **Basics: Daily sleep requirements vary: While elementary students normally require 10-12 hours/day, pre-teens 9-11 hours, teens 8½-10 hours, most adults normally require 7-8 hours/day. The operational rule is: If following your customary sleep period you feel sleepy during the subsequent afternoon period, then you need more sleep.**

The Working Group members also learned in their CEM training that it is critically important to use light-management practices in conjunction with implementing a new watch schedule, particularly when night work is involved.

New light-management policies

New light-management polices were implemented to help Night Watch and Day Watch crewmembers manage their Red Zone (period of lowest energy and alertness). These policies included:

- Crewmembers on Night Watch were asked to go to sleep in a totally dark environment after getting off watch in the morning, and to avoid light until they were called to report for their first watch of the day.
- Day-watch personnel were asked to sleep in a darkened environment and to avoid lighted common areas immediately preceding bedtime and throughout their sleep period.

New time-management policies

The following new meal and shower policies allowed the crew to take maximum advantage of their sleep opportunity:

Policy: Out-of-schedule showers will be allowed. However, crewmembers will be expected to discuss any work to be completed before taking early showers. An early shower does not relieve anyone of any duties to be performed on watch.

Policy: Out-of-schedule meals will be allowed, provided they do not interfere with the cook's schedule.

Policy: Crewmembers coming on watch will be given priority seating at meal times.

New watch policies

The following new watch policies helped prevent crewmember sleep debt.

Policy: On-watch napping will be allowed when prudent and practical.

Policy: On-watch napping will be allowed between 2300 and 0400, and between 0530 and daylight. Exceptions can be made when circumstances warrant; for example, following strenuous or lengthy duties, or recent travel.

Policy: No napping will be allowed until all necessary work is completed.

Policy: On-watch napping will be used to supplement, not substitute for, normal off-watch sleep periods.

Policy: On-watch napping will be limited to approximately one-half (½) hour per crewmember, per night.

Policy: During watch, at least one crewmember must be awake at all times.

Policy: Before on-watch napping, a crewmember must inform the remaining crew of his or her location.

Policy: Usual and standard on-watch practices will be maintained.

Environmental Recommendations

The Working Group recommended a set of boat policies and physical alterations toward enhancing sleep quality:

New shipboard policies

Policy: Common courtesy by crewmembers on duty will be exercised at all times toward crewmembers off duty.

Policy: Pilothouse personnel will actively avoid rapid changes in throttle settings to the extent possible.

Policy: Deck crew will actively minimize noise associated with the performance of their duties. This will include handling rigging with care near the vessel.

Policy: Crewmembers will avoid slamming doors or banging manhole covers, and will keep televisions, radios, hand-held VHF radios, etc. to mutually acceptable volume levels.

Physical changes

Problem: Stateroom doors have louvers to accommodate return airflow for HVAC. These louvers also allow an unacceptable level of noise and light to enter the room.

Recommendation: Install baffles that allow airflow while restricting noise and light, on all stateroom doors.

Problem: Blinds over exterior windows in staterooms do not adequately restrict light.

Recommendation: Install slide panels in all staterooms to replace blinds.

Problem: Stateroom lighting may be inadequate for entraining and adapting the body clock. Brighter lights can help crewmembers become alert more quickly after waking.

Recommendation: Install 48”, 4-tube, fluorescent fixtures using “daylight” bulbs.

Problem: Interior entry from living quarters to engine room is a single door, allowing noise to enter living quarters.

Recommendation: Install a second door to create a better sound barrier.

Problem: Smoke from the diesel engines sometimes penetrates into staterooms causing discomfort.

Recommendation:

- Replace the plywood sealing the exterior HVAC fan enclosure with electrostatic air filters.
- Install reusable electrostatic filters in 1st and 2nd deck return-air vents.
- Install HEPA/HEGA or ionizing air purifiers, or both, in staterooms.
- Seal all leaks currently allowing exhaust smoke to enter living quarters.

Phase II: Program Deployment

The process of deploying the CEM program on the example vessel consisted of the following:

- **Training the full crew**
- **Implementing the final CEM plan**

Training the Crew

A USCG CEM team trained the crew of the example vessel in sleep and body-clock management, stress management, time management, and other crew-endurance practices during a day-and-a-half workshop.

The example vessel's CEM coaches reinforced this initial training with ongoing training during normal operations.

Implementing the Plan

The process of implementing a CEM program consisted of the following:

- **Enlisting the support of the full crew**
- **Making the recommended system modifications**
- **Coaching the crew toward consistency**

Enlisting the Support of the Crew

The crewmembers were provided key information and training on CEM (benefits, factors, procedures, options, etc.), and were presented with the Working Group's CEM plan and the underlying rationale for each of its features. It was emphasized that changes were not being recommended merely for the sake of making changes, and that legacy systems were not necessarily the best possible systems simply because they had been in place for a long period of time.

Crewmembers were encouraged to suggest improvements to the Working Group's CEM plan and to support the final plan.

Caution! Crewmember buy-in is as critical to the success of a CEM program as is management buy-in. No buy-in, no success.

Making the Recommended System Modifications

The working group, together with company management and the example vessel's own endurance coaches (Captain, Pilot, and Mate), ensured that all of the system modifications recommended in the final CEM plan were made.

These modifications involved changes in watch schedule, physical changes to crewmember quarters, dissemination of new onboard policies, and requests to the crew for changes in personal choices (relative to the use of caffeine and over-the-counter drugs, for example).

Coaching the Crew

The captain, pilot, and first mate of the example vessel were enlisted and trained to serve as onboard CEM coaches. The responsibilities of the coaches included:

- Training individual crewmembers in CEM practices
- Serving as models of CEM practice for crew emulation
- Actively encouraging crewmembers to follow CEM practices
- Monitoring and enforcing adherence to the policies and procedures of the CEM plan

Note: The Working Group consistently supported all aspects of crew-endurance management aboard the example vessel.

Phase III: Program Assessment

At various times during the implementation phase, the program was assessed as follows:

- Crewmembers on the After Watch provided saliva specimens to measure adaptation to nighttime watch hours
- Crewmembers performed vigilance tasks to measure alertness
- Crewmembers completed computerized subjective questionnaires

Crewmembers who used light management consistently showed hormone (melatonin) levels typical of a well-adapted body clock, and experienced minimal lapses in alertness during the work hours following the long off-period.

Diet & Endurance Tips from the Captain

Here, in brief, is what the Captain of the example vessel, in his words, “preaches to his crew” concerning diet and endurance:

“The common diet aboard our vessels is extremely high in salt. This is due to a generalized use of canned and processed foods, and of condiments; crew preference; and the background of the cooks. Except in extreme cases, therefore, supplementing dietary salt requirements with salt tablets or the like is not necessary.

Water. There is no substitute. The amount of water absorbed from many flavored drinks, tea, carbonated drinks, and the like is diminished because the body uses a percentage of the water in the drink to flush the artificial flavors, artificial colors, et cetera out of the body. Some of the drinks themselves act as a diuretic. High sugar content can reduce magnesium absorption and thereby prevent calcium from being used efficiently.

I strongly recommend improving on the intake of potassium. The published recommended allowance for potassium is 1600 to 3500 mg/day. Crewmembers doing heavy work in heat, and sweating, require much more than this recommended allowance. I do not believe in the hyped benefit of most commercial sports drinks. As an example, the potassium content in Gatorade is about 25 mg/8oz., in Sqincher mix, about 50 mg/8oz., whereas grapefruit juice contains nearly 300 mg/8oz., orange juice about 450 mg/8oz.; V-8 Splash, 80 to 140 mg/8oz.; V-8 vegetable juice, over 500 mg/8oz.; and bananas, about 480 mg each.

By advising that my crewmembers actively increase their intake of water and juices, in addition to whatever other drinks they choose, I hear of fewer complaints of heat-related problems such as leg cramps, heat chills, muscle tremors, or heat-caused weakness."

SECTION III

Managing the Red Zone

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III. Managing the Red Zone

This section (**III**) describes and illustrates how to manage the Red Zone toward optimizing crew endurance in maritime operations.

The Red Zone

Performance (endurance) varies with the level of available energy, which itself, because of natural body rhythms, normally varies in a predictable pattern over the course of each 24-hour period. See Figure 4.

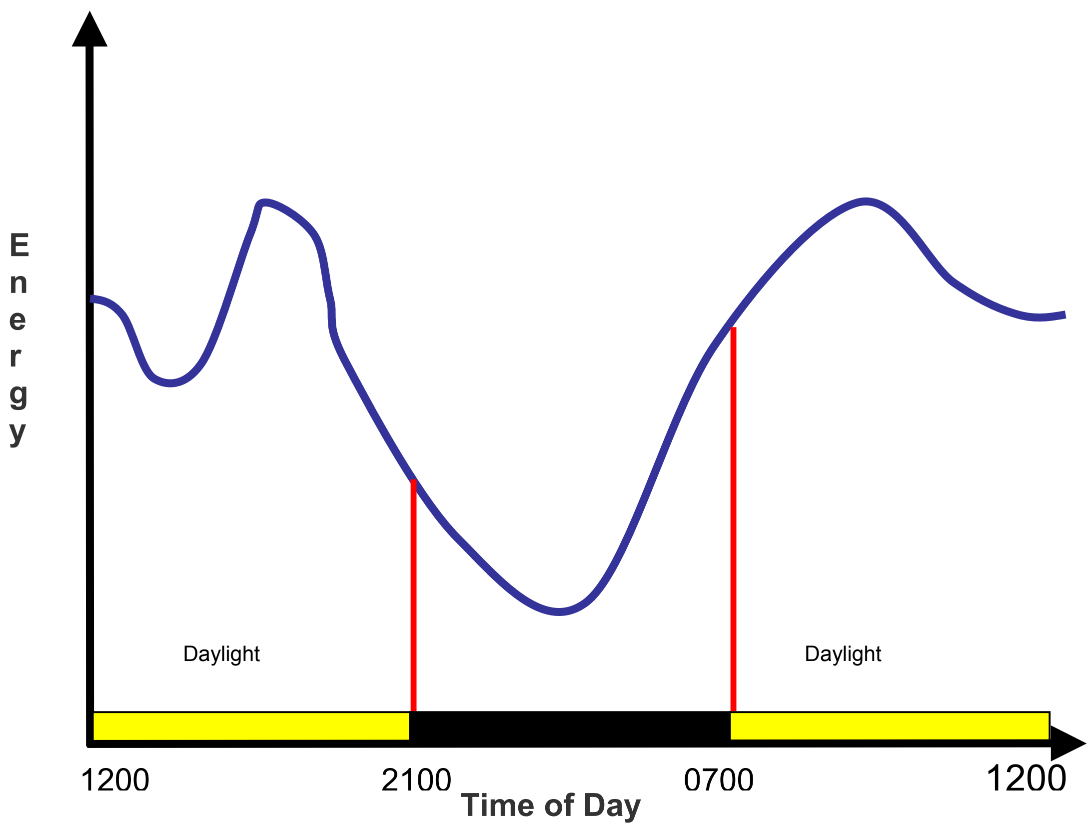

Figure 4. The **Red Zone** of energy and performance

For crewmembers working days and sleeping nights, energy and performance tend to peak during the daylight hours, and to bottom out during the dark nighttime hours.

The term **Red Zone** is often applied to the nighttime period of lowest energy and performance, because this is the portion of each day during which degraded endurance is most likely to have a negative impact. For a person who sleeps 7 to 8 hours per night, the Red Zone typically begins at about bedtime (2100 hours in our example) and lasts through the nighttime hours (until about 0700 in the example), **with the most-critical period spanning from 0300 to sunrise**. See Figure 4.

Several factors can influence the duration as well as the intensity of individual Red Zones, including crewmember sleep, social, and dietary habits; the current period of sustained wakefulness; and accumulated sleep debt.

BASICS: As sleep debt (getting less than 7-8 hours of sleep per day) increases over consecutive days, the Red Zone can expand into the morning, afternoon, and evening hours.

The Red Zone and Energy

The Red Zone is a function of energy level. It is important, therefore, to understand how energy is produced, how it affects endurance, and how it can be increased or decreased in certain situations.

FACT: Energy comes from the Greek word *energia*, or '*in-work*'; it refers to the capacity to do work.

What Energy Is and How It Is Produced

Production of molecules called adenosine tri-phosphate (ATP), found in all cells of the body, plays a key role in the production of energy. The amount of ATP produced by the body depends on good nutrition, adequate hydration (water intake), oxygen, and (perhaps most important of all) sufficient sleep.

Adenosine Tri-Phosphate molecules:

ATP = ENERGY

Studies of brain function have shown that seven to eight hours of **continuous** sleep are necessary for the body to produce a sufficient amount of ATP to restore depleted energy supplies. If the body does not produce sufficient ATP, and thereby sufficient energy, the brain and the nervous system cannot function efficiently, causing crewmembers to:

- Think less clearly
- Make poor decisions
- Become irritable
- Have problems communicating with others
- Experience degraded endurance throughout work and leisure hours
- Become withdrawn and less willing to resolve issues and problems
- Have less ability to fight disease

Unfortunately, ATP cannot be consumed as a dietary supplement; it must be produced within cells in the body. Regardless of how hard people might try to compensate for lack of energy, their ability to carry out both physical and mental tasks is reduced. This reduction in energy compromises their safety as well as the safety of those around them.

Caution! **Be cautious of products that claim to boost energy resources. These products can provide dietary input to the energy-producing machinery, but they cannot produce energy. The only way to produce energy is through sufficient sleep, adequate water intake, a balanced diet, a stable body clock, and regular exercise.**

How the Body Turns Food into Energy

The digestive system breaks food down into carbohydrates, proteins, and fats, which are then converted, by enzymes, into energy substrates: glucose (sugar), amino acids, and fatty acids. These substrates are then processed within individual cells into ATP (= energy). See Figure 5.

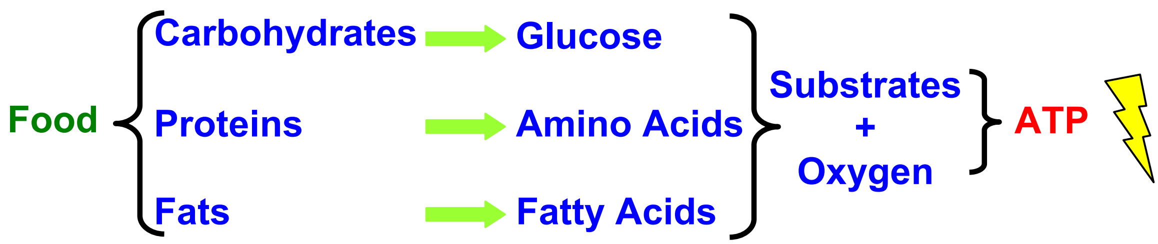

Figure 5. Food is broken down into energy substrates

When Energy Demands Outweigh Normal Production

Chronic stress and sleep disruption tend to deplete energy resources and to degrade endurance. This depletion of energy and endurance is harmful to crew health and safety in its own right; it can also cause crewmembers to make a bad situation worse by inclining them toward using artificial means to increase alertness.

The most common of these artificial means to increase alertness is the use of stimulants such as caffeine (found in coffee, soft drinks, and chocolate) and pseudoephedrine (found in cold and allergy medications).

High doses of caffeine, however, can result in increased anxiety, lack of concentration, and digestive disorders; frequent use can lead to addiction as well as an even further depletion of energy resources. And, while drugs such as pseudoephedrine and ephedrine can maintain alertness, they can also become addictive, and they can have adverse side effects as well.

CAUTION! All medications containing pseudoephedrine warn against chronic use. In fact, most recommend discontinuation after three days of continuous use, and always recommend supervision by a physician. Be sure to read the label to see if your medication contains pseudoephedrine.

There are ways of controlling our energy level that do not rely on caffeine or drugs. Some of these ways are suggested in the next section.

Controlling Your Own Energy Level

Here are a few tips on how to control your daily energy level:

- Exercise daily; any simple form of regular exercise helps: a 20-minute walk, running, weight lifting, 10-minute aerobic workouts, etc.
- Consume a balanced diet: low sugar, low fat, low starch, high in green and yellow vegetables, high in chicken, turkey, and fish (no turkey before watch, however, as it can cause sleepiness)
- Get sufficient sleep: 7-8 hours of uninterrupted sleep daily
- Use relaxation methods to reduce stress at the individual level
- And remember…ATP = ENERGY

Controlling the Red Zone

The human brain requires approximately **seven to eight hours** of uninterrupted sleep daily in order to replenish mental and physiological resources.

BASICS: Daily sleep requirements vary: While elementary students normally require 10-12 hours per day, pre-teens 9-11 hours, teens 8½-10 hours, most adults normally require 7-8 hours per day. The operational rule is: If following your customary sleep period you feel sleepy during the subsequent afternoon period, then you need more sleep.

During sleep, the brain cycles through successive periods of light sleep, deep sleep, and dream sleep. These cycles require approximately 90-120 minutes to complete, and are repeated throughout the night. Any interruption to these cycles by noise, bright lights, or sudden movements causes the brain to spend more time in light sleep, less time in deep and dream sleep.

Sleep disruption reduces the effectiveness of energy restoration processes and ultimately results in degraded endurance. A disruption resulting in full wakefulness will cause the brain to start the sleep cycle from the beginning, such that the entire cycle may not be completed.

CAUTION! Energy is restored optimally during uninterrupted sleep periods of 7 to 8 hours, with the sleeper reclined on a comfortable mattress in dark and quiet room at 65 - 70° F and 60 - 70% humidity.

Managing the Biological Clock

Optimally, sleep must take place during a period of time established by our internal biological clock. This clock is a physiological mechanism – composed of neural networks and hormonal outputs – that regulates the timing of sleep onset and wake-up, as well as the availability of energy resources (see Appendix A for details). The body's biological clock maintains a sleep/wake schedule in synchronization with local sunrise, sunset, and daylight duration. Because we are naturally inclined to sleep during nighttime hours, and to expend energy during daylight hours, the human biological clock reflects this same cycle.

The biological clock regulates energy cycles so that alertness increases after wake-up time, peaks in the mid-morning hours, dips through the late-morning and early-afternoon hours, peaks again in the early-evening hours, and then decreases throughout the late-evening and early-night hours, reaching a daily low in the middle of the night (see Figure 6 below). The exact times of these peaks and valleys depend on specific inputs to the biological clock system, namely wake-up times, bedtimes, and daily interval of daylight (or artificial bright light) exposure.

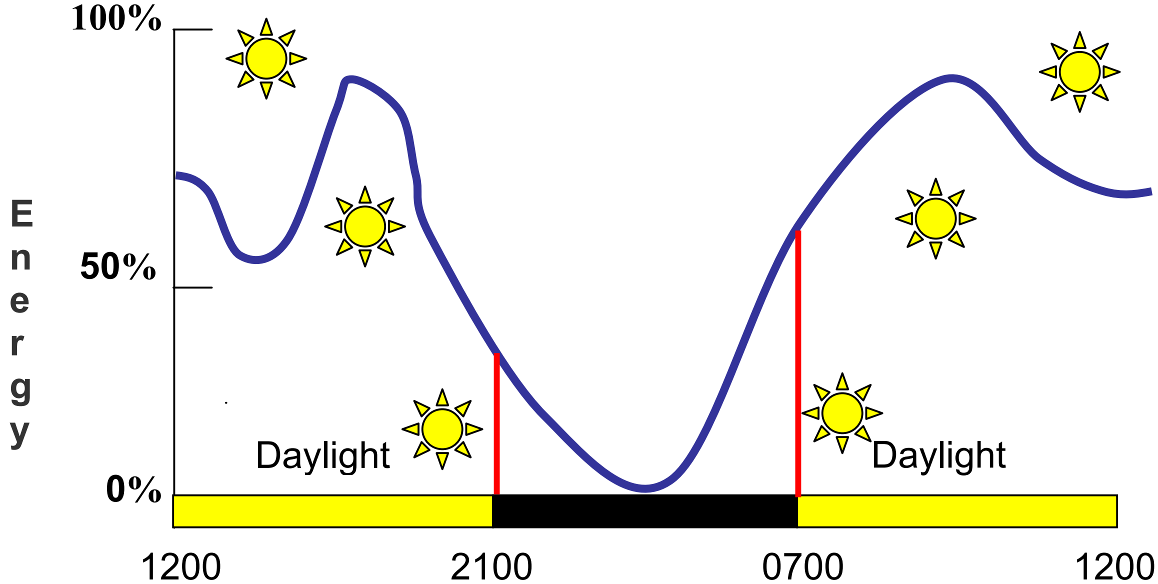

Figure 6. Daily energy cycle as a function of time of day

> **FACT: Personnel adhering to regular work schedules that provide day-to-day consistency enjoy the benefits of a well-adapted biological clock. A well-adapted clock ensures that daily energy restorative activities occur on a regular basis.**

Optimizing Work Schedules

Work schedules that impose frequent changes from daytime to nighttime duty hours tend to disrupt energy restorative processes and to degrade endurance. The same is true of work shifts greater than 12 hours within a 24-hour period.

Disruptions to the established rhythm of the biological clock can also degrade alertness and performance. For instance, if a person wakes up for work at 0600 over a period of five consecutive days, the biological clock will adjust itself to waking up at 0600. If this person then sleeps in on the weekend, say to 0830 each day, a conflicting signal will be sent to the biological clock, because the person is now sleeping past the previously set wake-up time of 0600. The biological clock will actually begin to adjust to the 0830 wake-up time, thereby disrupting the previously set rhythm, and degrading the level of wake-up alertness and performance.

Changes in the body's timing mechanism affect the normal regulation of physiological functions such as core body temperature, cellular metabolism, and production and release of hormones and neuro-transmitters.

In general, the biological clock system requires approximately two to three days to *fully* adjust to a new sleep schedule (e.g., a wake-up time that is two hours later). This readjustment will take place most efficiently if the new sleep schedule is consistent from day to day. If the changes are inconsistent, however, the clock's timing can become disorganized in such a way that the physiological functions under its control no longer occur in a predictable pattern.

FACT: Inconsistent inputs to the body clock can result in:

- **Sleepiness during work hours**
- **Paradoxical feelings of fatigue: feeling too tired to rest**
- **Lack of mental clarity**
- **Degraded physical ability**

Inconsistent inputs to the biological clock are common when personnel work night shifts. Night personnel typically work in normal or dim (artificial) light environments during most of their shift (e.g., on the bridge). Instead of being protected from bright natural light after sunrise, however, they are fully exposed to it. Hence, rather than their biological clock receiving a sleep signal following their shift, it receives the opposite signal and responds accordingly, often producing jet-lag-like symptoms.

> **CAUTION! Inconsistent inputs to the biological clock are common when personnel work during nighttime and/or early-morning hours. This is especially true for crewmembers on night watch, who are often exposed to full daylight after sunrise. Such inconsistencies can result in a degradation of sleep during the day, and of performance during the following night.**

Personnel accustomed to waking up and seeing daylight at approximately the same time each day (e.g., at 0700) will be more likely to work during daylight duty hours and to sleep during nighttime hours. Their biological clock will be day-oriented, that is, synchronized to provide energy and cognitive resources during daylight and evening hours.

As illustrated in Figure 6, two peaks of alertness and energy availability will take place throughout the day – one in the morning, and one in the early evening – with dips in energy and alertness immediately upon awakening, sometime in the mid-afternoon, and prior to sleep between sunset and bedtime. This pattern of energy availability will be maintained consistently if personnel obtain good-quality sleep during daily rest periods of seven to eight hours. Good-quality sleep consists of uninterrupted sleep in quiet and dark environments.

Interrupted sleep, and reductions in sleep duration to less than seven to eight hours per day, will result in an accumulation of daily sleep debt. The consequences of this sleep debt will be experienced as degradations in alertness, in decision-making ability, and in mental functions requiring logical ability. Persistent sleep debt throughout a week will result in increased daytime sleepiness and in an overall degradation in performance.

Using Light Management Techniques

A strategic use of light management can help adapt crewmembers to function optimally during nighttime rather than daytime hours. For example, exposing the human eye to artificial light during the period between sunset and 0200 can shift the Red Zone for Nighttime duty. See Figure 7.

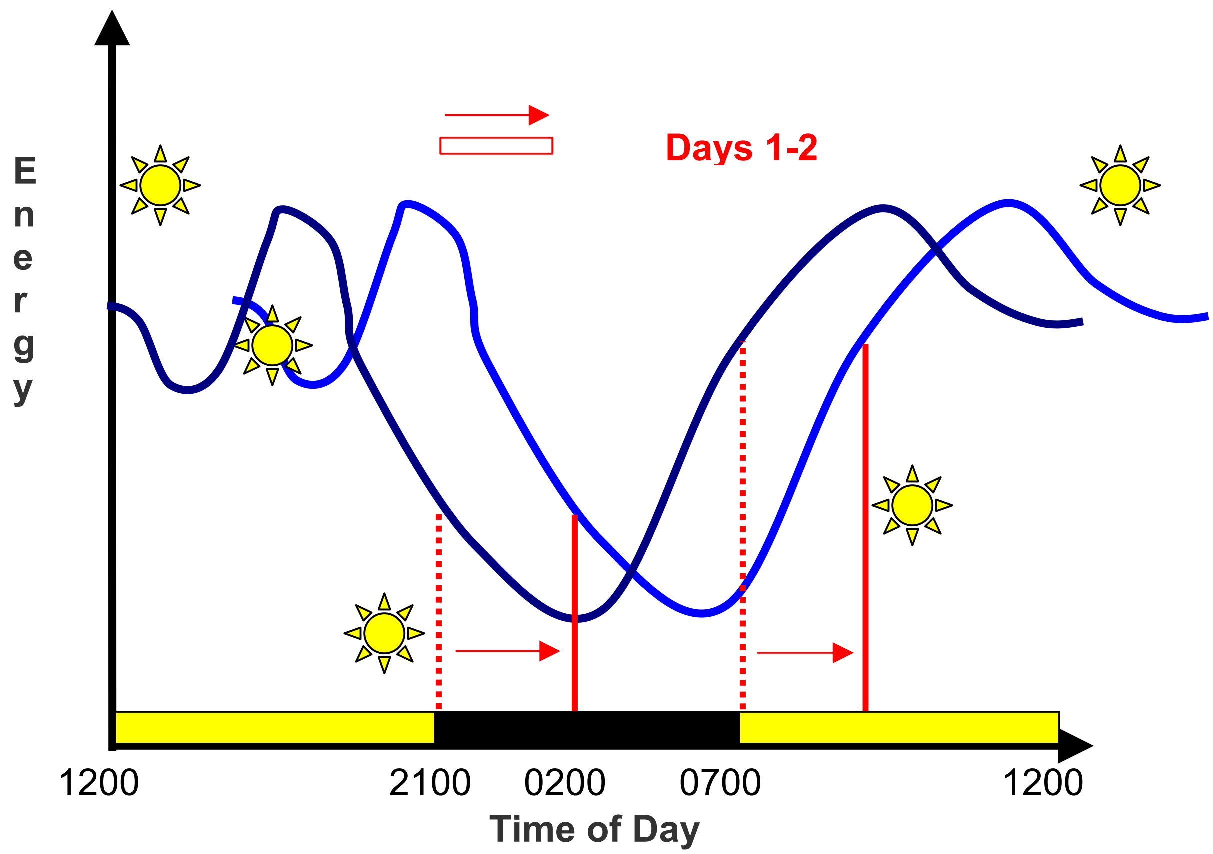

Figure 7. Shifting the Red Zone toward daylight hours

Light management involves the strategic use of artificial light to shift the Red Zone out of its normal nighttime range. See Figure 8.

Figure 8 shows the Red Zone being shifted into full daylight hours. The three arrows indicate the amount of relative shift realized by applying light-management techniques over three different periods of time. (Note that if sunrise occurs prior to 0700, natural light may be used for light management once daylight is of sufficient intensity.)

Note that it takes about five or six days of consistent light management to shift the Red Zone fully from a nighttime orientation over to a daylight (morning) orientation.

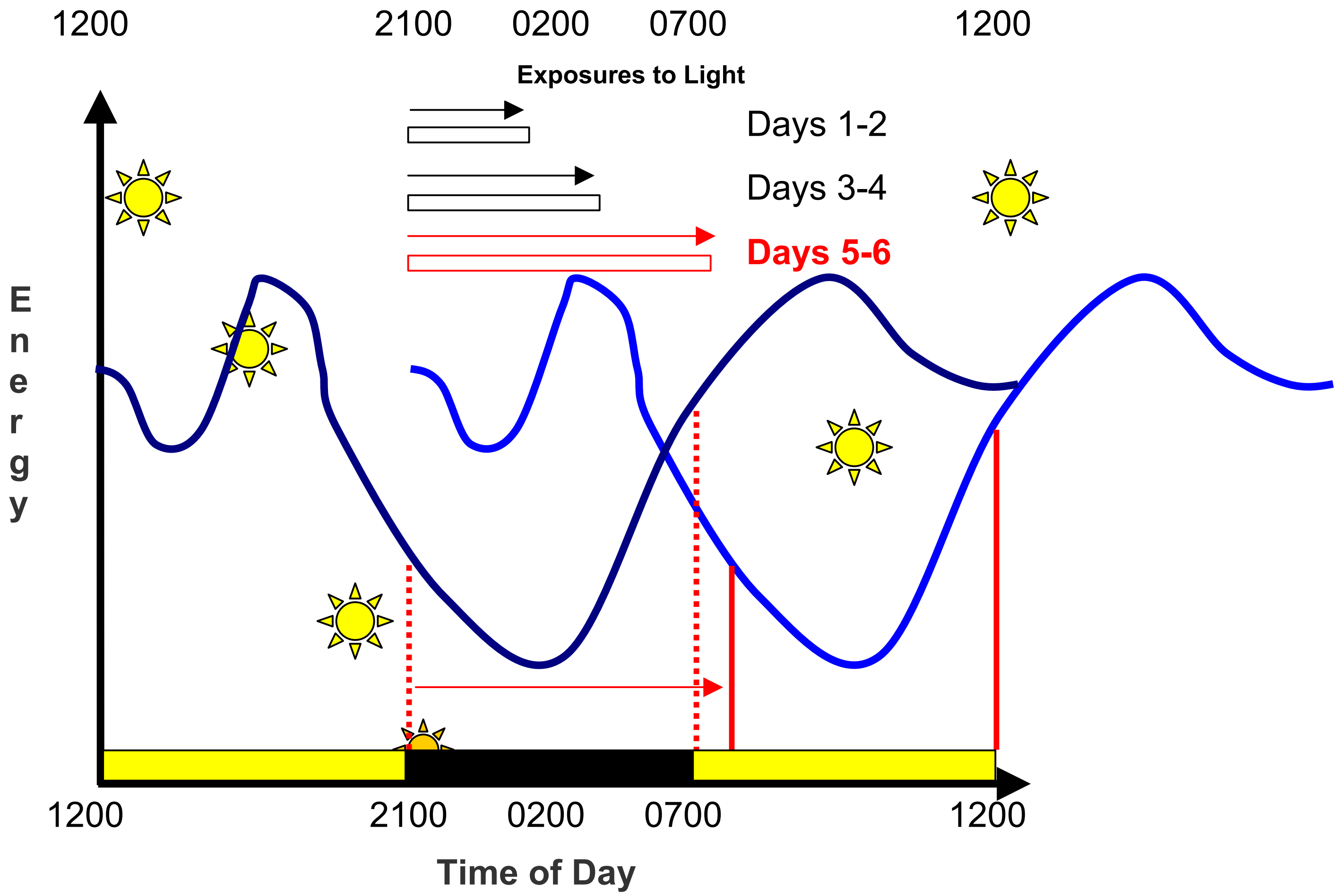

Figure 8. Shifting the Red Zone into daylight hours

Light management in this case would consist of closely replicating a daylight environment during nighttime hours, and a nighttime environment during morning hours. The result of this regimen is illustrated in Figure 9.

Details on how to implement a light-management regimen are provided in the following subsections.

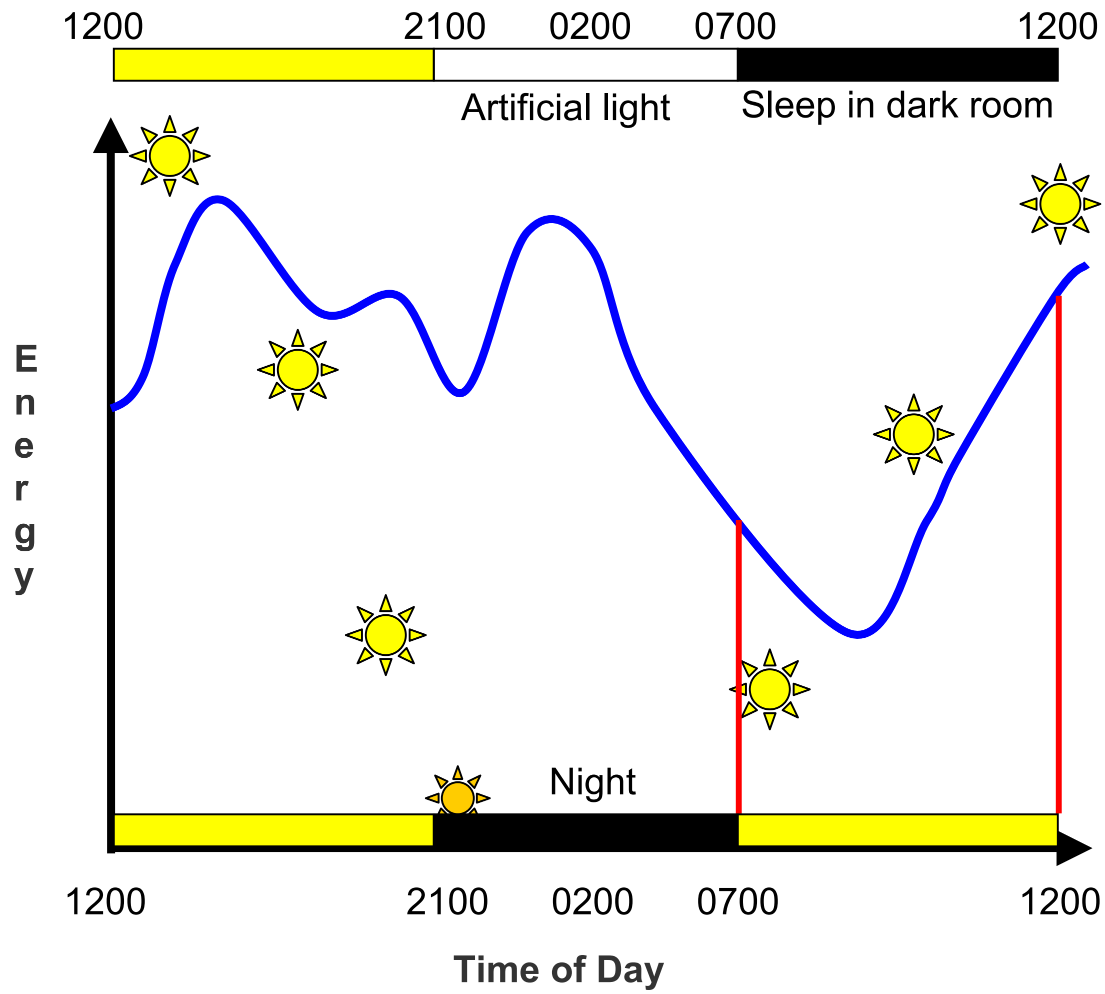

Figure 9. Fully-shifted Red Zone

General Recommendations

- Obtain 7-8 hours of uninterrupted sleep per 24-hour period.
- Compensate for any sleep loss with daily naps.
- Eat meals rich in lean protein sources (for example, chicken, fish, eggs, peanut butter) and vegetables (spinach, Brussels sprouts, zucchini, etc), but low in sugar, white flour, and fatty foods
- Consume the heaviest meal after waking up from the longest sleep period of the day

- Eat small light meals within 4 hours of the sleep period

- Reset the biological clock by using light management

  Exposure times may be as short as 30 minutes per hour; however, frequent exposures during the duration of the transition period are recommended. (**Note:** Do not stare directly into the light sources being used to replicate daylight.) It is recommended that normal activities be conducted while light management is being used.

- Avoid sunlight and bright artificial light during the sleep period

Watch Schedules

There is no 'one size fits all' watch schedule; different circumstances require different schedules. However, all watch schedules should be based on the following fundamental criteria:

- Crewmembers should have enough time off to obtain 7-8 hours of uninterrupted sleep per 24-hour period

- Crewmembers working at night should be able to maintain the same work-rest schedule for at least two continuous weeks

- Changes in work schedule from day to night, or from night to day, should be minimized in order to avoid sleep-cycle desynchronization (a condition similar to jet lag)

- Work periods should be no longer than eight (8) continuous hours, particularly when prolonged exposures to extreme temperature or humidity levels (see Section III) are involved

- Environmental light-management techniques should be used to adapt crewmembers to night watch (see next section)

The single most-important consideration is the human requirement for 7 to 8 hours of quality sleep per day.

Note: A CEM software tool is available for optimizing watch schedules for particular situations.

NOTE: Light management is a critical part of the process of adapting to new watch schedules.

Controlling Shiftwork Adaptation

Adapting to nighttime or daytime work requires synchronization of the biological clock to the work schedule. Maladaptation results if the biological clock is not adjusted to the work schedule. To adapt the biological clock, crewmembers must be exposed to daylight (or bright artificial light of 1,000 lux or more) both upon awakening and throughout their active periods (for example, during work hours). Also, crewmembers must avoid bright light from approximately three hours prior to the end of their long sleep period.

MANAGEMENT NUGGET: The only way to fully adapt to night watch schedules is to reset the biological clock so that energy peaks during nighttime. Work must take place under artificial light (of at least 1000 lux) that mimics daylight. Sleep must take place in a dark and noise-free environment for approximately seven to eight hours. Lacking control of daylight and/or light exposure is a significant contributor to fatigue and shiftwork maladaptation.

Maladaptation to shiftwork schedules and lack of energy-restoration sleep can result in persistent sleepiness, low energy, lack of motivation, and depression; in performance degradation during duty hours; and in increased safety risk.

Other health effects such as increased incidence of cardiovascular disease, gastrointestinal disorders, and sleep disorders have been historically documented in populations subjected to shiftwork maladaptation. The combined effects of disrupted sleep and biological clock disorganization can lead to endurance degradation, jet-lag-like symptoms, irritability, depression, and, in extreme cases, psychosis.

Optimizing Adaptation to Shiftwork

Optimizing crew rest, while preventing shift lag (inadequate adjustment to shiftwork schedules), can contribute significantly to crewmember adaptation to work and life aboard a maritime vessel. Listed below are some critical recommendations that can prevent watch schedules from inducing short and disrupted sleep periods and shift lag.

> **MANAGEMENT NUGGET: Avoid allowing personnel to work more than 12 hours in a 24-hour period. Count these 24 hours from the time crewmembers wake up from their longest daily sleep period (not naps).**

Total Adaptation to Night Work

- Provide bright-light exposure (e.g., fluorescent bulbs of at least 1000 lux) during the work period (see *Appendix A-4: Shiftwork, Sleep, and Biological Clock Management*). **Note:** This artificial-light exposure can only be implemented in environments where night vision is not required for performing normal duties (e.g., in engineering).

- Provide nighttime personnel with small-size meals that promote energy and alertness (high protein, low fat, low sugar, low starch, **no** dairy products or turkey).

- Adjust meal times so that midnight watch personnel can eat a brunch on waking (at approximately 1300), including brewed coffee and breakfast foods, if desired.

- Adapt the mess services to accommodate crewmember needs. This accommodation supports both safety and crew morale.

Partial Adaptation to Night Watch or Work Schedules

When bright lights cannot be used in the work environment, adhere to the following recommendations:

- Reduce the duration of the watch in order to minimize the impact of endurance degradation on safety. Promote exercise in the evening hours.

- Allow crewmembers in any watch ending in the morning hours to retire prior to sunrise, and to sleep at least seven to eight hours free of noise and with absolutely no interruptions. Overtime should be scheduled to occur after wake-up time (e.g., from 1400-1800), whereas leisure activities should be scheduled for the evening hours.

- A second approach to reducing endurance degradation in the Midnight Watch is to allow one watch section to work most of the night by extending the watch duration to five or six hours. For this approach to work, however, the night watchstanders must be allowed to retire before sunset, and to sleep seven to eight uninterrupted hours in a dark and quiet environment with absolutely no interruptions. Allowing one watch section to cover the entire watch avoids the need to adapt other crewmembers physiologically to night work.

  These crewmembers must see daylight or sufficiently bright artificial light (of at least 1000 lux) after they awaken from their uninterrupted sleep period, and throughout their work period. Exposure to daylight provides a critical input that facilitates the biological clock's adjustment to the sleep-work schedule.

SECTION IV

Controlling Performance Stressors in Maritime Operations

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IV. Controlling Performance Stressors in Maritime Operations

This section (**IV**) tells you how to control performance stressors commonly experienced in the maritime industry. The following performance stressors are covered:

- Cold-related illness
- Heat illness
- Motion sickness
- Physical and mental stress
- Caffeine
- Over-the-counter drugs and prescription medications

Cold-Related Illness

This section describes cold-related illnesses, and provides tips on controlling them.

- **Hypothermia**

  Hypothermia results when heat loss exceeds heat production. Accidental hypothermia results from total or partial immersion in cold water, or from exposure to cold air temperatures. Immersion in cold water differs from exposure to cold air because of two primary physical factors:

  - Water conducts heat away from the body approximately 26 times faster than air.
  - Water has a specific heat approximately 1000 times that of air, which means each cubic centimeter of water that contacts the skin extracts heat 1000 times faster than air.

  Symptoms involve shivering uncontrollably, confusion, carelessness, and disorientation. If left untreated, this condition can result in death.

  Management: Remove from cold (water/air); provide shelter; keep warm with blankets; remove wet clothing; place heated items (rocks/pads) near the skin, but not in direct contact; institute body-to-body rewarming. Do not heat oral fluids, and do not rub cold skin.

- **Frostbite** (skin tissue freezes at 30° F)

  Fingers, cheeks, nose, and ears are most at risk of frostbite. Symptoms include sensation of coldness, tingling, stinging, aching, and numbness. If left untreated, this condition can result in amputation or loss of function of the affected area. First aid requires treating tissue with warm water (102-110° F) as long as there is no chance for re-freezing tissue. Bed rest and medical attention must follow first aid.

- **Trench foot** (long exposure to wet and cold)

  Symptoms include tingling, itching, swelling, and pain. If left untreated, this condition can result in the death of skin tissue and ulceration, as well as in damage to the circulatory system. First aid requires moving crewmembers to a warm area, and treating the foot with warm water (102-110° F) or warm packs. Bed rest and medical attention must follow first aid.

Causes

Specific factors that can lead to cold-related illness include:

- Wet clothing
- Insufficient insulation of body, head, hands, and feet from wind, spray, and cold temperature
- Use of medication that disrupts the body's ability to regulate core body temperature
- Physical exhaustion
- Prolonged work-related exposure to cold, windy, and wet environments, allowing numbness of fingers and toes to set in

> **CAUTION! Winter months threaten crewmember health and endurance; working in unprotected deck areas exposed to the cold can result in an extreme reduction of body temperature (hypothermia) and in severe frostbite of hands and feet.**

Endurance Tips

Train crewmembers to:

- Wear 3-layered warm clothing
  - The outside layer serves as a weatherproof, breathable barrier that breaks the effects of wind chill. Gortex and nylon materials are best for this use.

- The middle layer absorbs sweat, retains vital body heat, and insulates the body from the external cold. Wool and synthetic-pile are recommended for this use.

- The innermost layer provides ventilation and allows perspiration to vent, keeping the skin dry. Synthetic fibers are best for this use.

- Bring a change of clothing to prevent having to work in wet garments; take a hot shower before changing.
- Keep the head covered at all times. Most body heat is lost when the head is left unprotected.
- Keep hands, feet, and face covered and warm. Fingers and hands cannot function properly below 59° F.
- Keep feet well insulated from cold and dampness. Layered socks and insulated boots are recommended.
- Keep garments clean. Soiled clothing loses its insulating properties.
- Drink plenty of water and maintain electrolyte balance (see Heat Illness).

<u>Provide Crewmembers with</u>:

- A heated shelter
- Local radiant heaters
- Thermal insulating materials placed over tool handles at environmental temperatures below 30° F
- Extra breaks in cold environments (deck personnel in particular)
- Reduced work pace
- Training session on how to endure cold-related risk factors

Heat-Related Illness

This section describes heat-related illnesses and provides prevention tips.

Exposure to high ambient temperatures is common during the summer months. However, this kind of exposure is always present in engineering spaces.

There are six major types of heat illness:

- Heat stroke
- Heat exhaustion
- Heat cramps
- Heat rash
- Heat syncope
- Heat fatigue

CAUTION! Heat illness is caused by exposure to high temperatures and humidity for prolonged periods, and by not drinking enough water. Crewmembers suffering from secondary illnesses that involve dehydration tend to be more susceptible to heat illness.

Heat stroke (hyperthermia) is a life-threatening disorder associated with working under very hot conditions. It results from a breakdown in the body's ability to regulate its temperature, leading to a rise in core temperature to over 107° F. Heat stroke is manifested by hot, dry skin; mental confusion; convulsions; and unconsciousness. Death frequently occurs, with a fatality rate of nearly 50 percent. Temperature-lowering methods must be initiated promptly: Remove outer clothing; apply cool water to the body surface; fan the body to create air movement; seek emergency medical attention.

CAUTION! If a crewmember exhibits heat-illness symptoms, use a cold-water bath or cold, wet towels to cool her or his core body temperature. Seek medical attention immediately.

Heat exhaustion results from a decrease in total body water and/or circulating blood-volume. It occurs when the amount of water lost by sweating exceeds the amount of water intake. The clinical manifestations of heat exhaustion include endurance degradation; extreme weakness; nausea; headache; fainting; and cool, clammy skin. Management of heat exhaustion consists of removing the crewmember from high heat and humidity, getting bed rest, and drinking plenty of fluids.

Heat cramps are painful muscular cramps commonly affecting the lower extremities. Heat cramps result when the loss of salt during long periods of work or exercise exceeds the amount of salt replaced. Salt is necessary for sweating. Note: Salt tables should **not** be taken.

Heat rash, otherwise known as 'prickly heat', occurs in hot, humid conditions, as a result of unevaporated sweat keeping clothes and skin wet. Heat rash may affect small areas (patches) of skin or the entire torso. The larger the affected skin area, the greater the compromise to sweat production and therefore to the body's ability to regulate body heat through evaporation. Following an instance of heat rash, sweat production may not return to normal for several (4 to 6) weeks.

Heat syncope is a benign condition manifested by dizziness and/or fainting. Heat syncope results from blood pooling in the lower extremities (in dilated vessels in the skin) and thereby reducing blood flow to the brain. Management of heat syncope consists of removal from heat, and rest.

Heat fatigue is a response to acute or chronic heat exposure. Symptoms of heat fatigue include decreases in motor skills, cognitive performance, and alertness, as well as reductions in performance capacity and concentration. Chronic heat fatigue improves naturally through acclimatization.

FACT: Heat acclimatization (the process of adapting to heat exposure) can be achieved by a minimum of sixty to ninety minutes of exercise, or strenuous work, in the heat each day for one to two weeks. Adaptation begins to occur within a few days.

Endurance Tips

To prevent heat illness:

- Never work when the ambient temperature is 104º F or above.
- Drink water on a regular schedule, even when not thirsty.
- Drink extra water when sweating heavily. Begin each work period by drinking approximately one pint of water. Water is best consumed in quantities of no more than one-half pint at a time.
- Drink extra water if urination becomes less frequent than normal, or if urine's color becomes darker.
- Replace electrolytes with fruit juices, V-8 juice, or bananas, or with commercial sports drinks that are at least 6-percent glucose and contain at least 10-25 mEq/L of sodium. Note: In most cases, it is not necessary to replace electrolytes specifically, because enough salt is obtained from regular meals and snacks.
- Wear loose-fitting clothes light in color.
- Seek well-ventilated places.
- Avoid the use of alcohol or other drugs that can impair temperature regulation, such as melatonin, aspirin, and acetaminophen (Tylenol).
- Adapt to heat exposure by working for 60 to 90 minutes each day within the work environment.

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Motion Sickness

This section describes motion sickness and provides tips on controlling the factors that contribute to it.

The symptoms of motion sickness include cold sweats, endurance degradation, dizziness, headaches, yawning, nausea, and vomiting.

Causes

Motion sickness is caused by an internal conflict in the brain. When we are standing on the ground, our brain senses the body's position relative to the ground. This sensory pattern is coded in our memory as a template. When we are standing on a moving platform, our brain becomes confused, because the information stimulating the sensory system does not match the existing memory template. This mismatch creates a series of changes in physiology as the brain struggles to create a new memory template.

A new template eventually forms by way of continued exposure to the particular motion state or states causing the confusion. In the case of 'sea sickness', getting this new template constitutes getting one's 'sea legs'. Some people get their 'sea legs' more quickly than others, while a few never get their 'sea legs' sufficiently to feel well enough to work.

> **WARNING! Motion sickness induces fatigue and deteriorates performance. Crewmembers experiencing symptoms should sleep as much as possible, and should walk around as much as possible in order to help the brain speed up the adaptation process. Safety is at risk when crewmembers encounter motion sickness, because fatigue and drowsiness are induced until the brain adapts to the moving environment.**

Endurance Tips

Medications are used to control the symptoms of motion sickness or to prevent its onset. A list of these medications, together with their side effects, is provided in Table 1.

It is recommended that crewmembers receiving medications to relieve the effects of motion sickness be warned that their performance will likely be degraded as a side effect of the medication. The captain, department head, or mate needs to keep in mind that crewmembers receiving medications should not be involved in tasks that might endanger their safety or that of other crewmembers.

If at all possible, crewmembers receiving motion sickness medication, or who are experiencing severe symptoms, should avoid shipboard work environments. It is strongly recommended that a medical officer closely supervise crewmembers using medications for motion sickness. Self-administration is strongly discouraged.

Table 1. Medications Used for Motion Sickness

MEDICATION	SIDE EFFECT	USE
Scopolamine[2] Patch	Drowsiness Degrades vision	Speeds adaptation within 72 hours
Dramamine	Drowsiness	Reduces symptoms
Antivert	Drowsiness	Reduces symptoms
Phenergan	Drowsiness	Reduces symptoms
Amphetamines	High blood pressure; disrupts heart rate; addictive	Reduces drowsiness
Ephedrine	High blood pressure; disrupts heart rate; addictive	Reduces drowsiness

[2] Scopolamine is the only medication that may help speed up the process of adaptation.

Stress

Chronic psychological stress – the type of stress induced by interpersonal relationships, task design, and management style – creates a constant drain on crewmember energy levels.

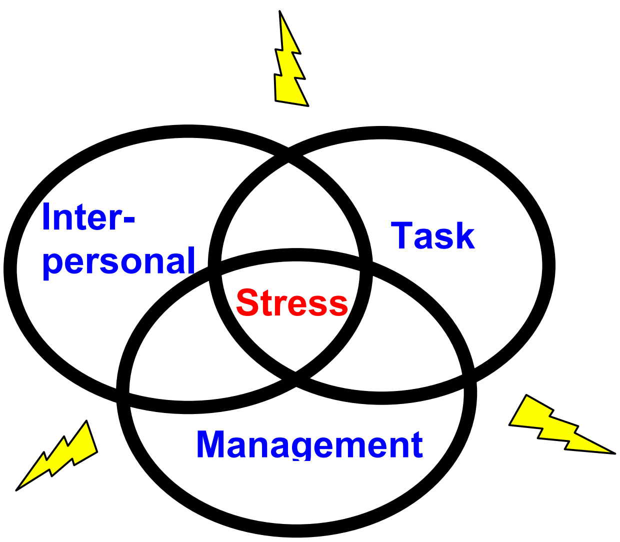
Causes

Interpersonal relationships:

- Lack of support from coworkers and supervisors

Task design:

- Heavy workload
- Infrequent rest breaks
- Long work hours
- Shiftwork
- Hectic routine tasks
- Little sense of control



Management style:

- Authoritative management style
- Lack of participation by workers in decision making
- Poor communication between management and employees
- Ambiguity or conflicting requirements
- Lack of family-friendly policies

These factors tend to induce physiological responses, such as elevated pulse rate and blood pressure, that use up energy even during rest periods.

Consequences

Normally the hormone epinephrine (adrenaline) is released during life-threatening situations to provide extra energy for a fight-or-flight response. However, this hormone can also be released in response to stress, including chronic stress. The presence of adrenaline in the body's various tissues temporarily increases the amount of energy available to the individual. Once this energy is released, however, it cannot be restored until the stress level is reduced. Hence, it becomes critically important that crewmembers not be under a chronically high level of stress.

> **FACT: The body's response to any kind of stress, life threatening or not, involves expending energy, and disrupting energy-producing activities during rest periods. Even during sleep, stress robs crewmembers of needed energy by disrupting the quality and duration of sleep.**

In a stressful work environment, crewmembers may have difficulty enduring physical and mental challenges. In addition, they may experience frequent periods of reduced mental concentration and awareness, states of mind particularly undesirable in safety-sensitive work situations.

The chronic use of over-the-counter pharmacological stimulants (e.g., caffeine and pseudoephedrine) to boost concentration and awareness can result in decreased attention, irritability, and adverse health effects. Therefore, implementation of stress management is a must-do for effective endurance management.

Stress management is particularly relevant for vessels where crewmembers work for long periods with little or no opportunity to break away from work-related duties. Under these conditions, work-related factors such as interpersonal relationships, task design, and management style can easily induce chronic stress if not adequately managed.

Endurance Tips

Stress reduction and morale boosters can render a large pay-off for a relatively small investment. For example, one maritime company found that installing satellite television and making cell-phone time available (e.g., 30 minutes weekly) to all crewmembers were consistent morale boosters.

Making shipboard phone use available, or providing shipboard Internet and e-mail access, can easily boost morale as crewmembers realize the company's interest in their mental and emotional well being. It can also help crewmembers communicate more with their families, and can help reduce the amount of time spent waiting in line for a public phone at port.

Management, captains, and crewmembers can contribute to the control of stress-related risk factors by implementing a consistent stress management program. The following recommendations provide a well-rounded list of ways to reduce stress:

- Train employees new to their job situation, particularly those recently promoted, to implement:
  - Time-management strategies
  - A regular exercise program
    - Make a variety of exercise equipment available to crewmembers (e.g., treadmill, free weights, stationary bicycle, rowing machine)
    - Allow crewmembers to have their own exercise equipment
  - Relaxation exercises (needed to reduce anxiety, increase concentration, and optimize the quality of rest periods)
- Promote crew participation in problem solving using a team approach

  The process of participation reduces the feeling of alienation, promotes feelings of self-worth, and allows individual crewmembers to become a valued part of a team effort.
- Identify and reduce stressful factors, particularly those involving interpersonal relationships
- Maintain good communication with crewmembers, realizing that alienation, withdrawal, and lack of participation are signs of stress
- Provide access to stress-reducing activities:

- Implement a nap policy during long work days
- Provide satellite television
- Provide consistent mental and physical health counseling

- Modify the daily menu so that meals are balanced, offering plenty of fresh vegetables and fruits, vegetable and fruit juices, whole-grain bread, and low-fat meats such as turkey, fish, and chicken (no turkey before watch, however, as it can cause sleepiness)

  It is best to consume proteins, carbohydrates, and unsaturated fat, and to let the body break down food into glucose, amino acids, and fatty acids *(see energy explanation in beginning of Section III)*.

- Provide a variety of nonalcoholic drinks, and avoid the use of highly sweetened soft drinks

  Promote fresh water and fresh fruit or vegetable juices as thirst-quenchers of choice.

Caffeine

Caffeine is a stimulant drug. For caffeine to serve as an alertness boost, it must be consumed at low levels, and only when needed.

Consequences

High doses of caffeine can result in increased anxiety, lack of concentration, and digestive disorders. Some people develop a greater sensitivity to caffeine and experience these symptoms even at low doses.

Frequent consumption of caffeine can result in addiction.

Common sources of caffeine include: coffee, tea, chocolate, soft drinks, and medications (over-the-counter and prescription).

Endurance Tips

Crewmembers addicted to caffeine should discontinue use and undergo withdrawal. Withdrawal can last two weeks and can include headaches, attention deficit, endurance degradation, and lack of motivation. Sleep patterns should begin to improve within this period, but energetic alertness after awakening may not be restored until the withdrawal process is complete.

If withdrawal is not desirable, reducing exposure to caffeine to one beverage (cup of coffee, bottle of soda, chocolate drink) per day can be a good compromise.

If caffeine is needed to maintain alertness during daytime hours, a physician should be consulted to evaluate the possibility of a sleep disorder.

Crewmembers taking over-the-counter or prescription medications that contain caffeine (or another stimulant) should closely follow the dosage instructions.

Caffeine should be used as a stimulant to boost alertness only when necessary, and should be avoided altogether within **four hours** of bedtime.

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SECTION V

Implementing a CEM Program

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V. Implementing a CEM Program

This section (**V**) describes how to implement a CEM program in maritime operations.

Implementing a CEM program involves three phases:

Phase I: Program Development

Phase II: Program Deployment

Phase III: Program Assessment

Phase I: Program Development

Developing a CEM program involves the following:

- Setting up a Working Group
- Analyzing the current situation
- Drawing up a CEM plan

Setting Up a Working Group

Setting up and training a Crew Endurance Working Group (CEWG) is fundamental to successfully implementing a crew-endurance management program aboard a maritime vessel.

The CEWG is responsible for all aspects of implementing a CEM program aboard a maritime vessel, including:

- Identifying the endurance risk factors relevant to the vessel
- Creating a collaborative network to facilitate implementing a CEM program aboard the vessel
- Devising and deploying a CEM plan specific to the vessel

To be effective, a CEWG must include or represent all those individuals who stand to be affected by implementation of a CEM program, especially regular crewmembers. A CEWG typically consists of the following individuals:

- One or two company officers
- The company operations or safety manager
- The captain and the relief captain of the vessel
- The pilot
- The first mate
- The chief engineer
- Two or more crewmembers, including the head cook

Because the head cook is likely to be considered unbiased, in being outside the chain of command, he or she is often a good choice for the CEWG, as is the chief engineer, who would likely be responsible for implementing any environmental changes decided on.

> **FACT: Controlling factors affecting crew endurance requires the development of a supporting organizational infrastructure. Without management support, individual crewmembers cannot effectively implement endurance management practices.**

The members of the CEWG must receive training in identifying and managing crew-endurance risk factors; creating collaborative networks to facilitate CEM implementations; and devising and deploying CEM plans.

Typically, the goal of a CEWG is to develop a CEM program for a particular situation – in most cases, a specific vessel; however, CEM plans can also be set up to apply to an entire company.

CAUTION! Successful working groups avoid personal or organizational agendas, and seek improvement of policies and crew management practices that will help crewmembers maintain endurance.

Analyzing the Current Situation

Before drawing up a specific plan, the Working Group must analyze the current situation. Table 2 Summarizes the four steps involved:

Table 2. Analyzing the Current Situation

Step 1	Receive training in CEM principles and practices
Step 2	Identify system areas of risk
Step 3	Identify specific risk factors
Step 4	Propose modifications

1st Step: Receive Training in CEM Principles and Practices

The CEWG meets initially to receive training in CEM practices and procedures, including how to create collaborative networks; how to identify and manage crew-endurance risk factors; and how to devise and deploy CEM plans. CEWG members also receive training in how to deal with cultural roadblocks: “This is the way we’ve always done it; why change?”

The CEWG also chooses a leader at this stage. In this regard, it is critically important that the CEWG choose a leader who is respected by all stakeholders, has authority to make decisions, and who is capable of guiding the group away from individual agendas.

2nd Step: Identify System Areas of Risk

The process of controlling endurance risk factors requires an analysis of the entire operational system of the vessel. This analysis consists of identifying the various areas of risk, such as workload, shipboard environment, weather, and company policy, as well as the relationship between these areas of risk (See Figure 10).

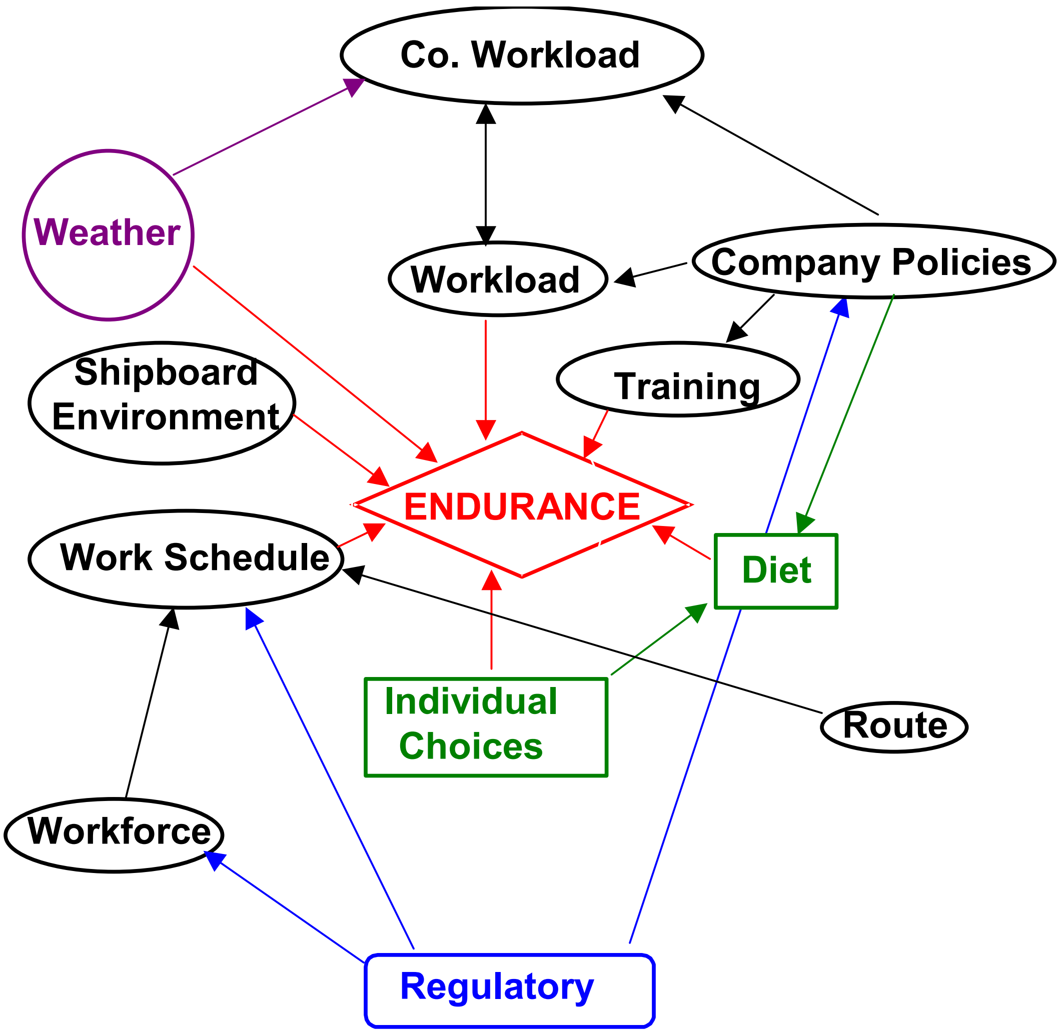

Figure 10. Operational analysis

Figure Legend:

Co. Workload	The accepted number of jobs at the company level.
Weather	Inclement weather can delay or stop operations.

Workload	Heavy workloads require more energy per hour from crewmembers.
Company Policies	Company policies can affect efforts by crewmembers to maintain endurance.
Shipboard Environment	Factors such as noisy, fumy, and light-porous quarters can disrupt sleep.
Training	The amount and the focus of crew training can affect stamina and alertness factors.
Work Schedule	Irregular or heavy work schedules can leave inadequate time for sufficient sleep.
Diet	How much, what, and when crewmembers eat impacts on energy, mood, stamina, and sleep.
Individual Choices	Individual choices (for example, watching TV during a sleep period) can affect stamina and alertness.
Route	Vessel routing can determine the type of work and the work schedule.
Workforce	The number of personnel allotted to each vessel can affect the watch regimen used.
Regulatory	CG regulations determine the maximum number of work hours per worker per 24-hour day.

The step 2 analysis (identifying system areas of risk) should be conducted over a period of at least 15 days (preferably 30 days) in order to properly document duty hours, workloads, and crew-rest routines associated with periods of low and high workload. Depending on the geographical location, workload may be directly affected by seasonal changes; thus, some evaluations must be conducted during both winter and summer seasons.

Information collected from the step 2 analysis helps CEWG members identify the specific risk factors that are currently affecting crew endurance. Identifying all these risk factors is fundamental to developing a CEM plan for a specific real-world operation. As the relevant risk factors are identified, the CEWG can then develop a specific plan to control the impact of these factors on performance and safety. For instance, some of the controls applicable to one particular operational situation were as follows:

- Encourage department chiefs to manage OT work ensuring that all crewmembers will have the opportunity to work OT without disrupting their rest periods
- Implement the alternate watch schedule during the underway period
- Revert to the standard watch schedule during frequent or lengthy in-port periods
- Train crewmembers to take advantage of rest opportunities under both the alternate and the standard watch schedules
- Identify conditions that prevent crewmembers from obtaining 7 to 8 hours of sleep per day, and develop plans to reduce the total number of days of exposure to these conditions

A key part of the step 2 analysis is documenting the impact of watch, work, and training schedules on crew rest and stress levels. Wrist activity monitors, used since the early 1980s to document sleep in field conditions, are highly recommended for this purpose. These devices, the size of a large wristwatch, can provide accurate information on the quality and duration of a crewmember's sleep.

The data collected with wrist activity monitors can be used to determine whether crewmember rest periods occur consistently, and whether they occur under environmental conditions that promote the restoration of alertness and physical energy from day to day. In addition, these data reveal how well personnel take advantage of rest periods. (For further details, refer to *Phase III: Program Assessment*.)

Note: The U.S. Coast Guard Research and Development Center can provide access to wrist activity monitors.

3rd Step: Identify Specific Risk Factors

The third step consists of analyzing the operational risk areas shown in Figure 10 to identify the specific risk factors (activities, environmental conditions, policies, operational situations) that appear to be affecting crew endurance. For example (from the commercial towing industry):

Work Schedule	The current 6-6-6-6 watch schedule was not allowing crewmembers sufficient opportunity to obtain the daily sleep required to maintain endurance.
Diet	Crewmembers were eating large meals immediately before going to bed after watch. Crewmembers were consuming large quantities of caffeine throughout the day, even close to bedtime.
Individual Choices	Crewmembers were consuming coffee throughout watches; staying up to watch TV, play games, or make lengthy phone calls; asking to be awakened an hour or more before a watch change. Crewmembers were being kept awake by noises associated with crews handling rigging near the vessel; slamming doors or banging manhole covers; using televisions, radios, hand-held VHF radios, etc. at high-volume levels.
Shipboard Environment	Crewmembers were being awakened by sudden movements of the vessel. Crewmembers were being kept awake by light entering crew quarters through windows and door louvers, and by engine noise entering through a single engine-room door.

	Lights in the crew quarters were not sufficiently bright for crewmembers to adapt to day or night work hours, or to become alert quickly upon waking. Smoke from the diesel engines was sometimes penetrating into staterooms, causing discomfort.
Company Policies	Crewmembers were accumulating sleep debt because of the 'no napping' policy. Crewmembers were being delayed from sleep time by not being able to take meals or showers until after watch change.

4th Step: Propose Modifications

The fourth step consists of suggesting modifications to the system shown in Figure 10 that address the risk factors identified in Step 3.

Typically these modifications involve changing the shipboard watch schedule, introducing light-management techniques (to control the Red Zone), changing crewmember dietary practices, controlling the use of caffeine and over-the-counter drugs, and making changes to crewmember living areas.

Refer to Section II for additional examples.

Drawing Up a CEM Plan

Upon completing an analysis of the current situation, the CEWG then draws up a formal plan of implementation. This process consists of:

- Agreeing on and prioritizing modifications
- Setting up a CEM Final Common Path

The process involved in arriving at a plan for implementation requires dedication, cooperation, and self-discipline. If individual agendas are allowed to take precedence, a meaningful CEM plan cannot be achieved.

In cases where individual agendas obstruct progress, it is recommended that the working group focus on identifying changes (no matter how small) that all stakeholders can support. In such cases, actions that elicit irresolvable disagreements must be considered 'long-term projects'.

Agreeing on and Prioritizing Modifications

The CEWG must agree on and prioritize the system modifications suggested in Step 4 of the analysis process.

The process of prioritizing system modifications involves placing them into one of three possible categories:

- Those that can be implemented easily
- Those that can be implemented with more effort
- Those that cannot be implemented

It is recommended that the working group place an initial emphasis on small or inexpensive modifications that yield relatively large benefits. Larger or more expensive changes can then be phased in over time.

It is paramount that CEWG members make their modification recommendations on the basis of information gathered in Steps 1-3, rather than on the basis of personal preference or a resistance to change.

Setting Up a Crew-Management Final Common Path

In order for a CEM program to succeed, a crew-management Final Common Path must be established and maintained. A crew-management Final Common Path consists of the following key elements:

- Setting up a team of onboard coaches to train crewmembers on the science and practices of CEM, and to serve as program models and monitors

  The team of coaches typically consists of the captain, the pilot, and the mate.

- Training the coaches in the science and practices of CEM

  Training for coaches is provided by company management, typically using resources available from the U.S. Coast Guard Human Element and Ship Design Division (202-267-2997).

- Training the crewmembers in the science and practices of CEM, modeling the required practices, and monitoring crew adherence to these practices

> **CAUTION! Experience has demonstrated that it is not sufficient to simply change a watch schedule from a, for example, 6-6-6-6 regimen to an alternative regimen such as 7-7-5-5. CEM implementation will fail If a Final Common Path has not been set up to teach crewmembers how to take advantage of the new schedule, how to use light-management techniques, and how to ensure that appropriate environmental changes have been made (for example, to control noise and light in sleeping quarters).**

Setting Up a Team of Coaches

Effective Crew Endurance Management requires constant encouragement and reinforcement. Providing encouragement and reinforcement is accomplished by a shipboard team of coaches specifically charged with:

- Coordinating crewmember training, and documenting crew rest during implementation of new work schedules
- Supporting the overall implementation of CEM practices by modeling CEM practice for crew emulation, actively encouraging crewmembers to follow CEM practices, and enforcing adherence to the policies and procedures of the CEM plan
- Providing information to vessel officers on how to design and implement work schedules that both meet the operational objectives of the vessel and do not result in inadequate adjustment to changing schedules

- Providing information to crewmembers on how to maximize the benefits of rest opportunities (refer to both Section II and Appendix A)
- Implementing crew-rest protocols that document: (1) the timing and number of rest opportunities made available for crewmembers, and (2) crewmember efficiency in taking advantage of rest opportunities

Training the Coaches & the Crew

Successful implementation of a CEM plan on a maritime vessel requires that all the relevant players be trained in crew-endurance practices and procedures. For the team of coaches, this training is the responsibility of the company, typically using resources available from the U.S. Coast Guard Human Element and Ship Design Division (202-267-2997). For the crew, this training is the responsibility of the shipboard team of coaches.

The training provided should include sleep and body-clock management, stress management, time management, and information concerning such risk factors as diet, caffeine use, over-the-counter and prescription medications, heat illness, and exercise.

> **MANAGEMENT NUGGET: Successful implementation of a CEM plan to improve endurance requires an aggressive education program designed to instruct company managers, vessel captains, all levels of vessel management, and crew personnel on the science and practices of crew endurance management.**

Phase II: Program Deployment

Implementing a CEM program requires that all levels of an organization share the responsibility for success. This responsibility includes the following essentials:

- Enlisting the support of the full crew
  - Crewmembers are presented with the Working Group's CEM plan as well as the rationale supporting each of its features. In addition,

they are provided with key information and training on crew-endurance benefits, factors, and procedures. It is emphasized that changes are not being recommended merely for the sake of making changes, and that legacy systems are not necessarily the best possible systems simply because they have been in place for long periods of time.

  - Crewmembers are reminded that all change, including implementing a CEM plan, requires making personal adjustments, with each adjustment supporting and improving on other adjustments.
  - Some benefits are immediately available, such as noise improvements and time-management practices. Others, such as easier integration back into a home living schedule, and easier adjustment back to a vessel schedule, may not be recognizable until either after a crewmember has left the vessel or when the crewmember returns to the vessel.
  - Crewmembers are invited to make suggestions toward improving the Working Group's plan, and are asked to support the final plan toward the mutual benefit of all concerned.

- Implementing the recommended modifications
  - The CEWG – working with company management, the vessel captain, and the shipboard coaches – ensures that all of the system modifications recommended in the final CEM plan are implemented.
  - These modifications might involve changes in watch schedule, changes to crewmember quarters and living areas, new shipboard policies, and/or requests to the crew for changes in personal choices (relative to diet, fitness, use of caffeine and other over-the-counter drugs, etc.).

- Coaching the crew toward consistency

  During and after initial implementation, the shipboard team of coaches is responsible for:

- Coordinating crewmember training, and documenting crew rest during implementation of new work schedules
- Supporting the overall implementation of CEM practices by serving as models of CEM practice for crew emulation, actively encouraging crewmembers to follow CEM practices, and monitoring and enforcing adherence to the policies and procedures of the CEM plan
- Providing information to vessel personnel on how to design and implement work schedules that both meet the operational objectives of the vessel and provide adequate adjustment regimens
- Providing information to crewmembers on how to maximize the benefits of rest opportunities (refer to both Section II and Appendix A)
- Implementing protocols that document the timing and number of rest opportunities made available for crewmembers, and that quantify the efficiency of crewmembers in taking advantage of rest opportunities

Phase III: Program Assessment

Phase III assessment evaluates how well a newly deployed CEM program is working under real-world conditions, and is usually conducted over the first 60 days of deployment, during normal operational tempo. Assessments conducted during slow- or high-tempo periods may not accurately determine true effectiveness.

As in the Phase I assessment, it is necessary to document the impact of watch, work, and training schedules on crew rest and stress levels. The same wrist activity monitors used in the Phase I (step 2) analysis are highly recommended for use in the Phase III analysis.

The data collected with wrist activity monitors can be used to determine whether crewmember rest periods are occurring consistently, and whether they are occurring under environmental conditions that promote restoration of alertness and physical energy from day to day. In addition, these data reveal how well personnel are taking advantage of rest periods provided by the implemented CEM plan. Methods to test the effectiveness of crew endurance plans are provided in several reports published by the R&DC.

Phase III data provide the CEWG with objective information on crew-rest and stress levels during the two-month implementation period. These observations can help determine whether additional modifications need to be made to the operational system.

As a matter of good CEM practice, the CEWG should maintain an active education program for new as well as veteran crewmembers, and should ensure that CEM evaluations are conducted at least semi-annually.

Summary

The implementation of CEM practices can help company and vessel crews enhance their current efforts toward maintaining high levels of crew endurance and safety. CEM practices provide a process for optimizing alertness and controlling normal operational stressors.

A key part of implementing a formal CEM plan is forming a Crew Endurance Working Group. CEWG members serve as champions of the endurance plan aboard vessels while contributing to the maintenance of crew endurance industry-wide.

Further information on equipment, development, and implementation of crew endurance plans can be obtained by contacting Crew Endurance Team members at U.S. Coast Guard Human Element and Ship Design Division (202-267-2997), or the U.S. Coast Guard Research and Development Center in Groton, CT (860-441-2600).

Appendix A

Sleep Management and Circadian Rhythms

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A-1: Sleep Management

Sleep cycle

Sleep consists of certain brain activities that progress predictably through five distinct stages (see Figure 11):

Stage 1 is the transition from awake to asleep. This stage is characterized by a slowing of brain activity. When aroused from this stage, many people believe they were never asleep. After about five to ten minutes of stage 1 sleep, a person progresses to a deeper sleep, stage 2.

Stage 2 is characterized by brain activity slower than that typical of stage 1, and is considered by many to be the true beginning of sleep. Within 10 to 15 minutes, brain activity slows even further and progresses into the deepest sleep, stages 3 and 4.

Stages 3 and 4 are termed slow-wave sleep (SWS). It can be very difficult to arouse a person from SWS, and once awake, the person may feel sluggish for several minutes. After 20 to 30 minutes of slow-wave sleep, brain activity reverts briefly back to stage 2 sleep, and is then followed by rapid eye movement (REM) sleep (stage 5).

REM, stage 5 or dream sleep, is characterized by quick eye movements, little to no muscle tone, and by very active brain patterns. The first REM period of the night is relatively short, lasting five to ten minutes. After REM sleep, the sleep cycle repeats itself, returning to stages 2, 3, 4, and 5.

Each cycle through the four stages lasts approximately 90 minutes, with approximately five to six cycles occurring per night. Most SWS occurs during the first half of the sleep period, while most REM sleep occurs during the second half of the period. Overall, stage 2 sleep occupies the majority of the sleep period, followed by REM sleep, and then SWS.

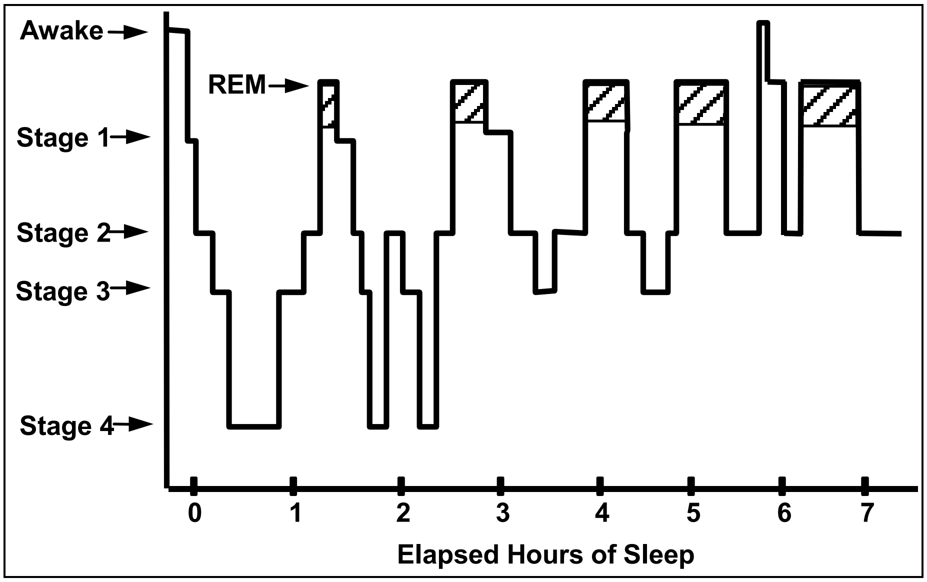

Figure 11. Sleep cycle

This cycle of sleep can be disrupted by such factors as schedule changes, frequent awakenings, and medications. Any disruption bringing on full wakefulness will cause the brain to start the sleep cycle from the beginning, with the result that the full cycle may not then be completed, because of time constraints. When chronic disruption occurs, endurance degradation ensues.

Everyday Sleep Management

The ability to achieve good-quality sleep depends largely on good sleep habits. Leaders and personnel should be aware of the following factors that can affect the ability to sleep, or the quality of the sleep achieved.

Planning for sleep

- The amount of sleep each person needs varies; one cannot determine individual sleep needs from what other people require.

  To determine your own sleep needs, follow this procedure: After at least 30 days on the same sleep/wake schedule, go to bed at your regular time without taking any sleep aids, and allow yourself to wake up naturally (no alarm clock) for three consecutive days. The amount of sleep time on the third day is your normal sleep requirement.

- Sleep aids (medications) should be avoided, except in extreme situations.

- If a sleep aid was previously used, the first and possibly the second night of sleep without medication may be disrupted. Falling asleep may be delayed, and the person may awaken several times during the night. However, this will subside within one to two nights.

- Try to sleep at the same time every day, including weekends. If possible, go to bed at the same time and get up at the same time each day.

- Alcohol should never be used as a sleep aid. Although sleep onset may come more quickly after ingestion of alcohol, actual sleep will be more disrupted and less restful after the first one to two hours.

- Avoid eating or drinking substances that contain caffeine (especially coffee, tea, or chocolate) four to five hours before bedtime.

- Do physical training no closer than one hour before bedtime; exercise has a temporary alerting effect.

Good sleep habits

- When trying to sleep outside the usual sleep period (e.g., during the day), prepare as if for a normal sleep period – wear usual sleep clothes, darken the room as much as possible, keep noise to a minimum, and, if possible, use a white-noise generator, such as a fan.

- Use bed only as a place to sleep; do not read, work, or do other similar activities in bed. Associating bed with sleep will eventually allow sleep to come more easily.

- After 24 to 48 hours of sleep deprivation, do not sleep overly long during the recovery period (more than ten hours). Sleeping too long may interfere with the normal sleep/wake schedule, and may cause significant sleep inertia and lethargy during the day. The normal sleep period for an individual is usually sufficient to recover from 24 hours of sleep deprivation.

- Take over-the-counter and prescription medications strictly as directed.

Problems with sleep

If you cannot fall asleep after about 30 minutes in bed, do not remain in bed awake; get up to avoid associations of waking and anxiety with being in bed. Stay up several minutes and then try again. Continue to get up if you cannot go to sleep within 30 minutes, no matter how many times this may occur during the sleep period. Eventually, endurance degradation will take over.

A person who has difficulty sleeping during his or her normal sleep period should not nap during the day, as doing this may delay sleep onset.

A-2: Napping

When the pace of operations and the staffing level permit, naps can be used to sustain performance during normal work periods. In such cases, leaders should allow time for napping, and should provide a quiet, comfortable place for personnel to take short naps as the situation permits. Leaders should also educate personnel about the benefits of napping, and should inform them that rest is not a substitute for sleep.

Napping during work periods can reduce performance impairment, but it cannot totally alleviate the effects of sleep deprivation. Individual differences in sleep needs must be considered in determining nap length. Several factors are important to consider when scheduling naps:

Pre-existing sleep loss

- The best time to nap is before significant sleep loss has occurred. Such preventive naps help ward off subsequent performance impairments during heavy work schedules. Personnel who nap for one to four hours prior to a nighttime work period will show better early-morning performance and alertness than personnel who do not nap. Preventive napping may be better than napping during a sleep-deprivation period.

- Naps do not totally eliminate the normal circadian dip experienced at around 0500, but degradation in both cognitive performance and alertness is reduced.

Nap length

- A single two-hour nap during a 24-hour continuous work-period can cause performance to be close to pre-sleep-loss levels.

- If longer naps are not possible, several naps of as little as ten minutes each, taken over a 24-hour period, can help personnel endure continuous operations.

Timing of the nap

- It is easier to nap when the core body temperature is at its lowest (at around 0300 and 1300); it is more difficult to nap when the core body temperature is at its highest (at around 1500).

- For several hours following waking from a nap during a circadian dip (see Figure 1), sleepiness is higher, and performance is lower, than for a nap taken during a circadian peak.

- Early morning naps (0200 to 0600) are beneficial in restoring alertness and performance; however, time should be allowed for personnel to fully recover from the nap.

Length of time between end of nap and work period

- Performance is generally lowest during the first five minutes after a person awakens from a nap (sleep inertia), but usually recovers after 15 to 30 minutes.

- Extensive sleep inertia is especially likely when a person is awakened from slow-wave sleep, which occurs most often within the first two hours of sleep.

- Awakening from sleep that follows a long period of sleep deprivation leads to high levels of sleep inertia; the longer the sleep-deprivation period, the higher the sleep inertia.

Naps during circadian dips should be avoided when crewmembers need to return to work immediately upon awakening, because sleep inertia under these conditions can be relatively high.

A-3: Circadian Rhythms

Physiology

The human body (biological) clock controls specific patterns of hormones, alertness, and core body temperature. The word *circadian* is used to describe biological and behavioral rhythms regulated by the human body clock.

The human body clock normally provides mental and physical energy during the day, but not during the night. This energy pattern is stable and predictable only if the body clock receives daylight exposure at consistent times from day to day.

Scientific research has demonstrated that mental alertness mirrors core body temperature and is inversely related to melatonin levels. Melatonin is a hormone produced during the night that regulates sleep and the timing of the body clock.

Consequences of Desynchronosis

Desynchronosis refers to a disruption of synchronized physiological functions caused by changes in sleep and work routines, or by travel across time zones. The following list summarizes a few specific work-related consequences caused by jet lag (travel across time zones), or by shift lag (shiftwork):

- Truck drivers have been shown to have twice as many accidents between 2400 and 0200 than during the day.
- Locomotive operators have an increased probability of missing warning signals when working the night shift.
- Night-shift workers perform worse than day workers on tasks of vigilance and reaction times.

- Compared to day fliers, aviators flying in flight simulators at night have reduced hand-eye coordination, poorer vigilance and calculation proficiency, and impaired flight performance.

Desynchronosis Controls

The following recommendations will help prevent circadian desynchronosis.

Once shift lag or jet lag actually develops, returning to normal can require a person to adhere to a consistent sleep schedule for **several weeks**. In other words, desynchronosis symptoms are not likely to disappear in just a few days of normal sleep.

General recommendations

Individual crewmembers and staff personnel planning work and briefing schedules should use the following general recommendations.

- After arriving in a new time zone or making a shiftwork transition, maintain consistent schedules for sleep, wake-ups, exposure to daylight, and naps.

- Avoid changing sleep/wake schedules during days off.

- Always sleep in completely darkened rooms. If sleep must occur during daylight hours, wear a black, cloth sleep-mask.

- Strive to sleep at least six continuous hours per day.

- Become aware of how many hours of sleep you need in order to feel refreshed and alert upon awakening. Short sleepers may need as few as five hours; long sleepers as many as eight hours.

- If after sleeping you feel sleepy during the afternoon hours, you need more sleep.

- Prevent noise from disrupting sleep periods. If external noises cannot be controlled, mask them with the sound of a fan, a power generator, a commercially available sound-masking device, or some other such device, or wear foam earplugs.

- Avoid meals high in fat content for least three days after transitioning to a new location or work schedule. Gastrointestinal disorders can surface while you are readjusting to a new time zone or work schedule.

Napping and circadian desynchronosis

Naps are recommended for certain situations, some of which are highlighted below:

- You should nap whenever you shift from day work to night work, cannot sleep more than four to five hours during your sleep period, and must work the following night.

- Naps longer than one to two hours are not recommended if your next sleep period will take place during the following night. In this case, naps taken during the day may interfere with the onset and duration of the following night's sleep.

- When rapid shift rotations are used, personnel should be encouraged to use naps during their time off in order to compensate for sleep loss incurred during the transition to nighttime duty hours.

- When shifting from daytime to nighttime duty hours, opportunities for naps may occur:

  - During the afternoon (e.g., between 1500 to 1700 hours)

  - In the evening (e.g., between 1600 to 1900 hours) prior to reporting for a nighttime duty period (e.g., from 2100 to 0500 hours)

Research on the effects of the restorative value of naps indicates that:

- A 2-hour nap taken in mid-afternoon (e.g., from 1500 to 1700 hours) results in a greater restoration of alertness than a two-hour nap taken in the evening (e.g., from 1900 to 2100 hours).

- Naps taken during the mid-afternoon (e.g., at 1500 hours) contain more total dreaming time (REM sleep) than naps taken at 0300 hours.

- When transitioning from daytime duty hours to nighttime duty hours later the same day, a nap at 1500 hours can compensate for sleep loss incurred during the assigned sleep period.

- Naps taken in the afternoon can be more restorative than naps taken in the evening prior to reporting for nighttime duty. Naps taken during a work period after midnight, however, can be less restorative than earlier naps, and can induce performance degradation for up to one hour. This consideration limits the value of a nap after midnight.

Pre-adaptation prior to travel across time zones

While potentially useful, pre-adaptation to a new time zone requires considerable coordination and cooperation. Under a pre-adaptation plan, personnel typically begin shifting their sleep cycle from their current time toward the new sleep cycle several days before transition:

- The number of days devoted to pre-adaptation, and the number of hours shifted daily, depend on many factors, including the number of time zones to be crossed and the amount of advance notice received.

- The magnitude of the phase shift should not exceed six hours per day, and should range from two to four hours per day.

- Pre-adapting personnel must be given off-hour access to finance and personnel services, properly timed meals, and so forth; otherwise, they will not be able to adhere to the out-of-phase schedule of their pre-adaptation plan.

- Family members should understand pre-adaptation techniques sufficiently to be sympathetic with a fellow family member's need to be out-of-phase with the rest of the family.

Timed light exposure

By carefully scheduling exposure to natural or artificial daylight, it is possible to speed adaptation to a new work schedule or time zone. Specific suggestions are included in the scenarios provided later in this appendix. However, the following general guidelines apply:

- Light levels of over 1000 lux (dawn brightness) are necessary to affect the body's timing mechanism. Exposures lasting at least one hour are effective in resynchronizing the sleep cycle and other physiological rhythms.

- For individuals who are accustomed to sleeping during the night, working during the day and retiring during the night (e.g., at 2200), daylight or sufficiently bright light exposure between 0300 and sunrise will consistently advance sleep onset approximately one to three hours earlier per day.

  The time period between 0300 and sunrise is referred to as the **advance body time zone**, because light exposure in this period results in earlier wake-up times and bedtimes. Predicting the exact amount of the advance requires information on physiological rhythms (e.g., core body temperature or melatonin production) that will be impractical to obtain in most field situations.

- In eastward travel, seeking daylight exposure during the advance body time zone (clock times calculated from the time zone that the traveler lived in prior to the trip) for the first three days will speed the resynchronization process. Daylight should be avoided between sunrise and 1100 local time (these clock times are calculated using the destination's time zone) for the first three consecutive days in the destination location.

  The advance zone will shift to earlier times from day to day; it is difficult to accurately predict the time range after two days of advances without data on physiological rhythms. Therefore, after the third day, daylight exposure should be coordinated to occur as soon after awakening as it occurred in the origination time zone.

- In westward travel, seeking daylight or bright light exposure between sunset and 0300 (**delay body time zone**) will help delay sleep onset. The duration of the delay depends on the duration of light exposure. In most cases, exposure durations of one to three hours will result in significant delays of one hour or more, depending on individual differences.

- Artificial bright lights can be used to influence changes in sleep prior to or during shift changes or travel, provided that the appropriate equipment is available. Bright light banks are available from commercial suppliers and appear to be effective. Providing a brightly-lit work area for night-shift workers can be beneficial.

- Wearing dark sunglasses can minimize unwanted exposure to daylight (see eastward travel, above). Very dark sunglasses may be ordered from commercial sources. If these are not available, conventional sunglasses can reduce light exposure.

A-4: Shiftwork, Sleep, and Biological Clock Management

Shiftwork Maladaptation

Optimizing crew rest, along with preventing physiological maladaptation to shiftwork, can contribute significantly to a person's ability to endure long-term exposure to harsh working conditions, without compromising work performance and safety. Shiftwork maladaptation results from an inability to adapt human physiology to rapidly rotating cycles of sleep and work.

Adapting to nighttime or daytime work requires adjusting physiological and cognitive activities that are regulated by the biological clock. The biological clock is a physiological mechanism composed of neural networks and hormonal outputs that regulate sleep and wakefulness cycles as well as the daily availability of energy and cognitive resources.

Maladaptation to shiftwork schedules, and the lack of energy-restorative sleep, result in a multitude of persistent symptoms such as:

- Low energy
- Lack of motivation
- Introversion
- Reduced and unclear communication with coworkers
- Apathy
- Reduced attention to detail
- Depression
- Performance degradation during duty hours
- Degraded endurance

- Reduced safety

Other health effects such as increased incidence of cardiovascular disease, gastrointestinal disorders, and sleep disorders have been documented in populations exposed to shiftwork maladaptation (Congressional report, 1991).

Inconsistent sleep and daylight exposure reduce safety

Personnel accustomed to waking up and seeing daylight in the morning (e.g., at 0700) are adapted to work during daylight duty hours and to sleep during nighttime hours. Their biological clock is day-oriented; adjusted, that is, to provide energy and cognitive resources during normal workday and evening hours.

Two peaks of alertness and energy availability will take place throughout the day: one in the morning and one in the early evening (see Figure 1). Day-oriented personnel will normally experience reductions in energy and alertness immediately upon awakening, again in the mid-afternoon, and again in late evening. This pattern of energy availability will be maintained consistently if personnel obtain good-quality sleep (uninterrupted sleep in quiet and dark environments) daily for seven to eight hours.

However, should the sleep period become reduced to fewer than six hours per day, or be frequently interrupted by bright lights, noise, or movement, a daily sleep debt will begin to accumulate. The consequences of this sleep debt will be first experienced in the degradation of:

- Alertness
- Decision-making ability
- Performance of mental function requiring logical ability

Persistent sleep debt throughout a week will result in increased daytime sleepiness and in degradation of cognitive and psychomotor performance. And, as performance fares so fares safety.

In addition to sleep duration, the stability of the body's biological clock directly affects both alertness and performance. Frequent disruption in the daily adjustment of the biological clock adds to a deterioration of alertness and performance. For instance, working on the bridge under a watch schedule that requires waking up at 0700 on Mondays, Wednesdays, and Fridays, but requires a 0330 wake-up on Tuesdays, Thursdays, and Saturdays, will send conflicting signals to the biological clock, particularly during the summer. On the days that wake-up times are required at 0330, the clock will receive daylight exposure earlier than usual (at approximately 0500,) resulting in an advance of wake up times and bedtimes.

Conversely, on the days the biological clock does not receive the early morning daylight dose, bedtimes and wake-up times will be allowed to slip to a later time. This advance of body time can be approximately one-half to one hour per day. These changes in the body's timing mechanism affect the alignment of daily peaks and troughs of other physiological rhythms such as core body temperature (usually high during daylight hours and low during nighttime), and production and release of hormones and neurotransmitters.

In general, the biological clock requires approximately three days to re-adjust to a new regimen, such as a two-hour advance in daylight exposure due to earlier wake-up times. This readjustment will take place if the new sleep/wake schedule is consistent from day to day. However, if the inputs are inconsistent, the clock's timing can become disorganized in such a way that the physiological rhythms under its control will no longer be expressed in a predictable pattern. The individual impact results in:

- Sleepiness
- Insomnia
- Deterioration of performance in mental and motor tasks

Inconsistent inputs to the biological clock are common when personnel work nighttime shifts and do not control daylight exposure at the end of the shift. For instance, a watch schedule prescribing a six-hour watch during the night (e.g., beginning at 2400), then six hours of time off (from 0600-1200), followed by a six-hour watch beginning at approximately 1200, can result in jet lag-like symptoms. In this particular work schedule, if personnel (e.g., engineering) work under normal lighting or in dim light environments (e.g., the bridge at night), exposure to daylight after sunrise will set the biological clock to a daytime orientation. In a daytime orientation, the biological clock predisposes the brain and energy cycles for sleep, and not work, during nighttime. Fatigue-induced deterioration of performance will occur during nighttime hours.

Shiftwork maladaptation prevention

Optimally, sleep must take place during a time of day scheduled by the internal biological clock. This clock system (details in next section) regulates the timing of sleep onset and wake-up times. Due to evolutionary pressures and physiological characteristics, the human body is predisposed to work during daylight hours and to sleep during nighttime hours. The body's clock system maintains a sleep schedule in synchronization with local sunrise and sunset, and daylight duration.

Energy cycles regulate the experience of high and low levels of alertness throughout the day. Alertness peaks in the mid-morning hours, dips in the afternoon hours, peaks again in the early evening hours, and begins to decrease in the early night, reaching daily lows in the middle of the night. The exact times of these peaks and valleys depend on specific inputs to the biological clock system; namely, wake-up times, bedtimes, meal times, and, more importantly, the time of daylight exposure (or exposure to artificial light).

Personnel exposed to regular work schedules that facilitate consistency from day to day will enjoy the benefits of a well-synchronized biological clock. These benefits include regular energy-restoration cycles, and predictable peaks and troughs of alertness. In contrast, work schedules that impose frequent transitions from daytime to nighttime duty hours tend to disrupt energy-restoration processes and thereby to degrade endurance.

Adjusting the biological clock requires implementing a specific schedule of daylight (or artificial-light) exposure, and maintaining a consistent sleep schedule. One way to minimize endurance degradation during nighttime work is to reverse the biological clock's synchronization from daytime to nighttime orientation. For the clock's timing to reset energy resources to peak during nighttime, work must take place under bright lights (approximately 1000 lux or more), mimicking the effects of daylight. Sleep must take place in a dark and noise-free environment. Lacking control of daylight (or bright-light) exposure times contributes significantly to endurance degradation.

If the use of bright, artificial light is not compatible with the work environment (e.g., on the bridge of a cutter or the cockpit of a helicopter at night), a specific light and sleep management schedule can be designed to shift the biological clock toward a night orientation. Because experimenting with light-exposure schedules can result in unintentionally inducing chronic endurance degradation and jet lag-like symptoms, it is recommended that professionals working in the fields of circadian rhythms and sleep management develop these light and sleep management schedules.

The synergistic effects of disrupted sleep (fewer than seven to eight hours) coupled with biological-clock disorganization can lead to endurance degradation, jet lag-like symptoms, and an exacerbation of psychological maladjustment symptoms, such as irritability, depression, and even psychosis. Other physiological symptoms associated with this condition include cardiovascular disease and gastrointestinal disorders.

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Appendix B

Supporting Documents

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