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CRISP REPORT

Connecting Research in Security to Practice

Fatigue Effects and Countermeasures in 24/7 Security Operations

James C. Miller, PhD, CPE

ABOUT THE CRISP SERIES OF REPORTS

Connecting Research in Security to Practice (CRISP) reports provide insights into how different types of security issues can be effectively tackled. Drawing on research and evidence from around the world, each report summarizes the prevailing knowledge about a specific aspect of security, and then recommends proven approaches to counter the threat. Connecting scientific research with existing security actions helps form good practices.

Reports are written to appeal to security practitioners in different types of organizations and at different levels. Readers will inevitably adapt what is presented to meet their own requirements. They will also consider how they can integrate the recommended actions with existing or planned programs in their organizations.

Drawing upon a range of studies, Dr James Miller, examines how fatigue, caused by working irregular or shift hours, can impact the performance of security personnel. Crucially Dr Miller highlights how human factors can be managed to ensure the maximum effectiveness of shift work systems. This report will most likely become an essential reference point to guide good practice.

CRISP reports are sister publications to those produced by Community Oriented Policing Services (COPS) of the U.S. Department of Justice, which can be accessed at *www.cops.usdoj.gov.* While that series focuses on policing, this one focuses on security.

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Connecting Research in Security to Practice

An ASIS Foundation Research Council CRISP Report

Fatigue Effects and Countermeasures in 24/7 Security Operations

James C. Miller, PhD, CPE

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Contents

Executive Summary

This report examines the effects of fatigue and night work on human cognitive performance and offers countermeasures that may be used to combat those effects. The report is applicable to security personnel and police in general, especially those who work night shifts. It draws from both experimental and field studies conducted with police and others who work evening and rotating shifts, as well as fatigue research conducted by the Department of Defense concerning the performance of weapon systems operators.

Human-Machine Interactions

Good human-machine system design exploits human strengths and protects the system from human weaknesses. The human operator brings much more performance variability to a system than one finds in software and modern hardware. Research indicates that once an operator has been trained and is current in system operation, the greatest contributor to that human variability is cognitive fatigue. Speed and accuracy on the job are only above average between 7:00 a.m. and 7:00 p.m. At night, efficiency is relatively poor, especially during the pre-dawn hours. Productivity decreases and safety risk increase across successive night shifts.

Sleep

Sleep is not a passive or vegetative state. It is generated by complex, active brain physiology, and humans have specific physiological and psychological requirements for getting adequate rest. Both sleepiness and cognitive fatigue are primarily caused by lack of sleep. When people do not get adequate rest, they may experience excessive cognitive fatigue when they are awake. This often affects their ability to perform safely on the job. Sleep loss of even one or two hours a night may significantly degrade alertness and performance.

Working at Night

Humans are not biologically wired to work at night. Evening is when our metabolic rate drops to its lowest and when the complex biological mechanisms in the brain that generate sleep operate most powerfully. Managers should use a principle-based approach to shift work scheduling that constrains the infinite number of possible schedules to those schedules that are simple, practical to implement, and least harmful to worker health, job performance, and attitude. Nine shift work scheduling principles are examined, as are the components of a shift work schedule.

Quantifying Fatigue

Quantitative fatigue-effects predictions may be derived from models such as the Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE™) simulation, QinetiQ's System for Aircrew Fatigue Evaluation (SAFE), and the Fatigue Audit InterDyne (FAID). The SAFTE™ simulation integrates quantitative information about (1) circadian rhythms in metabolic rate, (2) cognitive performance recovery rates associated with sleep, and cognitive performance decay rates associated with wakefulness, and (3) cognitive performance effects associated with sleep inertia to produce a three-process model of human cognitive effectiveness.

Fatigue Indicators

There are five generally-accepted fatigue indicators with limits that raise "red flags" with respect to the likelihood that human cognitive performance is likely to be impaired by fatigue, allowing a semi-quantitative approach to deciding whether a mishap may be fatigue related. The five indicators are the amount of sleep in the last 24 hours, cumulative sleep debt, hours awake since the last major sleep period, time of day on the body clock, and amount of jet lag or shift lag.

Security and Law Enforcement Research

Little research literature exists with direct applications to security operations. A number of studies of police shift work were conducted from 1983 through 2009. The lessons from these studies may be that while we know a fair amount about negative health effects in this population, there is a lack of information about the effects of fatigue on security job performance or about managing fatigue effects in security operations.

Fatigue Countermeasures

An organization's use of fatigue countermeasures must be initiated and sustained with a top-down management approach. This report provides information for countering fatigue at the organizational level. Subsequently, several specific countermeasures are described. These include sleep, which includes anchor sleep, napping, and the removal of sleep debt; alertness aids such as caffeine and modafinil (ProVigil®); sleep aids such as Ambien®; phototherapy; and melatonin. Perceived aids that do not work are listed and countermeasures that need more research are discussed.

An "Applications" section suggests how to use major pieces of information presented in the report.

Introduction

This report examines the effects of fatigue and night work on human cognitive performance and offers countermeasures to combat those effects. The report is applicable to security personnel and police in general, especially those who work at night. It draws from experimental studies and field studies conducted with police and others who work nights and rotating shifts, and from fatigue research conducted by the Department of Defense.

The report is divided into seven main sections. The first section, "The Problem of Fatigue in 24/7 Operations" examines the effects of fatigue on human cognitive performance and briefly describes the ubiquity, pervasiveness and insidiousness of fatigue effects. The following section, "Human Biology Rebels against Night Work," analyzes the physiological drive for sleep at night, the parameters of cognitive fatigue that result when inadequate sleep is acquired (circadian, acute, and cumulative), and the symptoms of cognitive fatigue.

The third section, "Stupid Scheduling Is Not the Answer; Smart Scheduling Is," offers a primer on the scheduling of regular, rotating shift work. "Predicting Fatigue Effects Quantitatively" describes a product of fatigue research, one that allows the prediction of times at which fatigue is likely to help cause workplace mishaps. This tool also allows one to assess mishaps after the fact to determine whether fatigue was likely to have been a causative factor.

The fifth section, "Studies of Shift and Night work in Police Operations," summarizes the findings of the known studies of police shift work conducted from 1983 through 2010. "Fatigue Countermeasures" provides information about countering fatigue at the organizational level and about several specific countermeasures. "Future Research Needs" describes fatigue countermeasures that show promise for reducing fatigue, but are some distance from practical application. "Applications" suggests how to use the major pieces of information presented in the preceding seven sections.

Section 1. The Problem of Fatigue in 24/7 Operations

In security operations, the human-machine system includes, in addition to the human operator, the overall environment that is being protected, the environment within which the operator works, various types of sensors and alerting devices (the human-machine interface), and various types of response devices, including weapons (Drury, 2008; Murray, 1995). Automation may be included in the machine side of the system, providing various levels of information acquisition, information analysis, decision and action selection, and/or action implementation (Parasurman, Sheridan, & Wickens, 2000).

Good human-machine system design exploits human strengths and protects the system from human weaknesses. Two strengths that the operator brings to a system are (1) much more powerful pattern recognition capabilities and (2) decision-making skills than can be provided in automation. However, the operator also brings greater performance variability to a system than one finds in software and modern hardware. After operators have been trained and are current in system operation, the greatest contributor to that operator variability is cognitive fatigue. Cognitive fatigue impairs, mainly, the operator's monitoring of sensor displays, execution of complex system control functions, and interactions with automation.

The monitoring of sensor displays requires the operator to remain "vigilant." That is, the operator must remain attentive and alert for extended periods, searching for rare but important events that are masked by frequent similar unimportant events. A security guard watching several videos for illegal or questionable actions in crowds of people must remain "vigilant." Unfortunately, humans inherently perform this task rather poorly. The military has sponsored a great amount of research on human vigilance performance. As late as 1980, little of that research was directly applicable to real-world operations (JC Miller & Mackie, 1980). However, since then a number of relevant studies have been published and reviewed (Warm, Parasuraman, & Gerald Matthews, 2008). The reader is referred to the latter publication for additional information on operator vigilance.

"After operators have been trained and are current in system operation, the greatest contributor to that operator variability is cognitive fatigue."

One of the world's leading shift work research centers combined the findings from numerous field studies conducted in companies engaged in 24/7 operations (Folkard & Tucker, 2003). The results of their efforts show what to expect in terms of safety and productivity. Their data revealed the patterns shown in the next several figures. First, the relative risk of injuries and accidents increases across the day and night, with the risk being 18% higher on the afternoon shift and 30% higher on the night shift than during the morning shift (Figure 1). Second, the relative risk of injuries and accidents increases exponentially with time on shift such that in hour 12 it is more than double that during the average of the first eight hours (Figure 2).

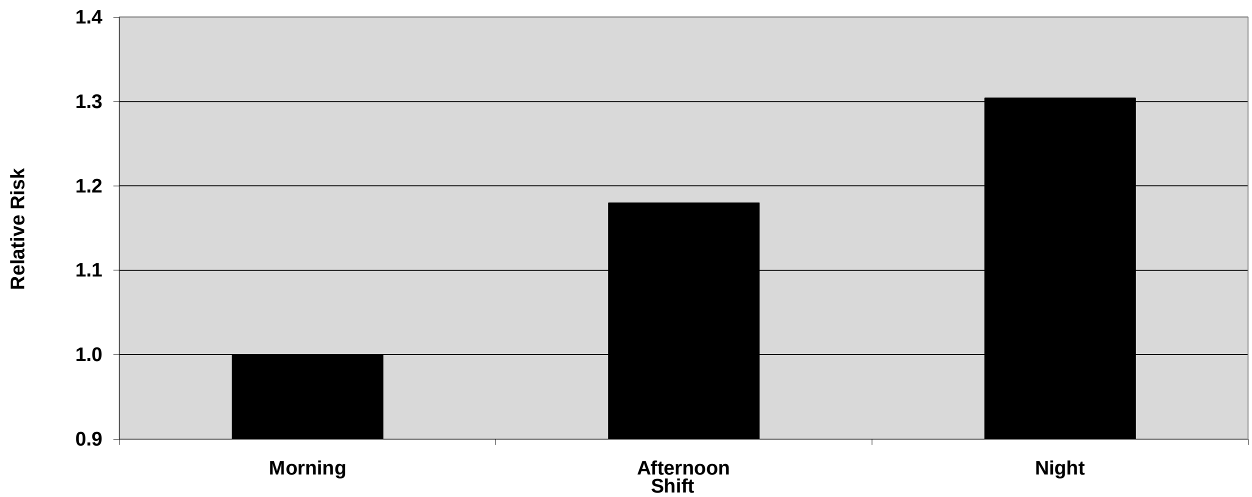

Figure 1. "Risk [of injuries and accidents] was found to increase in an approximately linear fashion across the three shifts, ... 18.3% [higher] on the afternoon shift, ... 30.4% [higher] on the night shift, relative to that on the morning shift." (Eight studies; re-drawn and quoted from Folkard & Tucker, 2003). The relative risk of 1.0 for this graph is during the morning shift.

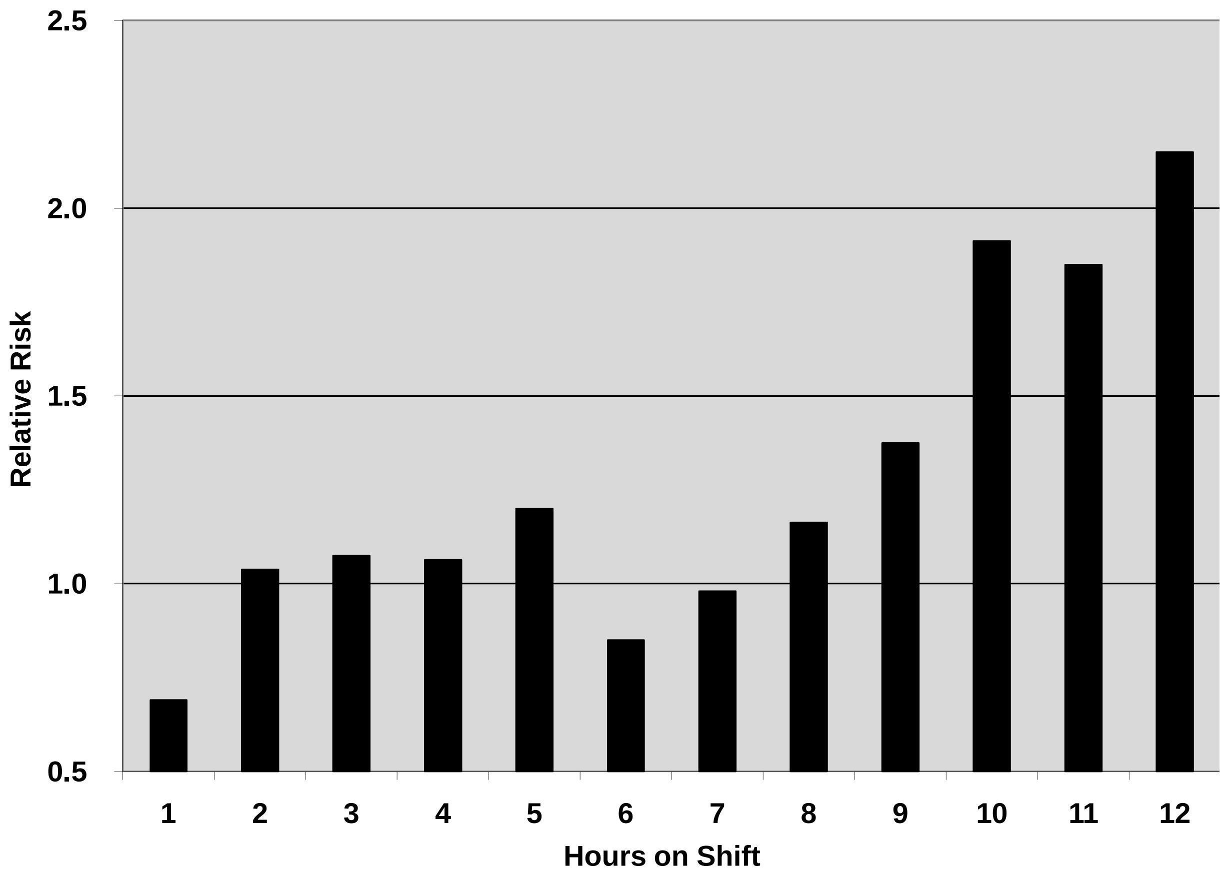

Figure 2. "... [R]isk [of injuries and accidents] increased in an approximately exponential fashion with time on shift such that in the twelfth hour it was more than double that during the first 8 h" (4 studies; re-drawn and quoted from Folkard & Tucker, 2003). The relative risk of 1.0 for this graph is the average of the first eight hours of the shift.

The lessons here are (1) too much time spent at work is likely to impair productivity, and (2) eight hours appears to be the maximum workday length to sustain good-quality productivity across days, weeks, months, and years. The security operations manager should plan to see either (1) reduced productivity and higher error rates after eight hours of continuous work, or (2) the slowing of work rate across duty periods longer than eight hours.

The combined data also showed that speed and accuracy on the job are only above average between 7:00 a.m. and 7:00 p.m. (Figure 3). At night, efficiency is relatively poor, especially during the pre-dawn hours (Fortson, 2004). Also, productivity goes down and safety risk goes up across successive night shifts: about 6-percent higher on the second night, 17-percent higher on the third night, and 36-percent higher on the fourth night, compared to the first (Figure 4) (Folkard & Tucker, 2003). Similar increases occur across successive day shifts, but the absolute error rates are lower. Thus, the relative penalty for successive night shifts, compared to successive day shifts, is a factor of about 2.5 times greater risk (op. cit.).

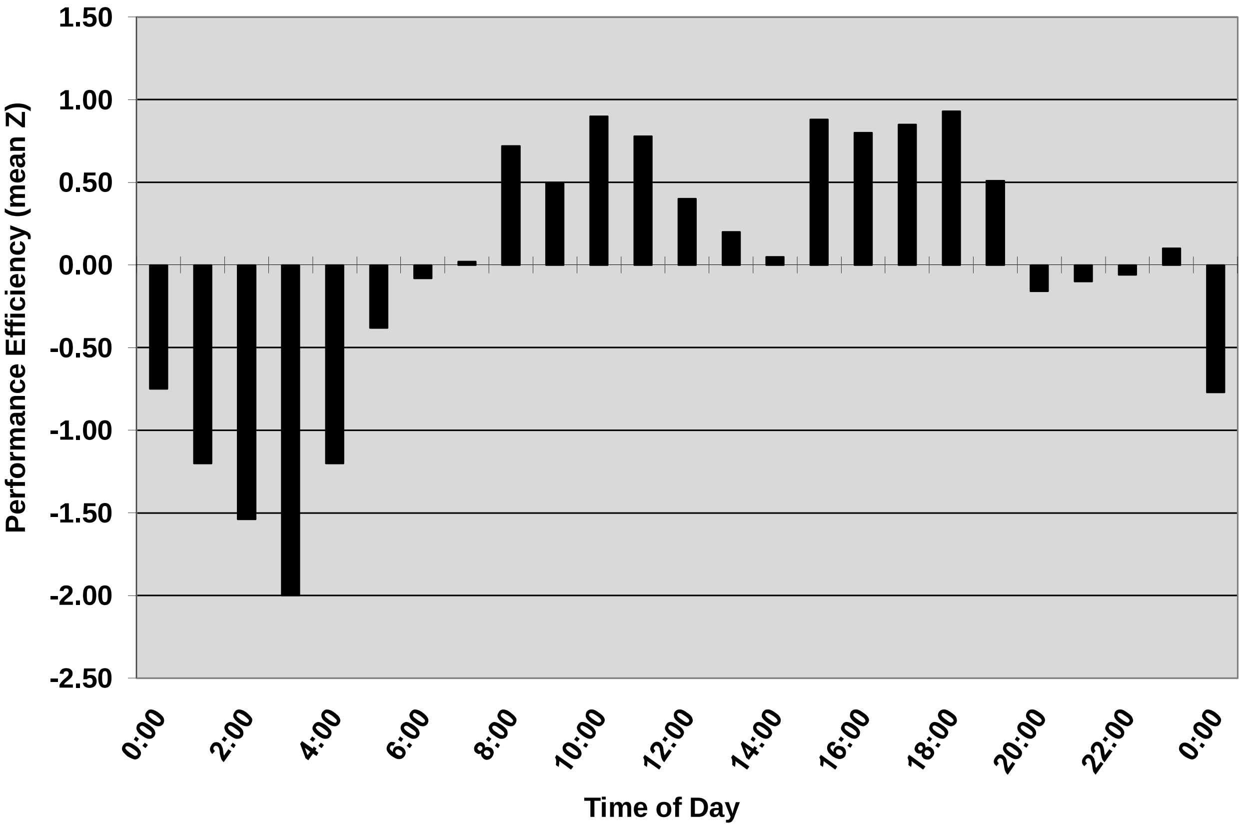

Figure 3. " ... '[R]eal-job' speed and accuracy measures are only above average between 0700 h and 1900 h; at all other times efficiency is likely to be relatively impaired, especially so during the early hours of the morning." (3 studies; re-drawn and quoted from Folkard & Tucker, 2003).

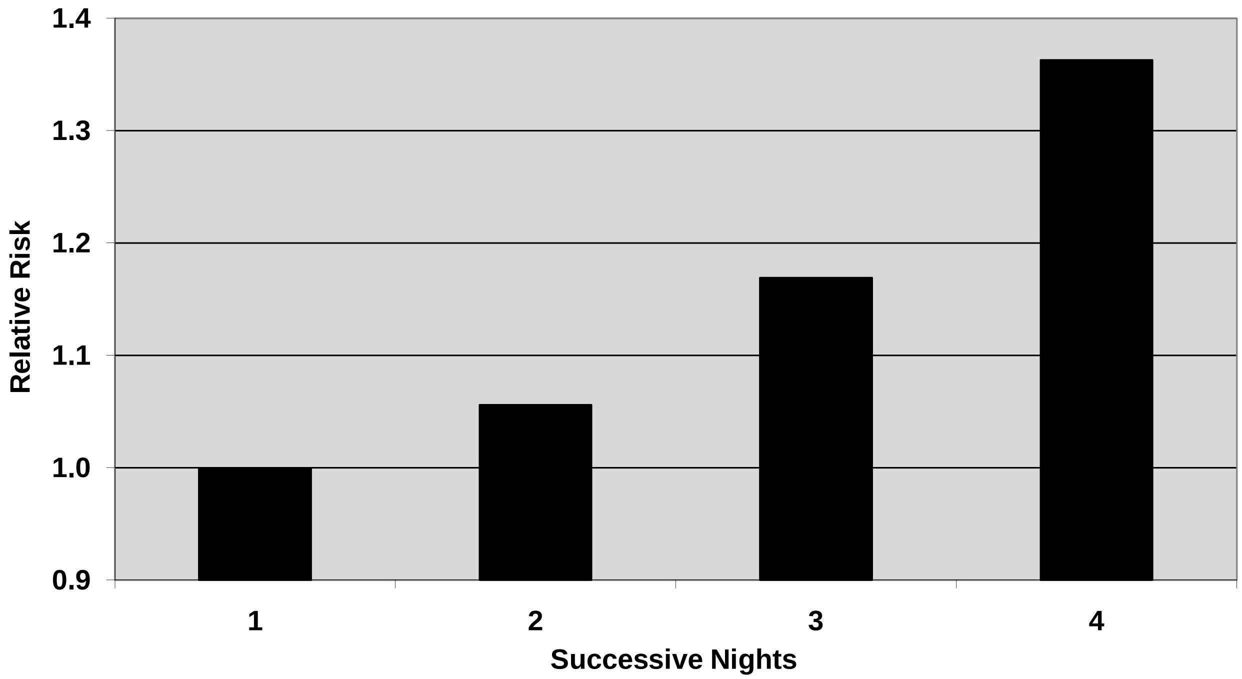

Figure 4. [The number of injuries and accidents] was ~6% higher on the second night, 17% higher on the third night and 36% higher on the fourth night (7 studies; re-drawn and quoted from Folkard & Tucker, 2003). The relative risk of 1.0 for this graph is during the first night.

There are indices the security operations manager may use to estimate levels of fatigue and fatigue-related mishap risk (Folkard, 2006). There are "two separate indices, one related to fatigue (the Fatigue Index) and the other to risk (the Risk Index)."[1] While the two indices are similar in many respects they diverge in others. The main differences are due to the different trends with respect to time of day in fatigue and risk. The indices, which have been implemented in the form of a spreadsheet, incorporate feedback from users of the previous index (op. cit.). A user's manual is also available.

In general, fatigue is ubiquitous, pervasive, and insidious. By ubiquitous, it is meant that fatigue affects everybody. There are individual differences: a few people are truly more resistant to fatigue effects than others. However, many people feel, without basis, that they are more resistant to fatigue effects than others. This misperception may cause them to form ill-advised intentions and/or to make bad decisions.

1 *http://www.hse.gov.uk/research/rrhtm/rr446.htm*

By pervasive, it is meant that fatigue affects everything each of us does. Again, there are individual differences. In the physical domain, there are athletes who are inherently able to achieve much greater levels of strength and endurance than others. This may also be true in the domains of cognition and attention: some people seem inherently less susceptible to cognitive fatigue than others.

By insidious, it is meant that often when we are fatigued, we are quite unaware of how badly we are performing. Most people have experienced the attention lapse associated with mild fatigue when they miss a freeway exit or realize suddenly that they don't remember the last mile or two driven on the highway. Similarly, many people recovering from a period of physical, emotional, or cognitive stress have uttered the phrase, "I didn't realize how tired I was."

Understanding these aspects of fatigue, it is easy to see how one may become tricked into conducting safety-sensitive jobs when we are too fatigued to be safe. Safety-sensitive jobs include, driving vehicles, operating weapons, and making command and control decisions (Harrison & Horne, 2000). If we think that we are more resistant to fatigue than we really are, and we don't realize that we are very fatigued, then we slog through our duty period while making poorer decisions, accepting more risk, and being more easily distracted than we should be. This is not an intelligent approach to any operation, though it has been the accepted approach on innumerable occasions. It is especially dangerous when senior managers believe that they are fatigue resistant and their fatigue-impaired decisions place others at risk (P. J. Murphy, 2002).

In his book, *How to Make Shift Work Safe and Productive*, Tim Monk described the insidious nature of the hazard posed by the shift worker (and anyone else who works nights): "It is hardly controversial to assert that alert, well-rested, happily married, community-minded employees are the ones least likely to be a high risk for human errors and therefore safety violations. It should, then, be equally easy to accept that someone who is getting very little sleep, who is permanently punch-drunk from jet-lag type symptoms, and who is experiencing major problems in family, domestic, and community relationships, is likely to be a major liability in the safety arena. Precisely that description can be applied to many a shift worker." (Monk, 1988)

Section 2. Human Biology Rebels against Night Work

This section briefly describes the physiological drive for sleep at night, the parameters of cognitive fatigue that result from inadequate sleep (circadian, acute, and cumulative), and the symptoms of cognitive fatigue. Sleep is not a passive or vegetative state. It is generated by complex, active brain physiology, and humans have specific physiological and psychological requirements for getting adequate sleep. Everyone knows how it feels to get too little sleep. Many individuals refer to this feeling as "fatigue" and/or "sleepiness." However, sleepiness and cognitive fatigue are different human states. Sleepiness is usually defined as an untimely desire to sleep and/or difficulty staying awake when wakefulness is required; mental fatigue includes many symptoms, such as memory impairment, slowed response time, and impaired vigilance. However, both sleepiness and cognitive fatigue are caused primarily by lack of sleep (with the exception of task-specific fatigue, below).

Both research results and common sense provide evidence that the need for sleep is a physiological drive, much like the need for food and water. As with insufficient food and water intake, insufficient sleep can lead to irritability and health problems. One may argue that the sleep drive is even stronger than the drive to eat and drink. Individuals may starve to death or die of dehydration. However, continued sleep deprivation eventually causes the individual to fall asleep, initiating automatic recovery. The brain regulates the amount of sleep that an individual needs.[2] This regulation operates somewhat like the thermostat on a furnace or air conditioner, generating a condition known as homeostasis:[3] the thermostat triggers heating or cooling when the room temperature exceeds a defined range of temperature, driving the room temperature back toward a given "set point." Similarly, in the absence of sleep pathologies, when we are too sleepy, we are driven to fall asleep; and when we have recovered enough, we are driven to awaken.

"[N]o one gets used to not getting enough sleep. They might be able to do it, but they never overcome the drive for sleep or the consequences that invariably follow sleep restriction" (Caldwell & Caldwell, 2004). The author, David Morgan, likened sleep debt to borrowing from a bank (D. R. Morgan, 1996). People who sleep less than eight hours per 24 hours are taking "little 'loans' from their sleep banker." Morgan cautions that "You know that your dangerously moody sleep banker may call in the loan when you are driving at 79 miles per hour on the freeway." You should "deposit eight hours in your sleep bank every day." In fact, the National Sleep Foundation[4] has

2 National Sleep Foundation, "Sleep Drive and Your Body Clock," *http://www.sleepfoundation.org/article/sleep-topics/sleep-drive-and-your-body-clock*.

3 The ability or tendency of an organism or cell to maintain internal equilibrium by adjusting its physiological processes. American Heritage® Dictionary.

4 National Sleep Foundation, "How Much Sleep Do We Really Need?" *http://www.sleepfoundation.org/article/how-sleep-works/how-much-sleep-do-we-really-need*.

integrated the results of decades of sleep research and observed that the normal range of sleep need for adults (about ages 25 to 70 years) is seven to nine hours per night.

When people do not get adequate sleep, they may experience excessive cognitive fatigue. This often affects their ability to perform safely on the job. Sleep loss of even one or two hours a night may significantly degrade alertness and performance, with greater effects with increased amounts of sleep loss.

If an individual loses sleep across successive days, the deficits cause an accumulation of sleep debt and cumulative fatigue. Frequently, we tend to gain some recovery sleep over our weekends or non-work days. However, recuperation from cumulative sleep debt requires getting more sleep per night than the individual typically needs for at least several nights (Balkin, Rupp, Wesensten, & Bliese, 2008; Jay et al., 2007; Rupp, Wesensten, Bliese, & Balkin, 2009). The effects of one night of sleep deprivation, for example not sleeping for 40 continuous hours, can still be detected in performance levels after five nights of sleeping six hours per night (Jay et al., 2007). If there is enough sleep deprivation or restriction, people will reach a level of critically-reduced alertness in which sleep spontaneously intrudes into wakefulness. These uncontrolled sleep episodes (micro-sleeps) can occur even when a person is standing or operating equipment.

"Sleep loss of even one or two hours a night may significantly degrade alertness and performance"

One of the main causes of sleep loss is working during hours outside the normal daylight routine (this is the basic definition of "shift work"). The primary reason for sleep loss in night workers is that they are trying to sleep at times when the brain's biological clock signals they should be awake. As a consequence, night workers may find it difficult to sleep, or sleep as long as they wish. Monk described some of the social problems associated with night work and day sleep: "You can imagine how day workers would complain if the phone kept ringing at 2:00 a.m.; if deliveries could only be made at midnight and if the TV repairman would come 'sometime between midnight and 6:00 a.m.!' For the night worker, though, this is exactly the case--everything in society is trying to intrude when he or she is trying to get some sleep" (Monk, 1988).

Social and family demands can contribute to sleep loss problems because individuals may choose to spend more time in these activities at the expense of trying to rest. Many people who work night shifts revert to a normal daytime schedule on the weekends or days off to synchronize with the rest of society. This can lead to a constant state of circadian rhythm desynchronization, (shift lag) in which the body clock and the local clock conflict.

A number of substances can interfere with sleep, including caffeine, alcohol, and over-the-counter drugs. The effects of caffeine typically last four to five hours, but may last up to ten hours in especially sensitive individuals. Similarly, alcohol may initially relax a person and cause sleepiness, but as it is metabolized there will be an alerting effect, causing a person to awaken more easily. Some nasal decongestants interfere with sleep because they contain the stimulant pseudoephedrine.

Other activities that may interfere with sleep include eating, exercise, and willful wakefulness. Food consumption stimulates gastrointestinal reactions that may result in discomfort and sleep problems. Exercise on a regular basis is good for promoting sound sleep, but excessive exercise should not be performed within several hours of bedtime because it has an alerting function and can shift the biological clock forward. Willful wakefulness occurs when individuals choose to socialize, play computer games, etc. at times when they could and should be sleeping in preparation for their next work period.

Many medical conditions result in sleep loss. Sleep apnea, a breathing disorder involving periodic interruptions of breathing during sleep, affects as many as 5 out of every 100 people. Key signs that a person has sleep apnea include loud snoring and irregular breathing when sleeping. Medical specialists can be consulted to determine if a specific condition exists that is interfering with sleep, and proper medical interventions can help alleviate the problem. Other common medical conditions that lead to insomnia include congestive heart failure and arthritis.

To understand not only how much sleep is needed but also how much is acquired by the average American adult and average American shift worker, the reader should reference the annual Sleep in America survey conducted by the National Sleep Foundation.[5] This is the best layman-oriented resource for information about sleep.

5 *http://www.sleepfoundation.org/*

Sleep Inertia

Sleep inertia normally occurs in the morning after awakening. It is a grogginess that usually lasts about five minutes but may last up to 15 or 30 minutes in a person with a sleep debt. Though sleep inertia may not be detected as a problem after napping (Driskell & Mullen, 2005), it is possible that when an individual taking a nap falls into the deeper stages of sleep and then awakens, they may experience this same sleep inertia. Thus, at least 15 to 30 minutes should be allowed after a nap to allow sleep inertia to dissipate before performing safety-sensitive jobs such as driving, operating weapons, command and control, etc.

Generally, fatigue researchers sort the generators of cognitive fatigue into four categories: circadian rhythm effects,[6] acute fatigue, cumulative fatigue, and task-specific fatigue.

Circadian Rhythm Effects

There are normal, inherent circadian rhythms in many physiological and behavioral human functions (Office of Technology Assessment, 1991). These rhythms are driven by a clock process located in the suprchiasmatic nucleus of the brain's hypothalamus. This "body clock" has a cycle length that is slightly longer than one cycle per day, but it is normally slaved, or entrained, to exactly one cycle per day by external time cues (Zeitgebers), especially the daylight-darkness cycle. There are interactions between the body clock and the ability to generate good quality sleep, such that sleep duration is impaired during night work (Knauth et al., 1980; H. Thorne, Hampton, L. Morgan, Skene, & Arendt, 2008).

There is a circadian rhythm in human cognitive performance that oscillates between a high point late in the day to a low point in the pre-dawn hours with peak-to-trough amplitude of about 5 to 10-percent of its average value. This rhythm is the basis for the pattern shown in Figure 3. Circadian effects on cognition may be caused by night or shift work, leading to Shift Work Sleep Disorder (SWSD[7]). The essential features of SWSD are "symptoms of insomnia or excessive sleepiness that occur as transient phenomena in relation to work schedules." In night work, this translates into feelings of malaise and fatigue during the midnight-to-dawn period on the body clock. This is the period when sleep drive and sleepiness are highest and body temperature and alertness are lowest. Shift lag includes the feelings of malaise and fatigue that accompany a change from day work to night work, and vice versa. Shift lag occurs during the period of attempted re-synchronization of internal circadian rhythms to new external time cues. Compared to jet lag, the attempt to re-synchronize

6 Sir kay' dee un. Once-per-day, cyclic fluctuations in physiological and psychological functions, controlled by the brain's biological clock. From the Latin roots, circa meaning "about" and dies meaning "day."

7 International Classification of Sleep Disorders, American Academy of Sleep Medicine (AASM; www.aasmnet.org); Code 307.45-1, a circadian sleep disorder.

to a night work and day sleep schedule occurs more slowly and is much less successful because the main external time cue, the daylight-darkness cycle, tends to inhibit re-synchronization. For most night workers, re-synchronization never occurs because of untoward exposures to daylight (NL Miller, Nguyen, Sanchez, & JC Miller, 2003; Nguyen, 2002; Sawyer, 2004).

Chronotype

Individuals differ from one another physiologically in their preferred activity and sleep times in terms of chronotype: some may be “larks” (morningness) and some may be “owls” (eveningness) (Horne & Ostberg, 1976). Larks tend to be morning individuals, arising early in the day and getting to sleep early in the evening. Owls tend to stay up later at night and arise later in the morning. Owls tend to perform better on afternoon and evening shifts. Most individuals (about 95%) tend to fall in the middle of the normal distribution between being an extreme lark or owl. One may assess one’s morningness-eveningness tendencies with the original rating scale (op. cit.) or with similar scales that are provided on the Internet.[8] A manager may wish to consider these tendencies in work scheduling.

From puberty through early twenties, all individuals apparently have a normal, unavoidable, physiological bias toward being owls (Crowley, Acebo, & Carskadon, 2007; Wolfson & Carskadon, 1998). Thus, when training younger personnel, better training performance is attained when sleep and activity times take this normal tendency into account by avoiding early-morning start times

Having knowledge of circadian effects on cognitive function, there is another pattern of errors about which managers should be aware. Circadian rhythms in many measures of performance and physiological activity have a two-peak (circasemidian)[9] daily pattern caused by a rhythm that has two cycles per day. Relevant behavioral and physiological observations support the need to consider 12-hour rhythmicity in the quantification of daily variations in physiological function and some kinds of cognitive performance (J C Miller, 2006b). The circasemidian rhythm usually serves to (1) elevate the pre-dawn peak in mishaps, (2) create a secondary peak in mishaps in the early afternoon (the “post-lunch dip”), and (3) depress the late-morning and early-evening troughs in mishaps. Thus, we refer to it as the “two-peak daily pattern of mishaps.” A good example of this error pattern is shown in Figure 5.

8 *For example, http://web.ukonline.co.uk/bjlogie/larks.htm.*

9 Sir ka semi dee un. From the Latin roots, circa – "about," semi – half, and dies – "day"

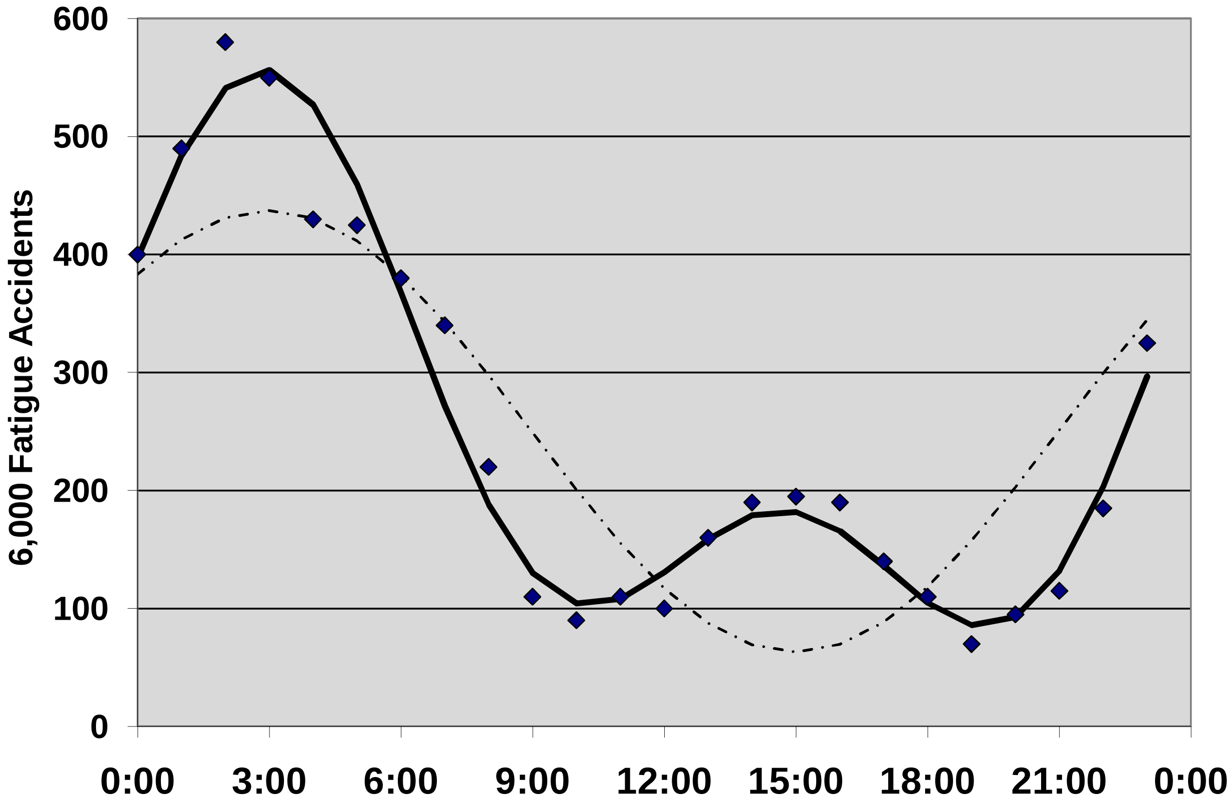

Figure 5. An example of the two-peak daily pattern of mishaps.

Acute Fatigue

Acute cognitive fatigue builds up normally and unavoidably within one waking period of about 16-hours. It is happening to you as you read this report. Recovery from acute fatigue occurs as the result of one good-quality, nocturnal sleep period of about eight hours.

Cumulative Fatigue

Cumulative cognitive fatigue builds up across major waking periods when there is inadequate recovery (due to inadequate sleep) between waking periods. Recovery from cumulative fatigue cannot be accomplished in one good-quality, nocturnal sleep period. The main contributor to cumulative fatigue is sleep debt.

Task-Specific Fatigue

Our understanding of task-specific fatigue has its roots in the study of physical work and acute muscle fatigue: repeated, demanding muscular work causes muscle fatigue and the need for recovery.[10] Work that is assisted by automation generally requires human operations that place demands upon specific, fine-motor and visual functions. Some of the work requires vigilance, and some requires repetitive operations. Thus, we observe task-specific fine-motor muscular fatigue, visual fatigue, vigilance failures, monotony, and repetitive-stress injuries in the automated workplace. Each of these problems requires task-specific, short-term and long-term fatigue management and recovery considerations.

If the individual cannot change tasks, then the effects of task-specific fatigue may be difficult to avoid. They may only be recognized and managed. Ideally, the manager should provide "a meaningful variety or mix of tasks so as to avoid boredom and performance decrement" (W. W. Murphy, Krusemark, & Moyer, 1968). Some system operators do not suffer very much from task-specific fatigue when they are in the control loop, i.e., "hands-on." They may suffer from sleepiness and reduced levels of vigilance that affect task performance, but their focus on the overall task seems to remain intact. Whether this is due to motivation, automated behaviors, and/or other factors is not known.

However, operators who monitor automated systems often fall prey to vigilance decrements, boredom, habituation, and/or task-specific fatigue. Some research suggests that, with respect to the interactions between acute fatigue and task-specific fatigue, that "fatigue disrupts matching of effort to task demands, such that the fatigued [operator] fails to regulate effort effectively when the task appears easy" (Desmond & G Matthews, 1997). This finding supports the practice of treating the effects of acute or cumulative fatigue and task-specific fatigue as additive (W. W. Murphy et al., 1968).

Variability and Lapses

One of the primary hallmarks of human fatigue is performance variability. This is due to large amplitude, moment-to-moment fluctuations in attentiveness associated with fatigue. The average performance of the operator may be acceptable, but there are brief periods when the operator's responses are extraordinarily delayed or absent ("lapses"). We often call this "distractibility" and note that fatigued system operators are more easily distracted than non-fatigued operators.

A practical and well-studied example of performance variability is the weaving back and forth of a vehicle operated on a highway by a fatigued driver (Mackie & J C Miller, 1978, 1981; Wylie, Shultz, J C Miller, Mitler, & Mackie, 1996).

10 Some argue that task-specific fatigue is actually habituation to a task and is not truly fatigue. Others may argue that a task is simply boring, and that this is not fatigue. Whatever it is called, the fact is that task performance declines as time performing the task continues. This is the same overall pattern that we have with wakefulness: performance declines as time awake continues. These two effects can be additive.

The average position of the vehicle in the lane may not change as the driver becomes more fatigued. However, the vehicle weaves left and right around that average position more and more due to the driver's fatigue-induced psychomotor delays. These delays cause the replacement of the quick, small steering wheel corrections used by alert drivers with slower, larger corrections. The excursions become longer, stronger and/or more frequent as fatigue becomes greater. Eventually, a lateral excursion may be so great that the vehicle can cross the lane line or even run off the side of the road.

Similarly, in simple response-time tasks, the alert person will respond with predictably-quick button presses, while the fatigued person will respond quickly many times and more slowly some times, and will occasionally fail to respond (D F Dinges & Powell, 1985). These failures to respond are called lapses. In complex tasks, the fatigued system operator may fail to respond to system prompts or failures because of impaired memory, impaired vigilance, narrowed or channelized attention, or other fatigue effects on cognition. The known, primary physiological and psychological effects of fatigue are shown in Figure 6 (J C Miller & Eddy, 2008).

Fatigue Effects

Basic Cognitive Functions

- Working memory impairment; inability to remember more than one or two items at a time
- Anterograde amnesia; forgetting newly-learned things
- Retrograde amnesia; forgetting old things
- Cognitive impairment; inability to conduct logical reasoning, mental arithmetic, etc.
- Slowed response time (RT) and reduced response accuracy on simple tasks
- Impaired manual control; larger variability when steering a vehicle (weaving) or using a joystick
- Vigilance impairment; inability to remain alert in a boring situation, watching for a rare but important target in a background of similar, non-target events (this is a task that humans do poorly to start with)
- Narrowed or channelized attention
- Intrusion of sleep-like dreams into drowsiness

Complex Cognitive Functions

- Willingness to accept greater risk
- Loss of situation awareness

Mood and Motivation

- Irritability
- Motivational exhaustion

Physiological

- General malaise
- Reduced aerobic capacity
- Drowsiness
- Sleep debt and need for recovery sleep
- Falling asleep on the job
- Dizziness
- Decreased altitude tolerance
- Decreased thermal tolerance
- Decreased acceleration tolerance
- Cardiovascular health effects
- Gastrointestinal health effects

Physiological Interactions

- Worsening of alcohol effects
- Modulation of drug effects

Interpersonal/Team Interactions

- Reduced interpersonal communications
- Impairment of shared situation awareness

Figure 6. The known, primary physiological and psychological effects of fatigue (Miller & Eddy, 2008).

Section 3. "Stupid" Scheduling Is Not the Answer; Smart Scheduling Is

This section provides a primer on the scheduling of regular, rotating shift work. Humans are not biologically wired to work at night. Daylight is when we see best and when our metabolic rate is highest. Night time is when our metabolic rate drops to its lowest level and when the complex biological mechanisms in the brain that generate sleep operate most effectively. Thus, during night work we tend to make about 30-percent more errors than during day work.

"Stupid" work-rest schedules are those that ignore the biology of the human component of a system or organization. Dictionary definitions of the word, "stupid," include:

- Slow to learn or understand; obtuse. Tending to make poor decisions or careless mistakes. Marked by a lack of intelligence or care; foolish or careless: a stupid mistake. Dazed, stunned, or stupefied.[11]
- Lacking ordinary quickness and keenness of mind; dull. Characterized by or proceeding from mental dullness; foolish. In a state of stupor; stupefied: stupid from fatigue[12].

A comparison of these definitions to the symptoms of fatigue cited in Figure 6, shows a number of parallels. In military history we find that commanders of old were well aware of the risks of poor scheduling. Napoleon Bonaparte advised his commanders: "You must not needlessly fatigue the troops."[13]

Here are a couple of shift work scheduling "lemons", in which three crews working eight-hour shifts cover a seven-day operation by working a lot of overtime or are supplemented by a "weekend warrior" crew:[14]

> Counter-Clockwise Rotation. The problem with the counter-clockwise rotation — working nights, then evenings, then days — is that it is diametrically opposed to the human body's innate daily (or "circadian") rhythms. Such rotation runs against research that finds the human body, without external cues such as sunlight to reset the biological clock, naturally drifts forward to later hours each day. This natural proclivity means that someone on a counterclockwise rotation may find adjusting to the night shift difficult and experience reduced alertness and chronic fatigue. The harmful effect of counterclockwise rotation contributes to what is known as "industrial jet lag" because it gives employees the sensation of constantly crossing time zones from west to east.

11 American Heritage® Dictionary

12 *http://www.dictionary.com/*

13 To the Armee d'Italie in 1796.

14 Promotional information distributed freely by Circadian Technologies, Inc. (*http://www.circadian.com/*)

Three Crews Covering Seven Days of Work / Weekend Warrior Crews. Having three crews cover seven days of work — a schedule common at plants that have converted from five-day to seven-day operations — presents a related fatigue problem. When employees are regularly asked or required to work overtime, it can become difficult for them to develop regular sleep patterns. Moreover, they may become more fatigued and prone to human error, leading to costly accidents, injuries, and poor-quality production. Weekend warrior crews, while less fatigued, typically cost more, have high turnover rates, and are generally inefficient due to lack of skills and experience.

How do you know if your scheduling system is a lemon? Some of the most obvious signs include workers who show up late for work, arrive at work tired, or fall asleep on the job.

To avoid "stupid" scheduling, a manager should use a principle-based approach to shift work scheduling that constrains the infinite number of possible schedules to those schedules that are simple, practical to implement, and least harmful to worker health, job performance, and attitude (J C Miller, 2006a). Having said this, it must be noted that there is no "good" continuous 24/7 shift work schedule: humans are not designed to work at night, therefore night work causes sleep loss and shift lag. In turn, these cause fatigue at work. Thus, even good-quality shift work scheduling cannot prevent sleep loss and shift lag. Instead, it should be viewed as an effort to minimize the negative consequences. This is good for the workers' health, safety and satisfaction, and for productivity.

There are at least nine shift work scheduling principles to consider (Hildebrandt, 1976; J C Miller, 2006a). These principles operate in a zero-based system of clock time and the calendar. Thus, some of the principles interfere with each other. For example, when the number of consecutive night shifts increases (Principle 3), recovery from night work is hampered (Principle 4):

- Principle 1, Minimize shift-lag: use a shift plan that maintains human circadian entrainment to the local, 24-hour light-dark cycle. Usually, rapidly-rotating plans are better at this than slowly-rotating plans.
- Principle 2, Shift length: use a shift length of no more than eight hours, with the exception of using a 12-hour shift length for jobs with low physical and emotional work stresses.
- Principle 3, Night shifts: schedule a minimum number of consecutive night shifts in the shift plan; preferably, no more than three consecutive night shifts.
- Principle 4, Recovery: schedule 24 hours of recovery (not "time off") after each night shift.

- Principle 5, Weekends: schedule the maximum number of free days on weekends.
- Principle 6, Days off: schedule at least 104 days off per year (equal to 52 weekends).
- Principle 7, Equity: provide all workers with equal demands for long duty days, night work and weekend work, and equal access to good quality time off and weekends off.
- Principle 8, Predictability: assure that the schedule is so easy to understand that workers may apply simple arithmetic to predict their actual work and free days well into the future.
- Principle 9, Good-quality time off: schedule long, contiguous periods of time off; operationally, this translates into three or more consecutive days off.

To create or analyze a 24/7 shift work schedule, one must examine the ideas and notations associated with:

- The shift work system,
- The shift work plan, or rota, and
- The shift work schedule.

Shift Work System

The information contained in a shift work system specification provides a general approach to understanding the fundamental nature of a specific shift work schedule and its underlying plan (Knauth, Rohmert, & Rutenfranz, 1979; Knauth & Rutenfranz, 1976). In the formula below, a work day (W) is a day on which a day, swing, or night shift starts. A free day (F) is the same as a day off (O) in a shift plan, and is a day on which no shift starts. The shift system sets the relative numbers of work and free periods, excluding holidays. A system is expressed as the ratio:

XnW:YnF

where

- X and Y are integers (the numbers 1, 2, 3, etc.), that describe the general form of the shift system, and
- n is a multiplier (also an integer).

Using this approach, Knauth and coworkers (op. cit.) showed the logical, mathematical usefulness of the 42-hour (average) work week in four-crew shift work schedules. They also suggested two useful measures for determining the acceptability of a shift system and for comparing systems: the average number of hours worked per day (or work load) and the number of days free per year. Useful systems for the 42-hour (average) work week for four-crew schedules are:

- Using eight-hour shifts
  - 3nW:1nF with n greater than 1
- Using 12-hour shifts
  - 2nW:2nF

Shift Work Plan

The shift plan, or rota, determines the sequence of work (W) and free (F) periods within a shift system. The shift notation used here includes 'D' (day), 'S' (swing, afternoon, evening) and 'N' (night, mid-shift) for the W periods, and 'O' (off) for the F periods. In shift plan notation, a D, S, or N means that a shift starts on that respective day (between midnight and 11:59 p.m.). An O means that no shift starts on that respective day (though a night shift may end on a day off). For plans using the 12-hour shift length, the notation is limited to D, N, and O.

The Continental rota, or 2-2-3 plan, is a good plan with rapidly rotating, eight-hour shifts in a 3nW/1nF system (n = 7), giving a 21W/7F shift system with a (21 + 7 =) 28-day cycle:

DDSSNNNOO DDSSSNNOO DDDSSNNOOO

The Metropolitan rota, or 2-2-2 plan, is one of many alternatives to the Continental rota. It is a plan with rapidly-rotating, eight-hour shifts in a 3nW/1nF system (n = 2), giving a 6W/2F system (8-day cycle):

DDSSNNOO

The following plan for rapidly-rotating, 12-hour shifts is an implementation of the 2nW/2nF system (n = 2), giving 4W/4F and an 8-day cycle:

DDNNOOOO

Note that all of these plans (1) rotate forward on the clock (i.e., the next shift start time will be later than the present shift start time unless days off intervene), and (2) schedule free days after night work. These are two general concepts that work best in most cases.

Shift Work Schedule

A shift work schedule builds upon the shift work plan which, in turn, is one sequence within a shift work system (J C Miller, 2006a). The schedule is made up of a number of interacting components. The components are organized into the following groups:

- People
  - Number of crews, the optimal number being four.
  - Employment ratio, to take into account holidays, annual leave, sick leave, training time, etc.
- Time
  - Shift type, i.e., fixed vs. rotating shifts, forward (clockwise) vs. backward (counterclockwise) directions of rotation, slow vs. fast rotation.
  - Shift length, especially eight-hour vs. twelve-hour shifts.
  - Shift overlap, period of time in which the current shift and next shift overlap.
- Other
  - Shift differentials in terms of hourly pay rates or different shift lengths across day, swing, and night shifts.

- Alignment of days off with weekends.
- Shift change times, especially when to begin the morning shift in order to allow as many shift workers as possible to sleep well at night.

There are four main secrets to creating a good-quality shift work schedule:

(1) Have enough people to do the job

(2) Use four crews

(3) Use a shift length of either eight or twelve hours (not including overlap)

(4) Worker satisfaction in terms of predictability, equity, and good-quality time off

Enough People

The most prevalent cause of shift work scheduling problems may be management's failure to calculate the employment ratio and to assure the availability of enough qualified shift workers to meet the 24/7 work demand (op. cit.). Employment ratios make allowances in scheduling for holidays, sick leave, annual leave, and other administrative and training time. An employment ratio is a number greater than one that may be calculated as, for example:

- ratio = (364 work + 10 hol + 14 vac + 14 sick + 14 tng) = 416 days per year
- ratio = 416 days / 364 days = 1.14

where there are 364 days[15] to be worked (work), 10 holidays per year (hol), 14 days of vacation (vac), 14 days of sick leave (sick), and 14 days of training (tng). Staffing may then be calculated as the product of the minimum number of people for a single crew, the number of crews required, and the employment ratio. If the minimum crew is ten people and four crews are needed, then staffing is:

- 10 workers per crew x 4 crews x 1.14 = 46 workers

where the quotient, 45.6 workers, is rounded up to 46 workers to avoid the bother of hiring six-tenths of a worker. Note that different divisions within your operation may require different ratios.

Four Crews

In regular, 24/7 operations, the number of crews used should be greater than the number of shifts per day, so that at least one crew is off each day, except in maritime operations (op. cit.). The number of crews that you decide to use sets the work demand in a regular schedule. In other words, it is the number of crews that defines the average yearly, weekly, and daily amounts of time worked by an individual. Each year provides (364 days per year x 24 hours per day =) 8,736 hours to be worked in continuous operations. Each crew must work their proportional share of the year

15 For shift work scheduling, think of one year as being 364 days; this is exactly 52 weeks. Also, think of a month as being 28-days long; this is exactly four weeks. Note that there are exactly thirteen, 28-day months in one 364-day year. Finally, note that there are 168 hours in a week.

Crews	Per Year	Per Week	Per Day
2	4368	84	12
3	2912	56	8
4	2184	42	6
5	1747.2	33.6	4.8
6	1456	28	4
7	1248	24	3.4
Weekday-only Workers	2080	40	5.7

Table 1. Average work demands in regular schedules for different numbers of crews and for weekday-only workers, in hours.

(see Table 1). If one specifies four crews, then each person in the crew must work 2,184 hours per year, an average of 42 hours per week and an average of six hours per day across all days of the year (this is not shift length). Note that the four-crew solution most closely approximates the usual work demand placed on weekday-only workers.

The four-crew solution, with an average 42-hour work week, makes good sense for regular shift work scheduling. Crews work, for example, 26 weeks at 40 hours per week and 26 weeks at 44 hours per week. Often, the Fair Labor Standards Act (FLSA) will force the payment of overtime for the 44-hour weeks. This amounts to 10% overtime for half of the weeks in the year, or 5% total overtime for the year. At an overtime rate of 1.5x, this means an increased total cost in worker pay of 7.5% for the year. In many cases, this cost may be offset by the savings provided by not needing to employ a scheduler and by increased retention (reduced turnover).

Unexpectedly, work demand does not change in a simple, straight-line manner when the number of crews changes (Figure 7). The relationship between the average amount of time an individual works and the number of crews used is curved. Thus, changing the number of crews may change related items such as staffing and payroll in unexpected ways. The four-crew solution provides the optimal balance between (1) the work, health, social, and safety demands placed upon the shift worker (in terms of hours

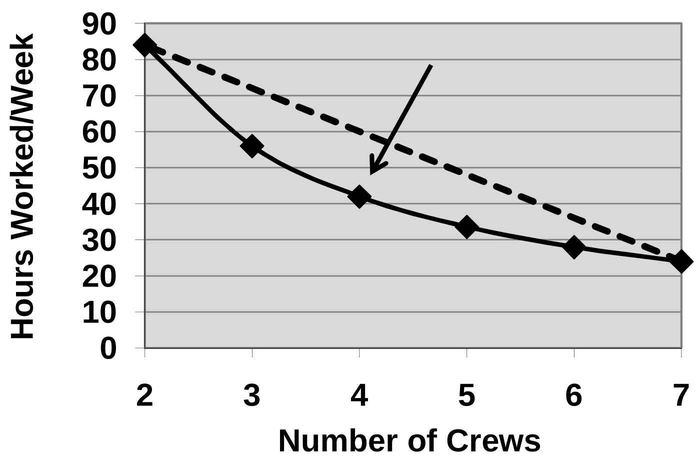

Figure 7. Average hours worked per week as a function of the number of crews.

worked per unit time; the y axis in the figure) and (2) the personnel cost to the employer for safe and productive system operation (in terms of the number of crews to be employed; the x axis in the figure).

Shift Length

In theory, shift length may be any amount of time up through 24 hours. In practice, only several factors of 24 hours (4, 6, 8, or 12) are useful (op. cit.). If one uses values that are not factors of 24 hours, then the time at which an individual reports for work on the same shift is unpredictable: it differs from day to day. If you think about working a schedule or managing others who do, in which the report time changes from day to day and night to night, you may imagine much frustration. Trying to determine one's irregularly-scheduled next report time through a haze of fatigue can lead to many erroneously-timed arrivals at work.

When you consider 8-hour vs. 12-hour shift lengths, recall the information presented earlier: the risk of injuries and accidents increases exponentially with time on shift such that in hour 12, it is more than double that during the average of the first 8 hours. Also, recall that it is the number of crews that determines the numbers of hours worked per year, not the shift length. Thus, you cannot reduce the required number of employees solely by changing the shift length from 8 to 12 hours.

Worker Satisfaction

Shift workers tend to appreciate equity, predictability, and good-quality time off (op. cit.). They focus on equity between themselves and weekday-only workers, and across shift work crews. Possible results of inequities or perceived inequities are poor morale and personnel retention. One approach to the equity problem is to use four crews, as discussed above. That way, the average work week for the shift worker is about as long as it is for the weekday-only worker. Equity across crews may be achieved by working carefully through the shift work scheduling components described earlier. The sequence of decisions that must be made concerning the components forces the development of an equitable schedule. Perceived equity may also be enhanced through participatory design and worker education.

One shift work consultant found schedule predictability to be the third-highest concern of shift workers (Coleman, 1995). Day-to-day and week-to-week, last-minute scheduling and failure to account for the simple arithmetic of the calendar and its cycles generates confusion among shift workers about their future work and free days. It also causes management to assign a front-line or middle manager as a "scheduler" to make sure that every job is filled every day. These are both expensive propositions. When a schedule is predictable and the shift worker asks a question such as, "My brother, whom I have not seen in three years, will be in town on the 15th and 16th of next month. Will I be working on those days?" The answer should be as simple as counting the number of days or weeks until then and applying the shift plan to that sequence of days.

Good-quality time off may be the primary concern of shift workers (op. cit.). Shift and weekday-only workers tend to prefer schedules with long, continuous periods of time off. Such schedules are perceived as being "good". For example for weekday-only workers in the United States, there are two popular types of work compression. One is the "10-hour day" schedule in which the 40-hour work week is completed in four days, allowing three-day weekends. The other is the "every-other-Friday-off" schedule in which there are eight, 9-hour work days and one 8-hour workday across a two-week period. This allows every other weekend to be a three-day weekend.

These weekdays-only schedules illustrate the important point that, because of the zero-sum nature of 24/7 operations, work compression is needed to allow the expansion of continuous time off. In a zero-sum system, any gain within the system must be offset by an equal loss within the system. For example, with four crews you may work six shifts at eight hours per shift, i.e., 48 hours, in eight days in the Metropolitan rota and have two days off:

DDSSNNOO

Or, you may work four shifts at 12 hours per shift, i.e., 48 hours, in eight days and have four days off:

DDNNOOOO

Note the difference in the number of consecutive days off: two days vs. four days. Why does this happen? The difference in continuous time off is due to a faster rate of work on the work days within the plan:

- With 8-hour shifts, you work 48 hours in six work days, a rate of 8-hours per day
- With 12-hour shifts, you work 48 hours in four work days, a rate of 12-hours per day
- The ratio of 12-hours per day to 8-hours per day gives a 1.5 times faster work rate

When you move from 8-hour to 12-hour shifts with four crews, the work that would have taken six days (144 hours) will now be accomplished in (144 hours ÷ 1.5 =) 96 hours (4 days), leaving the remaining 96 hours (4 days) in the eight-day cycle for continuous time off.

Perhaps it goes without saying that aligning days off with weekends (Principle 5) enhances the perceived quality of days off.

"The risk of workplace accidents and automobile crashes rises for tired shift workers, especially on the drive to and from work. Sleep may quickly overcome a driver."

Drowsy Driving

The risk of workplace accidents and automobile crashes rises for tired shift workers, especially on the drive to and from work. Sleep may quickly overcome a driver. This is one reason why single-vehicle, run-off-the-road accidents occur. Unfortunately, the compensatory actions recommended for dealing with shift- and night worker fatigue are often viewed as impractical or unnecessary because night workers almost always drive home safely after their shift. However, just as the public does not condone drunk driving, we should not condone the idea of sending a highly-fatigued driver into traffic or into a long commute. A 1998 court case provides an example of what can happen to a fatigued night worker. Nabors Drilling Co. employee, Roberto Ambriz, fell asleep at the wheel on Texas State Highway 490, about 20-minutes after ending his graveyard shift. His pick-up truck went into the oncoming lane, striking a Dodge pick-up driven by Martin Rodriguez. Rodriguez and his three passengers died at the scene, and Ambriz died from his injuries two days later. A decision was won against the employer for failure to train employees about the risks of driving after working a graveyard shift. This is not an isolated decision against the employer of night workers. There is a pattern of such awards in the United States. Managers should act to make preventive actions practical whenever possible. For example, the use of public transportation may substantially delay the onset of daytime sleep for night workers. Thus, managers may consider providing and/or requiring the use of a carpool with a rested, trained driver for night workers with relatively long commutes. Similarly, managers may consider providing pre-drive napping quarters for night workers and fatigued workers, as well as offering training on defensive and intoxicated driving.

Section 4. Predicting Fatigue Effects Quantitatively

This section of the report describes a product of fatigue research, one that allows the prediction of times at which fatigue is likely to be a factor in workplace mishaps. This tool also allows one to assess mishaps after the fact to determine whether fatigue was likely to have been a causative factor.

The SAFTE™ Model

Quantitative fatigue-effects predictions may be derived from the Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE™) simulation invented by Dr. Steven R. Hursh.[16] The SAFTE™ simulation integrates quantitative information about:

- Circadian rhythms in metabolic rate;
- Cognitive performance recovery rates associated with sleep, and cognitive performance decay rates associated with wakefulness; and
- Cognitive performance effects associated with sleep inertia

to produce a three-process model of human cognitive effectiveness. In the general architecture of SAFTE™, a circadian process influences both cognitive effectiveness and sleep regulation. Sleep regulation is dependent upon hours of sleep, hours of wakefulness, current sleep debt, the circadian process, and sleep fragmentation (awakenings during a sleep period). Cognitive effectiveness is dependent upon the current balance of the sleep regulation process, the circadian process, and sleep inertia.

The SAFTE™ simulation has undergone broad scientific review and the Department of Defense research laboratories consider it to be a complete, accurate, and operationally practical model to aid operator scheduling. The SAFTE™ simulation's software implementation (Chaiken, 2005) and applicability has been validated in both aviation (Eddy & Hursh, 2006) and railroad (Hursh, Raslear, Kaye, & Fanzone, 2007) work environments.

The FAST™ Tool

Based upon SAFTE™, the Fatigue Avoidance Scheduling Tool (FAST™) was developed by the United States Air Force in 2000–2001 to address the problem of aircrew fatigue in flight scheduling. FAST™ is a Windows® program that allows scientists, planners, and schedulers to quantify the effects of various work-rest schedules on cognitive performance (Hursh et al., 2004). It allows work and sleep data entry in graphic, symbolic (grid), and text formats. The graphic input-output display shows cognitive performance effectiveness (y-axis) as a function of time (x-axis; Figure 8). An upper, green area on the graph ends at the time for normal sleep: 90% effectiveness. The goal of the planner or scheduler is to keep performance effectiveness at or above 90% by manipulating the timing and lengths of work and rest periods. A work schedule is displayed as red bands on

16 The material presented here concerning SAFTE™ and FAST™ was adapted from material I posted on Wikipedia at *http://en.wikipedia.org/wiki/Fatigue_Avoidance_Scheduling_Tool*

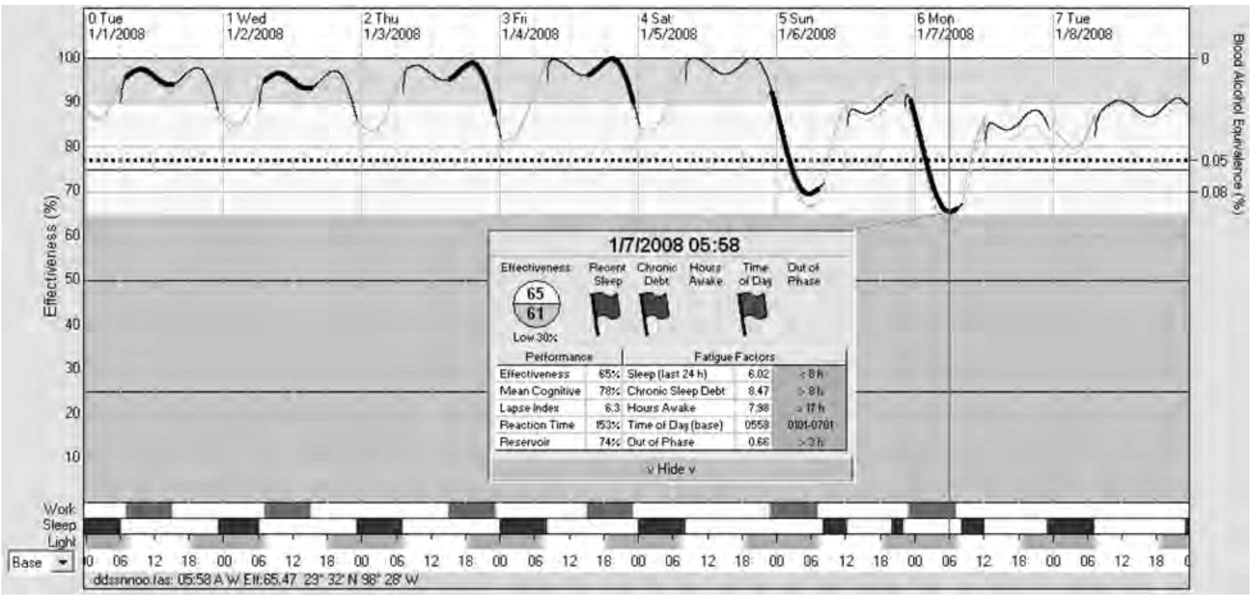

Figure 8. Graphic input/output screen in the Fatigue Avoidance Scheduling Tool (FAST™).

the time line. Sleep periods are displayed as blue bands across the time line, below the red bands.

The calculated performance effectiveness represents composite human performance on a number of cognitive tasks, scaled from zero to 100% on the y axis. The oscillating line in the graph represents expected group average performance on these tasks as determined by time of day, biological rhythms, time spent awake, and amount of sleep. Confidence limits around the average may be displayed. The graphic display may be cut and pasted with the Windows® clipboard. Cognitive effectiveness estimates for work periods of any length may also be cut and pasted in tabular format.

FAST™ was developed under contract awards from the U.S. Air Force Research Laboratory (AFRL) and is available commercially through Fatigue Science, Inc. The model and software include a blood alcohol equivalency estimate for fatigue, and an automated sleep timing algorithm that may be used when only work periods are known. FAST™ has been used to prepare guidance for various non-aviation operations (J C Miller, Lebegue, Long, Pinchak, & Herrera, 2008; J C Miller, 2006a; J C Miller, Dyche, Cardenas, & Carr, 2003; J C Miller & Eddy, 2008; J C Miller, Eddy, R. Smith, & Moise, 2008; M A Paul, Gray, T E Nesthus, & J C Miller, 2008; M A Paul & J C Miller, 2005). (Zimmerman et al., 2000). (MA Paul, TE Nesthus, & JC Miller, 2008).

Alternatively, there are two other world-class, quantitative models that may be used to help predict fatigue occurrences. One is QinetiQ's System for Aircrew Fatigue Evaluation (SAFE), which focuses mainly on issues in scheduling in commercial aviation. The other is the Fatigue Audit InterDyne (FAID), which focuses on estimating the risk of fatigue-induced errors. FAID is authorized for use as a tool in the implementation of fatigue risk management systems in Australian military operations and civil transportation sectors including aviation, rail, highway, and maritime. It has also been used in specific implementations in the U.S., Canada, UK, South Africa, and South-East Asia.

Fatigue Mishap Rate Estimation

It is relatively easy for fatigue experts to see fatigue-related factors in mishaps. However, most mishap investigators don't have this kind of insight, nor do they have a quantitative tool for determining whether fatigue may have been a factor. Fortunately, there is now a reasonably straightforward, quantitative approach to deciding whether a mishap may be fatigue related. There are five generally-accepted fatigue indicators with limits that raise "red flags" with respect to the likelihood that cognitive performance is likely to be impaired by fatigue (J C Miller & Eddy, 2008). These factors were deemed relevant by expert opinion in conjunction with the development of quantitative tools and identified in a training course established several years ago by the NTSB Training Center, titled "Investigating Human Fatigue Factors." The course was designed and taught by Drs. David F. Dinges and Mark R. Rosekind, well-known sleep and fatigue scientists. In addition to case studies and hands-on exercises, the course provided participants "with information and guidance to evaluate the role human fatigue plays in accident causation." It covered "fatigue-related issues including sleep length, sleep disorders, circadian rhythms, work schedules, and the effects of fatigue on performance and alertness."

The instructions and guidelines provided in that course indicated general acceptance of limits for the five fatigue indicators. These limits were incorporated several years ago into the "Dashboard" display of FAST™ When the limit was exceeded for any one of these indicators, a "red flag" image for that indicator was displayed in the Dashboard. The five indicators are:

- Amount of sleep in the last 24 hours
- Cumulative sleep debt
- Hours awake since the last major sleep period
- Time of day
- Amount of jet lag or shift lag

The limit for amount of sleep is a minimum of eight hours. Thus, if an individual has acquired fewer than eight hours of sleep in the 24 hours immediately preceding the mishap, then mental fatigue may have reached a dangerous level. For a full exposition of why eight hours was selected as the break-point, the reader is referred to the print and electronic media provided by the National

Sleep Foundation. On the basis of the applicable research, the NSF published a table of sleep needs for different age groups. The normal range of sleep need for adults was specified as seven to nine hours. The middle of that range was chosen for use as a minimum sleep need here.

The investigator should use some latitude in determining an individual's sleep need. If there is no information about the combination of the individual's sleep habits and waking performance, then eight hours is the best guess. If testimony is present indicating that the person always functioned acceptably with seven hours of sleep per night, then seven hours is a good minimum. Conversely, if the individual is known to always need nine hours of sleep per night, then nine hours should be used as the minimum.

"Cumulative sleep debt is the debt that builds up across a sequence of major sleep periods in which less sleep than the minimum is acquired."

Cumulative Sleep Debt

The limit for cumulative sleep debt is a maximum of 10 hours. Cumulative sleep debt is the debt that builds up across a sequence of major sleep periods in which less sleep than the minimum is acquired. If an individual has more than 10 hours of cumulative sleep debt, then mental fatigue is likely to have reached a point where cognitive performance will be degraded. Ten hours is 25% more than one average, full night of sleep. Most fatigue scientists would agree that after missing an entire night of sleep (or the equivalent), you have a serious debt that needs to be restored.

To calculate cumulative sleep debt, work backward in 24-hour segments from the time of the incident to the last time that the individual was fully "caught up" on their sleep; for example, when they had slept at least eight hours per night for a week or so. For each 24-hour period, estimate the hours of sleep acquired. Subtract each estimate from the minimum sleep need for the individual. When too few hours of sleep have been acquired, then the difference will be positive. When "recovery" sleep has been acquired in a given 24-hour period, the person will have slept more than their minimum and the difference will be negative. If the difference is negative, multiply it by two (because of our sleep physiology, we make up sleep faster than we lose it). Add all of the positive and negative values together to get the cumulative sleep debt. A six day example follows:

Day	Amount of Sleep	Difference from 8 Hours	Debt Type
Mishap day	10 hours	-4 hours	(recovery sleep)
Previous 24 hrs	6 hours	2 hours	(sleep debt)
Previous 24 hrs	6 hours	2 hours	(sleep debt)
Previous 24 hrs	7 hours	1 hour	(sleep debt)
Previous 24 hrs	8 hours	0 hours	(no debt)
Previous 24 hrs	7 hours	1 hour	(sleep debt)
	Cumulative sleep debt:	2 hours	

Hours Awake Since the Last Major Sleep Period

If an individual has been awake for more than 17-hours since the last major sleep period, then mental fatigue is likely to have reached a dangerous level. A major sleep period is considered more than three to four hours of continuous, good-quality sleep. On a day-to-day basis, the individual is expected to acquire eight hours of sleep and to be awake for 16 hours. However, on a given day in which there is no cumulative sleep debt, research data suggest that a dangerous level of mental fatigue is not likely to be reached until 17 hours of wakefulness.

Time of Day

The period of concern is between midnight and 6:00 a.m. on the body clock. More specifically, the period of concern is between one and seven hours before the predicted time of awakening on the body clock. For a person who typically sleeps from 10:00 p.m. to 6:00 a.m., this would be 11:00 p.m. to 5:00 a.m. If cognitive work is to be performed during this period, then cognitive fatigue may be at a dangerous level. This phenomenon exists because of the normal, unavoidable, daily (circadian) rhythm in metabolic rate and body temperature. This rhythm reaches its low point at about 4:00 a.m. in a person without jet lag or shift lag. If the person has (1) not changed time zones recently (including night shift workers), or (2) changed time zones recently at a rate of one zone per day or slower, or (3) changed time zones recently at a rate of one zone per day or faster and has been in the new time zone at least as many days as the number of time zones crossed, then the body clock time may be assumed to be the same as local time.

Amount of Jet Lag or Shift Lag

The limit is three hours of lag. Thus, if the body clock (circadian rhythm) is more than three hours out of synchrony with local time, then mental fatigue may be at a dangerous level. To calculate jet lag, work backward in 24-hour segments from the time of the mishap to the last time that the individual had spent at least two weeks in one single time zone. For each 24-hour segment, record the number of time zone changes that occurred. For each day after a change, subtract an hour of lag. In the following example, a six-zone change occurred two days before the mishap. The amount of jet lag on the day following the change was six hours and on the mishap day was five hours.

Days	Number of Time Zones	Jet Lag
Mishap day	0	5 hours
Previous day	0	6 hours
Previous day	6	0 hours
Previous day	0	0 hours
Previous day	0	0 hours
Previous day	0	0 hours

Calculating jet lag can be confusing for a novice. For example, if an individual flies across six time zones, has one sleep period in the new zone, and flies back immediately, you wouldn't count those crossings for jet lag. In cases like this, fatigue simulation software such as FAST™ can be quite useful.

To calculate shift lag, work backward in 24-hour segments from the time of the mishap to the time at which a change from day shift to night shift (or night shift to day shift) occurred. For each day, record the number of hour's difference in sleep start time. For each day after the change, subtract an hour of lag. In the following example, a change from swing shift to night shift occurred five days before the mishap. As a result, the individual's bedtime changed from midnight to 8:00 a.m. (8-hour change). The amount of shift lag on the following day was eight hours and on the mishap day was four hours.

Days	Number of Hours Shifted	Shift Lag
Mishap day	0	4 hours
Previous day	0	5 hours
Previous day	0	6 hours
Previous day	0	7 hours
Previous day	0	8 hours
Previous day	8	0 hours

To summarize the fatigue indicators:

- Less than eight hours of sleep in the preceding 24 hours
- A cumulative sleep debt of more than 10-hours
- More than 17-hours of continuous wakefulness
- Time of day between one and seven hours before the predicted time of awakening on the body clock, i.e., the pre-dawn hours.
- The body clock out of phase; i.e., in the process of shifting more than three hours.

Blood Alcohol Content (BAC) Equivalency

Generally, society considers it unacceptable to operate a motor vehicle while under the influence of alcohol. Thinking and reflexes slow down, judgment may be impaired, speech may slur, and there may be problems with memory. Several studies on the effects of lack of sleep on human performance provide a strong basis for looking at worker fatigue in the same manner (Arnedt, Wilde, Munt, & MacLean, 2001; Dawson & Reid, 1997; N. Lamond & Dawson, 1999). Since fatigue or tiredness is so difficult to measure, investigators compared impairment due to sleep deprivation with alcohol-induced impairment. Subjects performed tasks that allowed the quantification of accuracy and speed on grammatical reasoning, vigilance, and other mental functions. Results indicated that after about 20-hours of sustained wakefulness, a person may be as functionally impaired as someone with a BAC of 0.10%. This equivalency may be displayed in FAST™.

These findings support the suggestion that even moderate levels of sustained wakefulness reduce performance to an extent greater than is currently acceptable for alcohol intoxication. The results are important for anyone working extended hours over multiple days or weeks with inadequate periods of rest. You would not allow an intoxicated person to operate a motor vehicle. Thus, you must consider carefully your attitudes towards allowing someone who has one or more of the fatigue factors, discussed above, to conduct safety-sensitive jobs.

Section 5. Studies of Shift and Night work in Security and Police Operations

Very little research literature exists with direct applications to security operations; only three studies were located for this report. Thus, this section summarizes in the words of the investigators, the findings of the known studies of police shift work conducted from 1983 through 2010. For both security and police operations, the studies are presented in chronological order and summarized by types of finding.

One study of security operations "sought to relate the well-being of night workers to that of the working population in general" (Alfredsson, Åkerstedt, Mattsson, & Wilborg, 1991). "The results showed that the security guards had a 2-3 times higher occurrence of sleep disturbances and fatigue than the national sample." "It was concluded that sleep/wake disturbances are considerably more usual in permanent night security guards than in the working population as a whole."

Washburn et al. "examined the effects of time-on-task on participants who were searching for guns, knives and scissors in x-ray images of suitcases" (Washburn, Taglialatela, Rice, & J. D. Smith, 2004). "Although performance did change across the 25-minute test session, the characteristics of this change varied as a function of the sustained-attention skills brought to the task by participants, as measured with a continuous-performance task."

Basner et al. investigated "the effects of night work and sleep loss on a simulated luggage screening task (SLST) that mimicked the x-ray system used by airport luggage screeners" (Basner et al., 2008). Their "subjects performed the SLST every 2 h during a 5-day period that included a 35 h period of wakefulness that extended to night work and then another day work period after the night without sleep." They found that "night work and sleep loss adversely affect the accuracy of detecting complex real world objects among high levels of background clutter." Basner et al noted that, "If the results can be replicated in professional screeners and real work environments, [then] fatigue in luggage screening personnel may pose a threat for air traffic safety unless countermeasures for fatigue are deployed."

The following paragraphs recap, the known studies of police shift work (1983 through 2009). Peacock et al. found no difference in physiological or subjective measures for police switching from 8- to 12-hour shifts. The police accepted the 12-hour shift length. However, their 8-hour shift work plan called for backward rotation, known to be more stressful for most people than forward rotation. Perhaps these 8- and 12-hour shift plans were both stressful (Peacock, Glube, M Miller, & Clune, 1983).

Knauth et al. analyzed 120 police shift systems (Knauth et al., 1983). They included information on the "frequency distribution of the shift cycles, the duration of shifts, the start and end of shifts, the maximal number of consecutive night shifts, as well as the frequency of different kinds of free weekends." They also acquired diary data for eight days from 120 policemen (Knauth, Kiesswetter, Ottman, Karvonen, & Rutenfranz, 1983). "The mean duration of sleep was reduced before morning shifts, between night shifts, and after a morning shift that was followed by a night shift on the same day. The leisure time was limited in connection with afternoon shifts and between the combined morning and night shift. ... Rapidly rotated shift systems had more advantages referring to the total amount of night sleep than weekly rotated shift systems."

Goslin surveyed U.S. Air Force security police personnel (Goslin, 1986). "[N]ight and rotating shift workers reported significantly more work-related sleep problems than their day shift counterparts. Possibly related to the above conclusion, the perceived level of job effectiveness was significantly lower in night shift workers than day shift workers. Many day shift workers, however, reported that late night activities interfered with their job performance. Further, a significant number of night shift workers reported difficulty staying awake on the midnight shift. Clearly, however, the majority of these personnel *believed* they were more effective working a permanent as compared with a rotating shift schedule." (Emphasis added; belief and reality may differ)

Ottmann et al. assessed "the subjective health status of day- and shift-working police officers" (Ottmann, Karvonen, K. Schmidt, Knauth, & Rutenfranz, 1989). The 2,659 shift-working and 1,303 day-working police officers were divided into four, ten-year age classes. "Factor analysis revealed that all the symptoms included in the questionnaire could be grouped into six factors. The prevalence rates of complaints showed that four of these factors (autonomous symptoms [i.e., symptoms of anxiety], musculo-skeletal symptoms [i.e., aches and pains], disturbance of appetite and indigestion, respiratory infections) were influenced by the main effects of age and shift work. Across all age classes the age-related changes in prevalence rates were strengthened by shift-work. In the other two factors (nervous symptoms, gastro-intestinal symptoms) an additional interaction effect could be observed. While the prevalence rates of the day-workers increased with age, those of the shift-workers decreased in the oldest age class. This drop of prevalence rates may be attributed to the influence of selection processes."

O'Neill examined "the impact of shift work on the health of individual workers" and considered "why some workers are able to adapt to shift changes and others are not." The report also examined shift work maladaptation[17] and the effects of stress (O'Neill, 1991). He made four recommendations. The first dealt with selecting people by shifts, mainly by seniority. The second was to limit successive duty periods to four, with court appearances scheduled for the day preceding the first night shift. This latter recommendation precludes napping before the first night shift and may not be a good idea, though what alternative court schedule one might use is difficult to determine. The third recommendation was to minimize the numbers of officers on duty from 2:00 a.m. to 6:00 a.m., if possible. The fourth was to minimize the frequency of changing shifts to once every six months.

Garbarino et al. collected the Epsorth Sleepiness Score (ESS)[18] and a sleep disorders score from 1,280 policemen: 611 shift workers and 669 non-shift workers (Garbarino et al., 2001). "The ESS scores were not higher in shift workers than in non-shift workers, but the SD-score was found to be significantly influenced by shift work condition and seniority. The occurrence of sleep-related accidents was found to have been significantly increased for shift workers and related to the presence of indicators of sleep disorders. The sleepiness could be underestimated or even overcome by the influence of stressing conditions."

Reviewing the literature, Vila et al. found that "fatigue among police patrol officers arising from departmental policies and practices may degrade individuals' abilities and hence the performance of organizations" (Vila, Morrison, & Kenney, 2002). They noted that "few U.S. police departments have established comprehensive shift, work-hour, and fatigue management policies despite the well understood, long-standing, and profound influences that round-the-clock schedules have on worker health, safety, performance, job satisfaction, and family life." They discussed "policies and practices that police executives, managers, and supervisors can employ to minimize officer fatigue."

Senjo and Hewerd studied "the correlation between sleep measurements, fatigue, and police work" among "three types of law enforcement agencies in a single western jurisdiction" (Senjo & Hewerd, 2007). Their findings "unequivocally support the notion that law enforcement officers do not get enough recommended sleep" and that "municipal police, compared to sheriff deputies or highway patrol officers are more careful about excessive work hours, work fewer second jobs, and get more sleep. Highway patrol officers consistently placed second to municipal police among these variables while the sample of county

17 In the short term, sleeplessness, excessive sleepiness at work, alteration of humor, higher rates of accidents and incidents, and family and social problems. After several years, cardiovascular and cardiac diseases, absenteeism, and separation and divorce (Kumar, 1998). Includes Shift Work Sleep Disorder (SWSD).

18 The Epworth Sleepiness Scale is a validated, clinical questionnaire that helps identify excessive daytime sleepiness (Johns, 1991). The ESS is reproduced in Appendix A.

sheriff's was the most overworked, as well as the most under slept."

Eriksen and Kecklund compared "a flexible shift system (based on self-determined work hours)" to "a rapidly rotating shift system, with frequently occurring quick returns" (backward rotations) (Eriksen & Kecklund, 2007). The sample "included 533 randomly selected police officers, of which 26% were females. ... The results showed that the flexible shift system group did not differ [from the rotating shift] with respect to sleep/wake complaints and subjective health. However, the flexible shift group obtained more sleep in connection with the shifts, probably because of longer rest time between shifts. Thus, they worked less quick returns and long work shifts. The association between work hour characteristics and sleep/wake complaints was weak in the flexible shift group. Instead, sleep/wake problems were mainly associated with the attitude to work hours."

Charles et al. investigated "the association between shift work and sleep problems among police officers from Buffalo, New York" (Charles et al., 2007). "Among police officers, night shift work was significantly and independently associated with snoring and decreased sleep duration." They noted that "snoring is an important indicator of sleep problems that may be more readily noticeable than other measures associated with sleep apnea."

Kecklund, Eriksen and Akerstedt examined the claim that "shift workers give priority to long series of days off and therefore prefer compressed work schedules at the expense of what is optimal for long-term health" (Kecklund, Eriksen, & Akerstedt, 2008). The investigators evaluated the attitude to six new shift systems among a randomly selected sample of police officers. "The results showed that the most popular shift system was a rapidly, forward, rotating schedule with at least 16 h of rest between shifts, despite that it had fewer days off compared with some of the compressed shift systems."

Senjo and Dhungana sampled "law enforcement agency directors (e.g., police chiefs, sheriffs) to analyze policy constructs that affect the relationship between fatigue and job performance in law enforcement" (Senjo & Dhungana, 2009). Their findings revealed "the reality of a tired workforce but a low-level desire among agency chiefs to have fatigue reduction policy. Where such policy exists, a business-like "managerialism" dominated executive conceptualization rather than citizen safety or civil liability orientations. Informal controls, rather than formal rules, emerged as applicable tools used to address and reduce officer fatigue."

Landrum noted that "compressed scheduling offers advantages to a law enforcement agency" (Landrum, 2010). He provided support within the law enforcement community for the shift work scheduling principle of *good quality time off*, one of the advantages of compressed work schedules. "When using a compressed scheduling model the agents, their families, and the environment all benefit. This type of robust scheduling allows full-time employees to complete their work week in fewer days. Agents who report to work fewer days per week have more time for personal events, family events, and respite. A compressed schedule increases morale and recruitment while decreasing attrition." "It is time for strategic leadership in federal law enforcement to create equilibrium between the agents' vital needs and the mission of securing the United States of America. Implementation of a compressed work schedule for border patrol officers in the United States Border Patrol is clearly a sound strategic decision."

Summary of Research

One of the studies summarized above noted health implications for law enforcement personnel who were shift workers (Ottmann et al., 1989); and O'Neill (1991) provided recommendations for better schedules to help with this problem. Several studies documented sleep disturbances in both security and law enforcement personnel involved in shift work (Knauth et al., 1983; Alfredsson et al., 1991; Goslin, 1986; Garbarino et al., 2001; Charels et al., 2007; Senjo & Hewerd, 2007).

Washburn et al. (2004) documented time-on-task fatigue effects, and Basner et al. (2008) documented circadian and sleep loss effects on the performance of x-ray screening tasks. Increased numbers of accidents experienced by law enforcement personnel working shifts were discussed by Garbarino et al. (2001) and Vila et al. (2002).

Types of shift work schedules were examined in several studies (Peacock et al., 1983; Eriskson & Kecklund, 2007; Kecklund et al, 2008; Landrum, 2010). Generally, schedules were preferred that provided the best quality of time off. One assumes that this time off allows both for recovery from sleep debt and quality time with family and friends. Senjo and Dhungana (2009) discussed management controls that might reduce workforce fatigue.

One lesson from these few studies is that law enforcement and security operations personnel tend to suffer from the same health, sleep disturbance, and cognitive performance problems as other shift workers in industry and the military. This makes sense, since all shift workers have reasonably similar needs for nocturnal sleep, and this need is countered by night work and shift work. Thus, one may apply the results of decades of research on night work and shift work effects in non-police and non-security occupations to the management and scheduling of security operations personnel. For example, see the annotated bibliography published by the Naval Postgraduate School. (J C Miller & Shattuck, 2010) The shift work scheduling guidelines and quantitative tools described above should be useful in security operations.

Section 6. Fatigue Countermeasures

This section of the report provides information about countering fatigue at the organizational level. The use of fatigue countermeasures in an organization must be initiated and sustained with a top-down management approach.

Operational fatigue risk is managed best by an integrated program that addresses the requirements of all stakeholders. Immature fatigue management programs often begin by attempting to implement countermeasures in the absence of such an integrated program. However, this approach typically meets with limited success because individual implementations are not sufficiently understood or supported by all levels of management. Few of these programs become institutionalized. On the other hand, mature and established fatigue management programs introduce fatigue countermeasures from a foundation of commitment, cooperation, knowledge, assessment, and program refinement at all levels of the organization (McCallum, Sanquist, Mitler, & Krueger, 2003).

Organizational commitment requires allocation of resources sufficient for establishing and sustaining a fatigue management program. Senior executives must be involved in the formulation and support of their organization's fatigue management policy. Program policy should be established through a joint effort by all organizational stakeholders. The policy might include:

- Statement of goals and objectives
- Responsibilities and authority for managing fatigue and alertness
- Documentation of the support and expertise available to the program
- Policies regarding employee alertness and fatigue
- Objectives and methods for program evaluation and refinement

To help fully understand the need for organizational commitment to fatigue management, one should take a systems approach to the problem. For this, one might turn to the prescription for human-centered management (HCM) offered by Dr. Martin Moore-Ede of Harvard University (Moore-Ede, 1994). He suggested taking the following steps:

- **R**eevaluate human asset potential and priorities. This requires a fundamental shift in how human assets are viewed. In system design (e.g., technology monitored by personnel), make sure that technology enhances rather than degrades human performance.
- **E**stablish management commitment and support. This is a commitment at all levels, starting at the top. Visibly support and continually reinforce this commitment, even if changes must be made in job descriptions, supervisory and management structures, purchasing decisions, corporate policies, etc.

- **D**efine HCM as an integral part of organizational philosophy and mission. Institutionalize the commitment that people requirements, not machine have priority. Commit to HCM as you would to safety, quality, customer service, etc.
- **A**ssess current risks, liabilities, and hazardous exposures. Identify the components of the organization and its systems that are most sensitive to the risks of human fatigue and automation. It is essential to get input from the "front-line troops" during this process, in a non-threatening manner.
- **L**aunch appropriate change initiatives to reduce exposures and capture performance-improvement opportunities. Prioritize issues and opportunities on their likelihood of reducing risk or improving performance. Formulate and introduce programs, policy changes and organizational changes and start the process of institutionalization.
- **E**ducate and provide ongoing support and training for all personnel. In doing this, encourage the creativity and resourcefulness of innovators at all levels of the organization. Implement ongoing, not one-time, training and support.
- **R**eport results and measure performance to plan. Set up mechanisms to obtain the data needed to determine if the benchmarks and overall goals and objectives set for HCM are being achieved.
- **T**ranslate into a continuous, institutionalized process for improving overall productivity, quality, and safety performance. HCM will help you create schedules that help people work at their best and safety procedures that allow for human weaknesses.

Subsequently, Dr. Moore-Ede provided a number of tips, though no specifics, about how a senior manager might implement an alertness management program in their operation (Shiftwork Alert, Editors, 1999).

"Identify the components of the organization and its systems that are most sensitive to the risks of human fatigue and automation."

Dr. Mark Rosekind, then at NASA-Ames Research Center, was commissioned by the Department of Transportation to create a training course about fatigue for all modes of transportation. These workshops were held from 1993 to 1995. In 2004, Dr. Rosekind worked with the National Transportation Safety Board (NTSB) to create a course titled *Investigating Human Fatigue Factors* to help mishap investigators evaluate the role human fatigue plays in accident causation.[19]

Training materials were provided by Westfall-Lake and McBride (Westfall-Lake & McBride, 1997). In teaching about the hazards of shift work, the authors presented a checklist for managers that are relevant to operations today, i.e., doing more with fewer people and resources. The checklist, compiled from hundreds of interviews of supervisors in manufacturing, is adapted here:

- Your organization has been reduced in size recently. You wonder if the organization can make it safely with the current number of people.
- During higher-tempo operations, your personnel work extra overtime to cover for missing people. You sometimes wonder about their fatigue level.
- Your personnel are under pressure to "get it finished now." When you are at home and they are working irregular hours, it sometimes occurs to you that they may be cutting corners to get the work done on time.
- Your irregular-hours personnel are working for a new supervisor due to recent organizational changes. You wonder if everything is under control.
- Your personnel are living in an age of family upheavals, divorces, and other family problems. You wonder if personal pressures affect their attention to job safety.
- Your personnel are feeling economics pressures. More and more, you feel that they may tolerate anything (e.g., cumulative fatigue) to maintain pay level. You wonder if this is a safe situation, and whether they will speak up if they are too fatigued to perform the job well.
- Your personnel are working with more and more complex weapon and support systems. The equipment is more automated, yet it has more destructive potential than ever before. You see both day and night workers in the organization that have the potential to cause a major disaster. Certain night-related incidents stand out in your mind, such as Chernobyl, Bhopal, Challenger, and Three-Mile Island.

19 *http://www.ntsb.gov/academy/CourseInfo/IM303_2010.htm*

If you see these problems in your organization, the authors suggested the Fitness, Alertness, Sleep and sleeping environment, and Time off (F.A.S.T.) Tracking Performance and Improvement System as one remedy (this is not the FAST fatigue-modeling software described earlier).

A fascinating aspect of this work is the description of two types of shift workers: burnout and achievement. Understanding the sociological development of these two types turned out to be essential for the development of the training materials. They described the burnout and achievement paths taken by shift workers, beginning at the same point. Burnout leads to helplessness and hopelessness. Achievers avoid this fate by working on fitness (diet and exercise), alertness (pre-dawn and mid-afternoon), adequate sleep, and good-quality time off (especially home and family). These four areas form the basis for the authors' F.A.S.T. program. They provided a performance tracking system and some excellent checklists to support the implementation of the program.

Management-Labor Partnership

It can be a challenge for CEOs and their personnel to address fatigue management from a common perspective. At issue are work and rest schedules, which directly affect both operational efficiency and individual well being. Because these issues are so critical to the organization and individuals (reducing on-the-job accidents, improving employee health, and improving operational efficiency), they also serve as an important basis upon which to establish more productive relationships. An effective alertness or endurance management program will identify a means of involving both CEOs and their personnel in supporting these common objectives.

Evaluation

A fatigue management program requires periodic evaluation and refinement. Program evaluation should be tied back to established objectives. Measures that could be collected on an ongoing or periodic basis, include:

- Average number of sick days
- Numbers of accidents and incidents found to have resulted from operator fatigue
- Attendance at alertness management educational events
- Numbers of personnel completing confidential fatigue-screening
- Responses to a periodic alertness management survey

Additional information about assessment methods and tools is provided in Chapter 5 of the report by Miller (J C Miller, 2006a). Program refinements close the gap between established objectives and evaluation findings. The process of effectively managing operator alertness inevitably involves coordinating efforts across many members and levels of an organization. Successful refinement requires continued oversight and improvement of the alertness management program.

Specific Countermeasures

Research indicates that some of these countermeasures are effective, some are probably effective (but are still being studied), others require medical supervision, and some simply do not work or have harmful health effects.

Countermeasures that Work

The countermeasures described in this section are effective as shown by research data and operational experience. They encompass both the prevention of and cure for fatigue by getting enough sleep and the mitigation of fatigue symptoms. Individual countermeasures may need to be combined, based upon specific operational circumstances.

The most effective countermeasure for fatigue is to do as much as possible to prevent it from occurring in the first place. The primary culprit for feeling fatigued is sleep loss. Thus, the first and foremost countermeasure is ensuring adequate sleep opportunities, proper sleep-period timing, and appropriate sleeping accommodations. The principal advantage of getting enough sleep is that it will reduce on-the-job fatigue, thereby reducing the need for other countermeasures.

"The fundamental strategies for minimizing needless fatigue due to sleep loss are a routine approach to obtaining sleep, allowing enough time for sufficient sleep, and an appropriate sleep environment."

Limitations associated with this approach are factors that tend to be beyond the control of the individual, such as work shift start times, rotation of shift work schedule, and location factors that might influence sleep, i.e., jet lag or the sleep environment. Additionally, some individuals will sacrifice adequate sleep for social or family activities.

The fundamental strategies for minimizing needless fatigue due to sleep loss are a routine approach to obtaining sleep, allowing enough time for sufficient sleep, and an appropriate sleep environment. This means sleeping in an environment that is quiet, dark and not overly warm; waking up at the same time every morning; and allowing for an average of at least eight hours of nocturnal sleep. This regularity maximizes the coordination between sleep patterns and circadian rhythms, thus optimizing the preventive and recuperative benefits of sleep.

All other countermeasures except sleep should be viewed as "band-aid" approaches, to be used as a last resort when other measures are insufficient and a job must be accomplished. After band-aid measures are used, recovery sleep will still be necessary.

Personnel may be required to frequently change work and sleep schedules. This may lead to sleep-loss-induced fatigue because the body cannot acclimatize efficiently to sleeping at different time of day. The best approach to reducing fatigue due to sleep loss associated with a new work-sleep schedule is to start the new shift with no sleep debt—this means getting at least two nights of unrestricted sleep prior to beginning a new schedule. Unrestricted sleep may be accomplished through an early-evening bedtime. The average sleep length should be well over eight hours.

Another general approach to minimizing sleep loss is to match the physiology of the individual to the work demand. An individual's tolerance towards shift work has been found to be related to their chronotype, as described earlier. Larks cope more easily with early shifts; owls cope more easily with late shifts.

Anchor sleep refers to a regular sleep period of at least four-hours duration, obtained at the same time each night (Minors & Waterhouse, 1981). When less than eight hours, the anchor sleep period should be supplemented by an additional sleep period when operations allow.

Some jobs do not allow a full eight hours of sleep during the same period every day. To cope effectively with these operations, schedule at least four hours of sleep at the same time every night; additional sleep can be obtained as the operation permits. Anchor sleep periods have the advantage of stabilizing the body's circadian rhythms to the local day-night cycle, minimizing the effects of jet and shift lag on performance.

One may also use napping (at work or at home) as a fatigue countermeasure. Taking a nap will usually reduce fatigue effects and increase alertness during work periods. A nap can be very effective as a short-term countermeasure against fatigue effects, and to compensate during a period when personnel will need to remain awake for a long time (more than 17 hours). Some other situations where napping would be appropriate are:

- Less than 8 hours sleep during the main sleep period
- Awake for 30 minutes or longer two or more times during the main sleep period
- Poor quality nocturnal sleep
- During a long and/or night time duty period

Naps at work must be limited to a time, place, and duration that will not interfere with work tasks. It is important to recognize that when naps are needed because of reduced sleep opportunities, personnel are at risk of being critically fatigued.

Driskell and Mullen integrated "the results of every study on the effectiveness of naps as a fatigue countermeasure that was accessible via a comprehensive search procedure [as of 2004] and that contained data that allowed precise statistical tests of the effects of naps on performance or fatigue to be derived" (Driskell & Mullen, 2005). On average, post-nap mental performance was hardly below pre-fatigue baseline levels (reaction time, visual vigilance, logical reasoning, single digit substitution, etc.). This was true whether the naps were of short or long duration (range 10-min to 8-hours, mean 2.2 hours) and whether the assessment of nap effects was conducted after a brief or long post-nap interval (immediately after the nap to 45.5 hours after the nap, mean 8.7 hours after the nap). The effectiveness of naps was not influenced by the length of the pre-nap waking interval. Nap effectiveness did not depend upon circadian rhythms; the effects were the same regardless of time of day. Sleep inertia was not a significant concern; no effect was seen within first hour after awakening from a nap.

More detailed analyses by Driskell and Mullen revealed that "performance improved after longer naps, and the beneficial effects of naps deteriorated after longer post-nap intervals." Their regression analysis generated a predictive equation for nap effectiveness. According to this equation, a 15-min nap reverses the effects of sleep deprivation, i.e., returning performance to its baseline level, for about 1.5 hours after the nap, while a 4-hour nap reverses the effects of sleep deprivation for about 7.5 hours.

Napping is to be used as part of a continuous work period, and should not be used to extend the work period. When it is known that napping will be used as a countermeasure, it is important to plan where the nap will be taken. Locations will vary depending upon the operation.

There will be times when personnel feel overwhelmed by sleepiness despite a nap or even one sufficient sleep period before work. In this case, they should take an "emergency nap" as soon as tasks permit. If they are engaged in an activity, they will need to use other countermeasures until they get to an appropriate time or place for a break. When personnel are extremely fatigued, they can sleep anywhere and at anytime. In this case, use the philosophy that "any sleep is good."

Otherwise, naps should be planned to obtain maximum benefit. This will vary quite a bit depending on circumstances, but the following guidelines will probably be applicable when jet lag or shift lag are not present:

- Take advantage of the mid-afternoon alertness dip to schedule naps.
- Napping for several hours prior to the start of a night shift can be beneficial.
- Use brief "power naps" of any length almost anytime, as they can help refresh performance for a short period.

Morgan discussed briefly the work of Dr. Claudio Stampi on polyphasic sleeping and its practical applications in real-world operations, especially solo sailing (D. R. Morgan, 1996). Based upon Stampi's work, Morgan came up with this set of general guidelines:

- Nap ruthlessly. Because sleep is a strong and fundamental physiological need, you should push aside any person or thing that gets in the way of your nap.
- Nap securely. Use a security alarm system. Make sure that residence or vehicle doors are locked. Have someone scheduled to wake you up or set a wake-up alarm.
- Avoid sleep debt. Sleep debt will cause napping sleep to be very deep, triggering subsequent sleep inertia.
- Nap proudly, nap often. While others take a coffee break, take a quick nap. Remember that a nap is something that you take, while dozing off is something that takes you.

Alertness may be enhanced by consuming caffeine in the form of coffee, tea, soft drinks, or "power" drinks or food; or by taking non-prescription caffeine tablets (Committee on Military Nutrition Research, Food and Nutrition Board, 2001). Caffeine must be used only when needed and with reasonably good sleep beforehand, 200 to 600 mg can be a highly effective fatigue countermeasure. Caffeine is widely available and affects the nervous system within 15 to 20 minutes. The effects last about four to five hours and include a more rapid heartbeat and, for tactical caffeine users, sharply increased alertness/decreased sleepiness. The effects may last up to 10-hours in especially sensitive individuals.

Unfortunately, our brains build up a tolerance to the repeated consumption of caffeine at more than about 200 to 300 mg per day (about one mug of coffee). Thus, a frequent coffee drinker may be unable to obtain the same alerting effect from caffeine as a casual coffee drinker. Personnel should consume caffeine sparingly and save the boost effect until they really need it. This is called "tactical caffeine use." For example, they might plan to use caffeine to deal with the afternoon dip in alertness or, if working through the night, use it after midnight during the circadian low point (1:00 a.m. to 4:30 a.m.). Caffeine affects people's sleep differently. For some, even small amounts can cause problems sleeping. For others, caffeine has no apparent detrimental effect.

It is important to use caffeine only as a short-term way to boost alertness; regular use can lead to various undesirable side effects, including elevated blood pressure, stomach problems, and insomnia, as well as tolerance to its effects. Chronic overuse may also cause dehydration, nervousness, and irritability.

Coffee and "power" drinks/food have the highest caffeine levels, followed by tea, cola, and chocolate. Some over-the-counter cold medications contain caffeine, as do alertness aids such as NoDoz and Vivarin. The caffeine content of coffee may vary substantially depending on preparation. Here are some situations where the infrequent, selective use of caffeine makes sense:

- In the middle of a night shift
- Mid-afternoon when the alertness dip is greater because of inadequate nocturnal sleep
- Prior to an early morning commute following a night shift, but not within four hours of going to sleep

It is always best to try and reduce fatigue through obtaining enough sleep, but when this does not happen and there is a need to boost alertness for a period of several hours, using caffeine makes sense.

Automation is the engineering practice of replacing human physical and/or mental functions with electro-mechanical and/or software-based alternatives (Parasurman et al., 2000). Automation may be used best to deal with the weaknesses that the human in the loop may contribute to system operation; for example, vigilance decrements, boredom, habituation and/or task-specific fatigue. The manner in which we selectively allocate system functions either to the human operator or to automation has received quite a bit of research attention. The most acceptable philosophy applied to automating a system is to automate repetitive, manually controlled processes, increasing the freedom of the human operator to engage in pattern recognition and planning, goal selection, fault detection, and other cognitive, supervisory functions. Given adequate sensors, an automated system can perform tedious and complex control tasks far better than a human.

However, automation usually forces the human operator into the role of a system monitor, a function handled poorly in most cases by the human brain and setting up perfect conditions for lapses in attention. Concerns about automation include:

- Increased monitoring load placed on the operator and concomitant lapses in attention
- High level of operator responsibility with little to do
- Loss of operator manual skill proficiency
- Operator-out-of-the-loop problems
- Replacing the human's uniquely elegant pattern recognition abilities with less-competent sensors
- The classic vigilance problem is characterized in the story of the boy who cried, "wolf!"—that is, a high false alarm rate will cause the operator to ignore indications of system malfunction, and malfunction detection rates by the operator may drop to near zero

- Displays that fail to support optimal performance by the operator, and that do not allow for variations between individuals in their abilities to remain vigilant
- Misinterpretation of automation problems, leading to the wrong "fixes" being implemented
- Failure to recognize subtle vigilance problems until after the occurrence of many accidents involving automation

Countermeasures that Require a Prescription

The following countermeasures require either a prescription by a physician (alertness aids, sleep aids) or guidance by a scientist trained in circadian physiology for effective use (bright light, melatonin). Alertness aids and sleep aids are prescription drugs used to counter the symptoms of sleep loss temporarily and enhance alertness.

Modafinil (ProVigil®) is an alertness aid which, if used before decreased alertness occurs, greatly increases alertness during a period of expected impairment (Caldwell & Caldwell, 2005; Caldwell, Caldwell, & R. A. Schmidt, 2008; Caldwell et al., 2009). Modafinil is approved by the Federal Drug Administration for use by night workers and may be prescribed by a physician. It has no known side effects that may lead to abuse or judgment problems. It has fewer unwanted side effects than caffeine and may one day be available without prescription.

There are now safe, non-habit-forming, prescription sleep aids that may be used to promote sleep when operations preclude normal, nocturnal, recuperative sleep (op. cit). There are three sleep aids available and recommended for Department of Defense operations: temazepam (Restoril®) and zolpidem (Ambien®) which usually sustain sleep for 6 to 8 hours; and zaleplon (Sonata®), which reduces the amount of time needed to get to sleep. Prescription sleep aids are applicable to a number of situations such as shift changes, night work, jet lag, and stress-related short-term insomnia.

Countermeasures that Require Technical Assistance

The following countermeasures, phototherapy and supplemental melatonin, require guidance by a scientist trained in circadian physiology for effective use. One may be able to time one's exposure to daylight or bright indoor light to shift the circadian rhythm to correspond to a new work schedule or time zone, or to enhance alertness during night work.

Advancing the circadian rhythm means shifting it so that its high and low points, as measured by alertness, body temperature, or natural melatonin levels in the blood, occur earlier on the clock, and vice versa for delaying the rhythm. Advancing the rhythm allows partial adjustment prior to eastbound travel or prior to working an earlier duty period.

In general, bright light exposure after the low point in the individual's circadian rhythm in body temperature will advance it, making it easier to go to sleep earlier and wake up earlier. Conversely, exposure to bright light well before the low point will generally delay the rhythm, making it easier to work and sleep later. In practice this means knowing the status of the individual's body clock and then exposing the individual to bright light during the expected sleep onset time to delay the rhythm, or exposure to bright light around the expected wake up time to advance the rhythm. It is difficult to determine the status of a person's body clock unless they have been on a very regular schedule of day work and night sleep.

If used successfully, then personnel can get more sleep and be more alert on the job. However, the use of light exposure for resetting the circadian rhythm is a complex undertaking, and should be guided by a scientist knowledgeable in circadian physiology. Additionally, the benefits of resetting the circadian rhythm can be maintained only through fairly rigid adherence to the procedure, and ensuring that other time cues (e.g., daylight) are minimized.

In addition to light exposure, it is also important to control the timing of darkness. This is especially true for personnel who may be traveling between work and home in the bright morning sun. In these cases, it is important that they minimize exposure to daylight (i.e. wearing dark glasses) or that their sleeping quarters are blacked out.

For night workers, exposure to bright indoor lighting levels during the night shift can promote alertness. This is a good countermeasure to use if there is the flexibility in the work environment to control the lighting. It may not be feasible in some work environments where night vision is required.

Melatonin is a hormone produced at night by the pineal gland in the brain. Synthetic or natural melatonin taken orally is used to induce sleepiness and may be used to adjust the circadian rhythm to new schedules. Melatonin in small doses (0.3 to 5 mg) has rapid sleep inducing effects and lowers alertness and body temperature. With proper timing, melatonin may help adjust circadian rhythms to earlier duty/sleep schedules and reduce the effects of jet lag and shift lag.

Because use of melatonin can cause drowsiness, it should not be taken if you intend to participate in safety sensitive jobs. The sleep inducing effects are temporary, so while melatonin may be able to help induce sleep at unusual times, personnel may not sleep as long as desired. Reported, but rare, side effects include worsened fatigue, depression, coronary artery occlusion (possibly increasing heart attack risk), and possible effects on fertility.

The timing of melatonin use is an important factor; it needs to be taken in the proper relationship to the individual's body clock to achieve the desired effect. Melatonin is much more effective for advancing the rhythm than delaying it the rhythm. To advance the rhythm, melatonin should be taken well before the low point of the individual's circadian rhythm.

Recent work by the Canadian Forces with research subjects who have sustained schedules of regular nocturnal sleep and diurnal wakefulness has shown that when taken at 4:00 p.m., 3 mg of slow-release melatonin will cause a phase advance of almost three-quarters of an hour (M A Paul et al., 2010). When a bright light treatment is given from 7:00 to 8:00 am, a phase advance of almost one-third of an hour occurs. Combining the two treatments produces a phase advance of about one hour.

Countermeasures that Don't Work

The following approaches have been advocated as fatigue countermeasures. However, scientific data have demonstrated their ineffectiveness (for example, diet or aromatherapy), or associations with health problems (tobacco and/or nicotine) (McCallum et al., 2003). Other countermeasures that have been suggested widely, such as exercise, diet, or listening to the radio, have minimal or no impact on fatigue, even though people think they do (op. cit.). These myths can be especially dangerous since drowsy people who believe them may also believe that they are alert when, in fact, they are cognitively impaired.

Valerian root, chamomile, kava, and lavender are promoted as herbal sleep aids, but the evidence for their effectiveness is not clear. Herbal stimulants are unregulated by the Federal Drug Administration, and the effects of many are unknown. All herbal stimulants are unproven and should be viewed as safety hazards.

Some personnel will use over-the-counter (OTC) products to try to promote sleep, the primary advantage being that they are available without a prescription. The principal ingredient in most OTC sleep aids is diphenhydramine (Benadryl®), which is an antihistamine. Decongestants are not designed for increasing alertness; this happens as a side effect, along with increased drying of mucous membranes. Though there is scientific evidence regarding the sedating effects of OTC drugs, there are also documented performance degradations and hangover effects. Thus, their use is not recommended.

Nicotine is a stimulant, which has effects on performance and mood similar to but less than that of caffeine; that is, it enhances alertness for a period following consumption. The duration of nicotine in the bloodstream is approximately two hours. This should not be interpreted as meaning that the alerting effect will last that long because the effects of nicotine are quite dose dependent, with large individual differences in reaction depending on frequency of use. The addictive and other adverse health effects of nicotine, especially from tobacco use, far outweigh the small alerting effects obtained. Additionally, nicotine reduces the quality of sleep when consumed within several hours of bedtime.

Altering the airflow and temperature in the work environment is fairly easy. However, while there may be a brief alerting effect from these changes, research data suggest the impact is very short, and not likely to increase alertness for longer than a few moments. However, it is important to ensure that the air quality in the immediate operational environment is good, since fatigue is one of the symptoms often associated with impurities in the air. The fatigue that results from impurities is often a physiological reaction to reduced oxygen or elevated carbon dioxide, and an indication that the environment should be changed. Also, a high ambient temperature (> 86 deg F; > 30 deg C) tends to impair alertness. So, if personnel are already sleepy, a warm environment may increase those feelings. However, a change to a colder environment will not increase the performance of sleepy personnel for more than a few minutes.

Regular, aerobic physical exercise has the principal benefit of improving overall cardiovascular health and muscle tone. Additionally, it promotes good sleep: falling asleep more quickly, and sleeping more soundly. Brief periods of exercise can reduce feelings of sleepiness, although cognitive performance does not improve. In rested individuals, a morning exercise break may improve alertness and performance for a brief period afterward.

While regular, aerobic exercise may promote health and improve sleep, it does not allow a reduction in the average need for eight hours of sleep per night. Also, while exercise may reduce immediate feelings of fatigue resulting from schedule changes and sleep deprivation, that effect lasts only about 30 minutes. The effects of exercise breaks on job performance are complex, and tend to wear off quickly, possibly even making performance worse in the afternoon. So, while personnel may feel better after exercising during a sleepy period on the job, their cognitive performance is unlikely to improve.

There would be substantial advantages to a dietary fatigue countermeasure, if it actually worked. Unfortunately, specific food content has little, if any, impact on alertness or feelings of sleepiness (Lucero & Hicks, 1990; Neumann & Jacobs, 1992). However, dietary supplementation and unusual variations in diet may have mild effects. For example, supplemental bed-time carbohydrate intake suggested that "relatively high blood glucose levels were required to alter sleep, and perhaps lead to more 'restful' sleep" (Porter & Horne, 1981).

Subsequently, it has been found that the effects of high carbohydrate meals on sleep, sleepiness, and alertness are complex and confusing. The effects may depend in part upon gender, age, and time of day of consumption (Spring, Maller, Wurtman, Digman, & Cozolino, 1982). Females reported greater sleepiness after a carbohydrate meal, while male subjects reported increased calmness. When meals were eaten for breakfast, individuals 40-years or older felt tenser and less calm after a protein than after a carbohydrate meal. But they were impaired on a test of sustained selective attention after consuming a high-carb lunch. This finding suggested negative effects on concentration when older subjects consumed a high-carb, low-protein lunch.

A high-carb lunch has been shown to increase the length of a siesta (Zammit, Kolevzon, Fauci, Shindledecker, & Ackerman, 1995). However, it has also been shown that drowsiness may be offset immediately after both high- and low-glycemic index (GI) carb intake, and that low-GI carb intake may delay the onset of drowsiness (Landstrom, Knutsson, Lennernas, & Soderberg, 2000). An evening high-carb meal with a high glycemic index (GI) shortened sleep latency compared to a low GI meal (Afaghi, O'Connor, & Chow, 2007). Thus, the idea that high-carb meals will help induce sleep may not be useful.

A comparison of low-fat, high-carb meals to high-fat, low-carb meals indicated the latter were associated with greater feelings of sleepiness and fatigue (Wells, Read, Uvnas-Moberg, & Alster, 1997). Of course, those prone to gastric reflux disorders should avoid large or high-fat meals before bedtime.

Getting a balanced, nutritious diet at appropriate times is often difficult for personnel involved in 24/7 operations. They are often forced to eat what is available whenever they have time. When possible, meals should be taken at times that correspond to normal meal times; this will help maintain a regular sleep-wake cycle, since meals are a time cue that mildly influences the circadian rhythm. Even partial fasting may trigger sleep disruption and fatigue: low blood glucose may elevate plasma glucagon and concomitant elevations of heart rate and blood pressure, and these are not conducive to restful sleep (Roky, Chapotot, Hakkou, Taoudi Benchekroun, & Buguet, 2001). Of course, hypoglycemia may also lead to poor cognitive performance.

Using sound from sources such as radio or personal audio devices briefly increases the physiological arousal level by adding stimulation to the environment. Music or radio/TV talk and news in the work area are simple ways to change a monotonous environment, and the change may briefly reduce fatigue effects or prevent inadvertent sleep (McCallum et al., 2003). If personnel are already sleepy, it may have little, if any effect. Although the brief alerting effect of sound may seem to reduce fatigue, cognitive performance will continue to deteriorate. This countermeasure may be a useful means to alert personnel for a few minutes until they can find an opportunity to take a break. Engaging in conversation is another means to increase stimulation.

There is no good-quality scientific evidence that the use of aromatherapy with scents such as peppermint or lavender will enhance alertness, increase performance, or promote sleep. Subjects in aromatherapy studies tend to rate themselves as more alert after being exposed to an aroma but their cognitive performance does not change.

"Even partial fasting may trigger sleep disruption and fatigue: low blood glucose may elevate plasma glucagon and concomitant elevations of heart rate and blood pressure, and these are not conducive to restful sleep (Roky, Chapotot, Hakkou, Taoudi Benchekroun, & Buguet, 2001)."

Section 7. Future Research Needs

This section of the report describes fatigue countermeasures that show promise for reducing fatigue, but are some distance from practical application and are not available for implementation without the assistance of fatigue research professionals. This is because of the procedures relative complexity, difficulties of practical everyday implementation, and in some cases, insufficient demonstration that they would be effective in a real-life environment.

Fitness-for-duty testing determines whether an individual is fit to perform their job at the moment of testing (Gilliland & Schlegel, 1993; L. Hartley, Horberry, Mabbott, & Kreuger, 2000). This means: (1) testing when the individual shows up for work, and/or (2) periodically testing an individual during a work period to determine if he/she is still performing with a satisfactory level of alertness; and/or (3) testing prior to being permitted to work an additional work shift or overtime.

Fitness-for-duty testing attempts to predict "readiness to perform" within acceptable levels of cognitive alertness, and to predict if good performance can be sustained over the duration of the ensuing work shift. It is an idea similar to conducting daily drug or alcohol tests, but without the stigma or policy implications of drug testing. The latter distinction is absolutely necessary: if an individual is found to be overly fatigued at the beginning of a duty period and it is because he/she was up all night with a sick child, then no stigma should be attached to that determination.

Fitness-for-duty tests do not reliably predict whether a worker will perform adequately some number of hours in the future. Because of limited use, there is no universal agreement on an acceptable performance level. However, performance outside of two standard deviations from the individual's recent performance history was a well-accepted metric for failure.

Fitness-for-duty tests generally employ short tasks of 5- to 10-minute duration to measure and analyze an individual's psychomotor abilities that would be affected by fatigue. Often the individual must perform two tasks simultaneously. The tasks have included:

- Reaction time
- Eye-hand coordination tasks
- Tracking, including simulated driving
- Dividing attention between tasks
- Short term memory
- Involuntary eye reflexes such as pupil diameter
- Speed and amplitude of pupil response and saccadic velocity

Alertness maintenance monitoring involves the continuous tracking of the performance or physiological measures of system operators to determine if they are approaching drowsiness or impairment. Vehicle-based technologies compare current operator performance on such factors as driver steering-wheel variability, vehicle acceleration, speed variability, braking, gear changing, lane deviation, distances between vehicles, and route navigation against the operator's "normal" performance. Operator status monitors often seek to measure and record, in near real time, some physical or physiological features of the operator's eyes, face, head, heart, brain electrical activity, muscular activity, reaction time, etc (L. Hartley et al., 2000; J C Miller, 2005).

One utility of either type of monitor is self-management of the individual's level of alertness or fatigue. Relatively unobtrusive instrumentation can continuously provide the individual with personal, real-time feedback of actual performance or offer a personal physiologically-based alertness index. If the measures exceed criteria for degraded performance, the monitor warns the individual by an alerting mechanism (e.g., visual, auditory, and/or tactile/vibratory signals). Additionally, the monitors may report collective, multi-operator data to a supervisor who, in turn, may use real-time personnel-substitution and on-duty napping methods to assure alert operators at each station. A recent Department of Transportation pilot study of devices that may be useful for monitoring driver fatigue was conducted (D Dinges, Maislin, Brewster, Krueger, & Carroll, 2005).

Integrating combinations of several different monitoring technologies, employing both performance and physiological status indicators, offers the best chance of keeping an operator informed of his/her alertness status and impending fatigue effects on safe performance. When effectiveness in terms of reliability, sensitivity, and validity is attained through formal validation testing, it may prove worthwhile incorporating them into corporate operator fatigue management programs. Computerized micro-miniaturization of many of these devices will make them affordable. Developing operator trust in the systems will be an important element of these alertness monitoring technologies.

Security managers should not try to implement this budding technology without extensive help from fatigue researchers. Even then, they should note that fitness-for-duty testing and biometric monitoring methods have not been validated for security operations. Advances in the biometrics field may be described online in the NeuroTech Business Report.[20]

20 *http://www.neurotechreports.com/pages/alertness.html*

Section 8. Applications

This section provides a series of suggestions of how to apply the information presented in the preceding seven sections.

View the security operation as a human-machine system, within which security personnel contribute strengths in pattern recognition capabilities and decision-making skills to the system, but also contribute weaknesses due to cognitive fatigue. The latter impairs their abilities to monitor sensor displays, execute complex system control functions, and interact with automation.

Remember and plan for the likelihood that the risk of injuries and accidents:

- Increases across the day and night, with the risk being 30% higher on the night shift than during the morning shift, and
- Increases exponentially with time on shift such that in hour 12, it is more than double that during the average of the first 8 hours.

and that:

- Speed and accuracy on the job are only above average between 7:00 a.m. and 7:00 p.m., and
- Productivity goes down and safety risk goes up across successive night shifts: about 36% higher on the fourth night, compared to the first.

Do not be tricked into believing that you or your colleagues are extraordinarily resistant to fatigue. The results of an unsubstantiated belief in resistance are poor decisions, acceptance of more risk than usual, and being more easily distracted. Remember "no one gets used to not getting enough sleep...they never overcome the drive for sleep or the consequences that invariably follow sleep restriction."

Teach that sleep is not a passive or vegetative state. It is generated by complex, active brain physiology, and humans have specific physiological and psychological requirements for getting adequate sleep. Sleep loss of even one or two hours in a night may significantly degrade alertness and performance, with greater effects with increased amounts of sleep loss.

Teach that sleep may be impaired by substances including caffeine, alcohol, and over-the-counter drugs such as decongestants; by eating, exercise and willful wakefulness; and sleep disorders.

Recognize that sleep inertia may last up to 15- or 30-minutes after a person with a sleep debt awakens from a major sleep period or a nap.

Understand there is a circadian rhythm in human cognitive performance that oscillates between a high point late in the day to a low point in the pre-dawn hours. Circadian effects on cognition may be caused by night or shift work, leading to Shift Work Sleep Disorder. Use the fact that individuals differ from one another physiologically in their preferred activity and sleep times in terms of chronotype: some may be "larks" (morningness) and some may be "owls" (eveningness).

Teach that acute cognitive fatigue builds up normally and unavoidably within one waking period of about 16-hours, and recovery occurs as the result of one good-quality, nocturnal sleep period of about eight hours. Cumulative cognitive fatigue builds up across major waking periods when there is inadequate recovery (due to inadequate sleep) between the waking periods. Recovery from cumulative fatigue cannot be accomplished in one good-quality, nocturnal sleep period. The main contributor to cumulative fatigue is sleep debt.

Recognize that a hallmark of human fatigue is performance variability due to large amplitude, moment-to-moment fluctuations in attentiveness. There are brief periods when responses are extraordinarily delayed or absent ("lapses"). Fatigued system operators are more likely to have lapses than non-fatigued operators.

Use a principle-based approach to shift work scheduling that constrains the infinite number of possible schedules to those schedules that are simple, practical to implement, and least harmful to worker health, job performance, and attitude. Apply the guidelines in the body of the report for each of the nine scheduling principles. Build a good shift work schedule upon a good, quantitative shift work "plan" which, in turn, is built upon a good shift work "system."

When creating a schedule, consider all of the components described in the body of the report. Recall there are four main secrets to creating a good-quality shift work schedule:

- Enough people to do the job
- Use four crews
- Shift length of either 8- or 12-hours (not including overlap)
- Worker satisfaction in terms of predictability, equity and good-quality time off

Investigate the usefulness of the quantitative tools for predicting the effects of various work-rest schedules on cognitive performance. Implement the use of the five fatigue indicators that raise "red flags" with respect to the likelihood that human cognitive performance is likely to be impaired by fatigue:

- Less than eight hours of sleep in the preceding 24 hours
- A cumulative sleep debt of more than 10-hours
- More than 17-hours of continuous wakefulness
- Time of day between one and seven hours before the predicted time of awakening on the body clock, i.e., usually the pre-dawn hours
- The body clock out of phase; i.e., in the process of shifting more than three hours

Remember that the quantification of fatigue effects has also shown that even moderate levels of sustained wakefulness reduce performance to an extent greater than is currently acceptable for alcohol intoxication. Understand the risk of workplace accidents and automobile crashes rises for tired shift workers, especially on the drive to and from work.

The security operations and law enforcement research studies cited showed a number of things that may useful in planning security operations. First, there may be health implications for law enforcement personnel who are shift workers. Second, there are well-documented sleep disturbances in both security and law enforcement personnel involved in shift work. Third, time-on-task fatigue effects and circadian and sleep loss effects have been shown for the performance of x-ray screening tasks. Fourth, increased numbers of accidents experienced by law enforcement personnel working shifts have been observed. Thus, it appears that law enforcement and security operations personnel tend to suffer from the same health, sleep disturbance, and cognitive performance problems as other shift workers in industry and the military. Generally, law enforcement personnel prefer shift work schedules that provide the best quality of time off, as predicted by shift work scheduling principles.

The use of fatigue countermeasures in an organization must be initiated and sustained with a top-down management approach. Organizational commitment requires the allocation of resources sufficient for establishing and sustaining a fatigue management program. The success of this program requires periodic evaluation and refinement.

The first and foremost specific countermeasure to prevent fatigue is ensuring adequate sleep opportunities, proper sleep-period timing, and appropriate sleeping accommodations. Additionally, a nap can be very effective as a short-term countermeasure against fatigue effects, and to compensate during a period when personnel will need to remain awake for a long time. Consider implementing at-work napping strategies for night workers.

Alertness may be enhanced by consuming caffeine. However, due to tolerance, caffeine must be used only when needed and with reasonably good sleep beforehand.

“Thus, it appears that law enforcement and security operations personnel tend to suffer from the same health, sleep disturbance, and cognitive performance problems as other shift workers in industry and the military.”

Automation may be used best to deal with the weaknesses that the human in the loop may contribute to system operation; for example, vigilance decrements, boredom, habituation, and/or task-specific fatigue. However, automation usually forces the human operator into the role of a system monitor, a function handled poorly in most cases by the human brain and setting up conditions for lapses in attention.

Use occupational health physicians to advise you on the usefulness of prescription drugs for shift workers. Modafinil (ProVigil®) is an alertness aid which, can be used to increase alertness during a period of expected impairment. Modafinil is approved by the Federal Drug Administration for use by night workers and may be prescribed by a physician. Safe, non-habit-forming, prescription sleep aids may be used by shift workers to promote sleep when security operations preclude normal, nocturnal, recuperative sleep.

Two interesting methods for dealing with fatigue in the workplace are currently some distance from practical application and are available for implementation without the assistance of fatigue research professionals. First, fitness-for-duty testing determines whether an individual is fit to perform their job at the moment of testing. Second, alertness maintenance monitoring involves the continuous tracking of the performance or physiological measures of system operators to determine if they are approaching drowsiness or impairment.

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Appendix A. Epworth Sleepiness Scale

How likely are you to doze off or fall asleep in the following situations, in contrast to just feeling tired? Though you may have not done many of these things recently, please estimate their effect on you the best you can. Use this scale, and enter one number on each line:

0. Would never doze

1. Slight chance of dozing

2. Moderate chance of dozing

3. High chance of dozing

______ Sitting and reading

______ Watching TV

______ Sitting inactive in a public place; for example, a theater or meeting

______ As a passenger in a car for an hour without a break

______ Lying down to rest in the afternoon when circumstances permit

______ Sitting and talking to someone

______ Sitting quietly after lunch without alcohol

______ In a car while stopped for a few minutes in traffic

Notes:

- The Epworth Sleepiness Scale is a validated, clinical questionnaire that helps identify excessive daytime sleepiness (Johns, 1991).
- A sum of 10 or greater is cause for concern if safety-sensitive tasks are to be performed.
- The scale should be infrequently use; perhaps once per month or less.

About the Author

James C. Miller, Ph.D., CPE, provides consulting and investigations concerning human performance and fatigue. He has over 35 years of experience in the measurement and analysis of human physical and cognitive performance in military and civil aviation; highway, rail and maritime transportation; and night and shift work. He is also a former Air Force pilot (C-130E Hercules) and Vietnam veteran.

Additional CRISP Reports

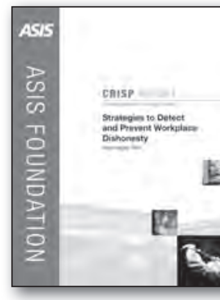
From the Ground Up: Security for Tall Buildings
Dennis Challinger

This report focuses on security challenges facing tall commercial and residential buildings. Challinger examines security threats, building vulnerabilities, and a variety of current responses. He also reports on research relating to the physical design of—and crime in—such buildings. His analyses lead to numerous research-justified recommendations.

Preventing Gun Violence in the Workplace
Dana Loomis, PhD

New legislation may complicate your company's "no-weapons" policies. And there are many more potential perpetrators than just the usual suspects, from disgruntled former employees to domestic disturbances gone toxic. This report examines gun violence in the workplace and offers recommended approaches to prevent problems and minimize potential threats.

Strategies to Detect and Prevent Workplace Dishonesty
Read Hayes, PhD



Employee theft may account for 40-50 percent of all business losses. How can employers promote a culture of honesty? This report provides practical strategies to reduce workplace theft and fraud. Hayes examines the factors that lead to these behaviors; analyzes select prevention techniques, policies, and technologies; and offers research-based solutions.

Lost Laptops=Lost Data: Measuring Costs, Managing Threats
Glen Kitteringham, CPP

Replacing stolen laptops is just the start: lost productivity, damaged credibility, frayed customer relations, and heavy legal consequences can cripple your organization. This report reveals seven steps to protect laptops—and data—at the office, on the road, or at home. You get practical checklists and classification schemes to help determine adequate levels of data protection. Plus physical, electronic, and security measures you can immediately implement.

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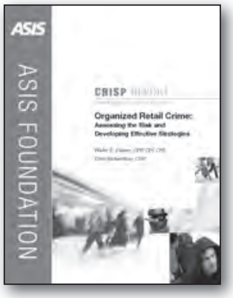
Additional CRISP Reports

Organized Retail Crime: Assessing the Risk and Developing Effective Strategies



Walter E. Palmer, CPP, CFI, CFE
Chris Richardson, CPP

This CRISP report invites retailers to take a critical look at their handling of Organized Retail Crime (ORC). Chris Richardson and Walter Palmer combine their extensive experience of advising retailers on how to manage security risks with a very helpful summary of previous research, to stimulate thinking on how best to respond to ORC. Their starting point is that retailers and any others involved need to be clear about the type of ORC problem they are facing and its drivers, as well as the types of measures that are already in place that can be marshalled as part of an overall approach to making a response effective. They unpick the merits and limits of different types of security and offer a number of frameworks to guide practitioners. In so doing it is likely that this paper will become one of the essential reference points for those who need to tackle the ORC threat.

Preventing Burglary in Commercial and Institutional Settings: A Place Management and Partnerships Approach

Tim Prenzler, PhD

In this report Tim Prenzler, PhD, looks at how to assess, manage, and respond to burglaries that occur at commercial and industrial sites. While there is a considerable amount written about domestic burglary, research is less in evidence when the locale is non-residential. His report looks at the context in which burglaries occur, and includes a consideration of the burglar's approach. He examines a range of solutions, which aim to make it more difficult for would be offenders particularly in the workplace, and he shows where security managers can have an impact. Drawing together a range of data, he looks at approaches from different levels, from the police, the government, and from those closer to the offence, the "place managers." Those charged with preventing burglary at commercial and institutional settings now have a source of information, which connects research to practice to guide them in their prevention strategies.

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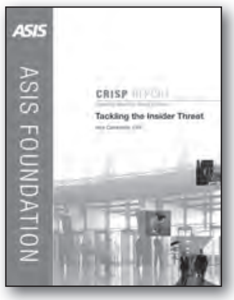
Additional CRISP Reports

Tackling the Insider Threat
Nick Catrantzos, CPP



This CRISP report focuses on managing the insider threat. In addition to evaluating traditional approaches, the author Nick Catrantzos, CPP, reports on new research which posits a different way of dealing with the potential threat posed by those who work in the organisation. His insights align with those who advocate the importance of a positive security culture, as he supports a greater role for engaging staff meaningfully in the protection of the organisation. His approach, termed 'no dark corners' draws upon a range of others that will be familiar to many readers, and his findings will invite many to critically assess whether they are doing all they can, in the best way, to manage different types of insider threat.

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