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DISASTER RELIEF: FATIGUE AND COUNTERMEASURES

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DISASTER RELIEF: FATIGUE AND COUNTERMEASURES

by

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Disaster Relief: Fatigue and Countermeasures

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The need for sleep is real, inescapable and expressed, even at the cellular level. The impact of fatigue on performance is greatly magnified when individuals have to operate under conditions of high emotional, psychological or physiological stress: all inherent conditions for disaster response teams. Fatigue can induce sleepiness and drowsiness, decrease the ability of workers to operate safely, and, thereby, increase the risk of fatalities and injuries. Fatigue in disaster relief workers is an understudied and critical safety issue in the complex process of disaster management and relief. This paper is designed for leaders in disaster agencies and management as a guide to understanding the problem of fatigue in the austere, uncontrolled chaos of a disaster event. In addition to disaster situations, research shows that operator fatigue affects all modes of commercial transportation. As with disaster workers, fatigue can induce sleepiness and drowsiness, decrease the ability of workers to operate safely, and increase the risk of fatalities and injuries. The National Transportation Safety Board (NTSB) has found that the incidence of fatigue is underestimated in virtually every transportation mode, because it is so difficult to quantify (2001). Many accident investigations do not obtain the information

necessary to determine the contribution of fatigue; namely, the condition of workers, the extent to which they have been deprived of sleep or their state of alertness.

The report will examine other occupational areas to demonstrate that the unstudied hazard of fatigue exists and, more importantly, that by comparing and reviewing these areas the reader will be prepared to address the challenge of severe decrements in cognitive and physical performance caused by fatigue. The goal is to educate disaster relief leaders about fatigue, human fatigue physiology, the risks and hazards of fatigue and countermeasures to fatigue. Armed with this new knowledge, leaders will be better able to address fatigue and to establish policies that improve disaster relief safety.

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CHAPTER 1: INTRODUCTION

Nothing is so fatiguing as the eternal hanging on of an uncompleted task.

William James (1842-1910)

American philosopher and psychologist

The United States is a nation that prides itself on a strong work ethic. Often, the cost of this hard work devalues the necessary quantity and quality standards of sleep. In March 1998 Jane Brody wrote an article in the Health section of *The New York Times* entitled "Facing Up to the Realities of Sleep Deprivation" (Brody, 1998). Citing a national survey conducted during National Sleep Awareness Week by the National Sleep Foundation (1997), Brody argues that the results clearly indicate that Americans remain woefully ignorant about sleep, its critical role in their lives and the hazards of not getting enough sleep. While the average adult needs eight to nine hours of sleep a night, most get only seven, and nearly one-third of the 1,027 adults surveyed in late 1997 and early 1998 got six hours or less during the work-week. Two-thirds of those surveyed reported having a sleep-related problem but only five percent had consulted a physician or sleep specialist about it. More than a third said they were so sleepy during the day that it interfered with their daily activities (National Sleep Foundation, 1997).

The impact of fatigue on performance is greatly magnified when individuals must operate under conditions of high emotional, psychological or physiological stress – all inherent conditions for disaster response teams. Understanding the risk of fatigue during disasters requires a baseline understanding of the science of sleep and a clear grasp of the facts surrounding the numerous myths that abound. This first chapter will outline sleep;

explaining sleep stages, circadian rhythm, biological clocks, factors that affect sleep other relevant areas, and the neurochemistry governing sleep. A basic knowledge of sleep will help in understanding the complexities of sleep management presented in later chapters.

BACKGROUND ON SLEEP

The last 75 years has seen a remarkable growth in the scientific understanding of sleep. Sleep is a universal mammalian behavior. Beginning in the late nineteenth century, scientist began to study sleep. Since then, Akerstedt, 1988; -- working unusual hours or a schedule which shifts work and therefore sleep back and forth from night to day -- has become increasingly common. In the 1980s and 1990s, 15-20% of the working population was estimated to be employed in some form of non-standard work schedule (Knauth, 1993; Costa, 2003). During the past thirty years, the cognitive psychomotor performance impairment associated with sustained wakefulness/sleep deprivation has been extensively documented (Torsvall,& Akerstedt, 1978; Akerstedt, Torsvall, & Gillberg, 1987; Akerstedt, 1988; Akerstedt, 1992; Dinges & Broughton, 1989; Belenky et al., 2003).

Canadian researcher and scholar Stanley Coren, in his excellent text on sleep, *Sleep Thieves*, poses the key question, "What is sleep?" and "Why should we spend one-third of our lives at this unproductive activity?" He explains that sleep is a process so important to the physical and psychological well-being of living things that evolution has gone to great lengths to ensure it: some birds can sleep in flight, fish can sleep while swimming and some animals sleep with one half of their brain while using the other half to stay alive (Coren, 1996).

The first chapter of his book explores the idea that Thomas Edison, the creator of over 1,300 inventions, including the light bulb, profoundly changed the world in his attempts to eradicate the need for sleep, which he considered a waste of human potential (Coren, 1996). Edison was convinced that sleep was deleterious to health and made people lazy and unproductive. He felt that sleep wasted valuable work hours; its elimination would therefore improve productivity, bring prosperity to all society, and hasten the progress of civilization. Coren uses examples such as Edison's light bulb to illustrate society's negative attitudes toward the need for sleep (1996).

PHYSIOLOGIC REQUIREMENT

So what is sleep and what is important about it? Sleep is an actively induced, highly organized brain state marked by four qualities: reduced motor activity, lowered response to sensory stimulation, adaptation of stereotypic postures (such as lying down with the eyes closed) and easy reversibility (as compared to coma or hibernation) (Rechteschaffen and Siefel, 2000). Sleep can be a very complex process involving the human circadian system, cognitive performance, sleep propensity and sleep structure; the relationship of sleep-wake cycle and cycles in alertness and cognitive performance to the endogenous circadian pacemaker; the effect of homeostatic regulation on sleep propensity, sleep structure, and subjective alertness; the interaction between circadian and homeostatic mechanisms and their phase relationships on consolidation of sleep and wakefulness; neuroanatomic and physiologic aspects of the interaction of circadian rhythm and homeostasis (Rechteschaffen and Siefel, 2000); and the effects of age (Dijk, Duffy, & Czeisler, 2001; Bliwise, King, Harris, & Haskell, 1992). The goal of this section is to give a brief overview of the current understanding of sleep.

Sleep is the regular state of natural rest observed in all mammals, birds and fish characterized by a reduction in voluntary body movement and decreased awareness of the surroundings. Therefore, since consciousness is literally the awareness of surroundings, being asleep is just an altered state of consciousness, as opposed to being unconscious. Sleep is heavily influenced by circadian rhythms as well as hormonal and environmental factors (Rechteschaffen and Siefel, 2000). Sleep appears to perform a restorative function for the brain and body, as evidenced by the myriad symptoms of metabolic dysfunction that result when animals are deprived of sleep (Laposky et al., 2006).

CIRCADIAN RHYTHM

A circadian rhythm is a *roughly-24-hour cycle* in the physiological processes of plants, animals, fungi and cyanobacteria. The term "circadian" comes from the Latin *circa*, "around", and *dies*, "day," meaning literally "around a day." It was initially discovered in the movement of plant leaves in the 1700's (Halberg et al., 2003). Circadian rhythms partly depend on external cues, such as sunlight and temperature. Early researchers observed that some sort of "internal" rhythm must exist because plants and animals did not react immediately to artificially induced changes in daily rhythms. Overall, circadian rhythms are defined by three criteria: the rhythm persists in constant conditions (e.g., constant light) within a period of about 24 hours; the rhythm period can be reset by exposure to a light or dark pulse; and finally, the rhythm is temperature compensated, meaning that it proceeds at the same rate within a range of temperatures (Halberg et al., 2003).

Asking the question "why do we awaken?" instead of "why do we sleep?" yields a different perspective toward understanding how sleep and its stages contribute to a healthy organism. The influenza epidemic of 1918 forced scientists to entertain the idea that sleep and waking might be controlled by a brain structure called the brainstem. A series of clinical observations were noted in victims following infection by the influenza virus. Damage to the front of the midbrain resulted in insomnia and over-activity while damage to the back of the midbrain resulted in excessive sleepiness. This insight, as well as the companion hypothesis that the brain stem supports sleep, was first articulated by the Viennese neurologist Constantin Von Economo (Hobson, 1989) who served in the Austrian Army Air Force from 1915-1916. As a neurologist he coined the term "encephalitis lethargica" for those patients suffering from excessive sleepiness. He postulated that the brainstem contained one system to regulate waking and another to regulate sleep. Von Economo further speculated that the two centers worked via chemical substances (Hobson, 1989). From these ideas, the modern field of sleep research blossomed. It is interesting to note that the modern ventilator evolved from the struggles and fatigue faced by medical staff trying to ventilate thousands of critical pulmonary patients during the flu epidemic (Hobson, 1989). The fatigue and logistical challenge of ventilating mass numbers of patients is still addressed and planned for by agencies like the CDC, hospitals and the military (CDC, 2005a).

The circadian "clock" is located in the suprachiasmatic nucleus (SCN), a distinct group of cells located in the hypothalamus (Kryger, Roth, & Carskadon, 1994). The hypothalamus is noted below in Figure 1. Destruction of the SCN results in the complete absence of a regular sleep/wake rhythm (Coren, 1996). Contributing to this clock are photoreceptors found in the retina known as melanopsin ganglia. These cells, which contain a newly discovered photo pigment called melanopsin, follow a pathway called the retinohypothalamic tract leading to the SCN. It is interesting to note that, if cells from the SCN are removed and cultured, they maintain their own rhythm in the absence of external cues (Hobson, 1989). Circadian rhythms are important in determining the sleeping and feeding patterns of all animals, including humans. There are clear patterns of brain wave activity, hormone production, cell regeneration and other biological activities linked to this daily cycle, which will be discussed later. Furthermore, the current technological age has added additional factors

SUPRACHIASMATIC NUCLEUS

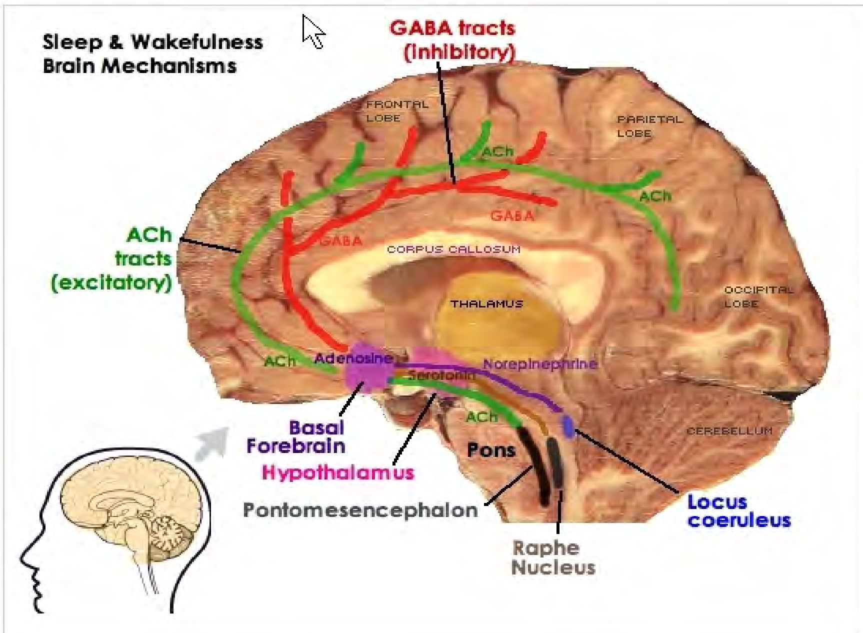


Figure 1. Cross Section of the Human Brain with Sleep and Wakefulness Mechanisms, open source.

that affect sleep. Coren found that the average rate young adults sleep now is 7.5 hours compared to 9 hours in 1910. He points out that the timing of the 1910 study is key to interpreting this difference because modern tungsten-filament light bulbs were introduced in 1913 (Coren, 1996). Earlier versions of carbon filament light bulbs provided dim light, were expensive and short lived. Coren points out that Thomas Edison's goal was to banish darkness in order to remove the major "excuse" for sleep; hence, we can thank Edison for the average reduction of one and a half hours in sleep per day that results in 500 hours of additional waking time per year we live (1996).

Dr. David Dinges, an internationally recognized authority on sleep, argues that the suprachiasmatic nucleus (SCN) of the hypothalamus plays an important role in the regulation of circadian rhythms (Dinges, 2006). Human circadian rhythms or clocks run whether you sleep or not. It is genetically enforced and the human brain will respond to the imperative of daily sleep and its timing. The SCN is located in the hypothalamus (Figure 1) and is influenced by external light and also generates its own rhythm in isolation. In the presence of light it sends messages to the pineal gland that instruct it to cease secreting melatonin.

BIOLOGICAL SLEEP CLOCK

During the 1950's, the system of wake and sleep proposed by Von Economo and others was disproved. Sleep was shown to be induced by electrical stimulation of the thalamus by a Swiss physiologist, Walter R. Hess (Hobson, 1989). Since the 1930's, whole texts dedicated to the subjects of neuroanatomy and neurophysiology have attempted to understand the correlation between sleep and the brainstem. The last 50 years of research related to fatigue uncovered relationships between localization of sleep control mechanisms in the basal forebrain and brainstem, the investigation of the electrical activity of neurons in the brainstem during sleep and the investigation of chemical influences on the rest of the brain that turn on or off during sleep (Hobson, 1989). The key issue surrounding fatigue is that mammals require sleep and will function progressively worse without sleep (Hobson, 1989). This topic of restricted sleep outcomes is becoming more and more mainstream. It routinely makes it into the media and for good reason. A widely publicized study performed at the University of Pennsylvania School of Medicine demonstrated that cognitive performance declines with fewer than eight hours of sleep (van Dongen and Dinges, 2003).

Interestingly, the brain has been determined to have its own source of self-activating power (Hobson, 1989). It appears that the SCN interprets day length from the retina and passes it on to the pineal gland, a pea-like structure found on the epithalamus, which in higher animal cells secretes the hormone melatonin in response. Melatonin, or 5-methoxy-N-acetyltryptamine, is a hormone found in all living creatures from algae to humans, at levels that vary in a diurnal cycle, peaking during the night and ebbing during the day (Figure 2). Thus, it has been proposed that melatonin plays a role in affecting sleep and circadian rhythms. The SCN and associated melatonin-induced process does not appear to be able to react rapidly to changes in the light/dark cues (Dinges, 2006).

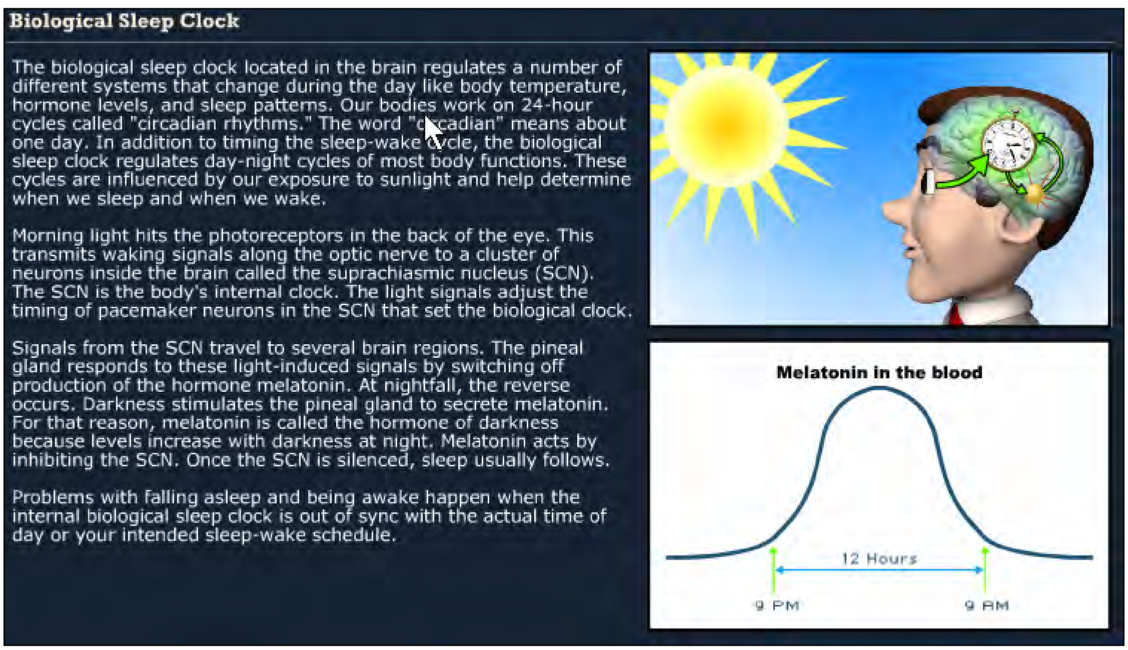


Figure 2. Biological Sleep Clock. With permission from the National Sleep Foundation 2007.

Recently, evidence has emerged that circadian rhythms are found in many cells in the body—outside the SCN "master clock." Research on the 4-hour ultradian cycle found that cells from many parts of the body appear to have "free-running" rhythms" (Edmunds & Adams, 1981).

Suffice it to say that biological circadian rhythms are very important in living organisms and have been conserved and created by evolution. The circadian clock system occurs at the cellular level and even the molecular level as transcriptional activators and auto-regulatory feedback loops respectively. These positive and negative effects on gene expression are thought to be at the source of circadian rhythms (Reppert and Weaver, 2001). The inter-workings of these internal clocks are not yet completely understood by science, necessitating more research. However, it is clear that the need for sleep is real, inescapable and expressed–even at the cellular level.

The next important area to understand in sleep physiology is sleep regulation. The cycle of sleep and wakefulness is regulated by the brain stem, the thalamus, external stimuli and various hormones produced by the hypothalamus. Some hormones and neurotransmitters are highly correlated with sleep and wake states (Hobson, 1989). For example, melatonin levels are highest during the night, and this hormone appears to promote sleep. The nucleoside adenosine seems to be involved in generating energy for biochemical processes: during wakefulness it gradually accumulates in the human brain but decreases during sleep (Hobson, 1989). Some researchers believe that this accumulation during the day encourages sleep (Blanco-Centurion et al., 2006). The stimulant properties of caffeine are attributed to its negating the effects of adenosine (Wyatt, Cajochen, Ritz-DeCecco, Czeisler & Dijk, 2004).

ELECTROENCEPHALOGRAPH

Since sleep stages and brain cycles (and their recordings) are part of the universal language of sleep science, a brief review and understanding for disaster relief personnel is useful. All mammals and birds fulfill the criteria for sleep based on brain wave cycles that can be recorded using an electroencephalograph, or EEG (Hobson, 1989). Billions of cells, called neurons, make up the brain. These cells communicate via electrical and chemical signals. Each neuron in the brain contains an electrical charge across its surrounding membrane, so it is a power source. The first recording of this occurred in 1928 by a German psychiatrist Hans Berger (Hobson, 1989). He correctly inferred that the brain generated the signals he recorded, which he called electroencephalograms or EEGs (Figure 3). These are what most people would recognize as a "sleep recording." The brain is very sensitive to major changes in input. Simply closing our eyes changes the brain to higher voltage but slower EEG rhythms.

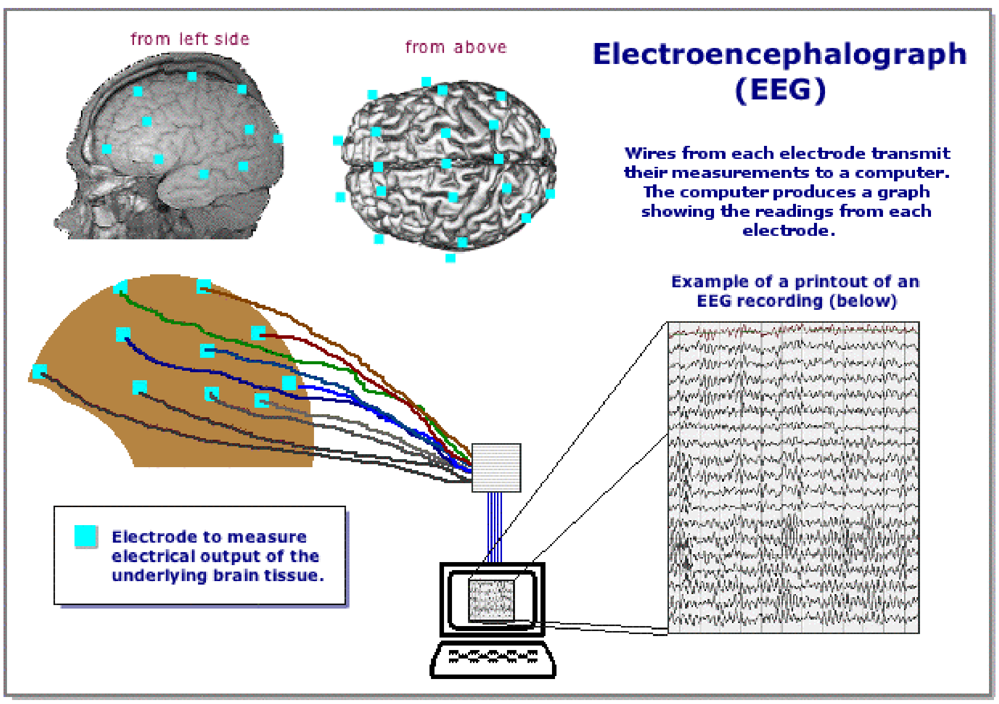
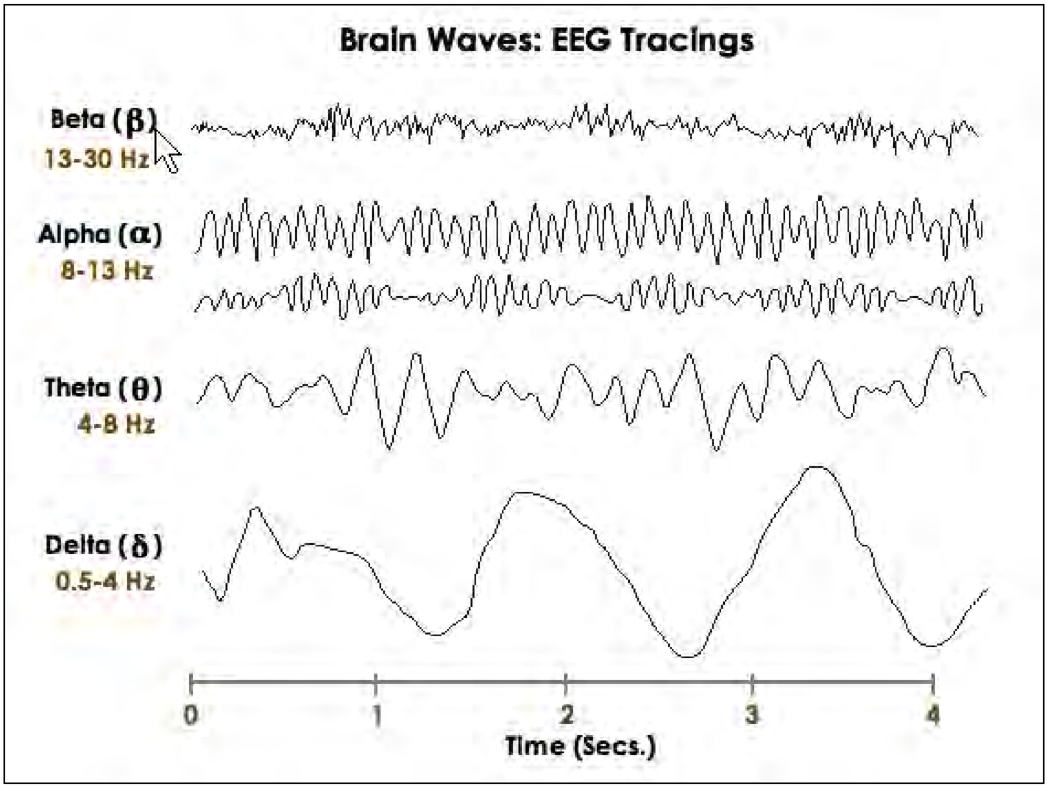


Figure 3. Electroencephalograph (EEG). Open source.

Many researchers worked in this area in the 1920's and 1930's (Hobson, 1989). In 1933, Edgar Adrian and Brian Mathews performed work that confirmed Berger's findings. The characteristic patterns seen from light sleep to deep sleep have become known as the four stages of sleep (Hobson, 1989). An EEG will slow in frequency and grow in amplitude as a person moves into sleep and it deepens. When humans pass from alert to relaxed awakening, to drowsiness, to light sleep and finally to deep sleep, their brain waves change in a specific pattern. The EEG has allowed us to better understand the activity of the brain in both the awake and sleep states. While we are awake, we might be in one of two different states according to the EEG: a relaxed mental state (alpha waves) or an alert mental state (beta waves). During sleep, we enter several different states including theta and delta waves (Figure 4). These EEG waves are much slower than those in awake states (Rechteschaffen and Siegel, 2000).

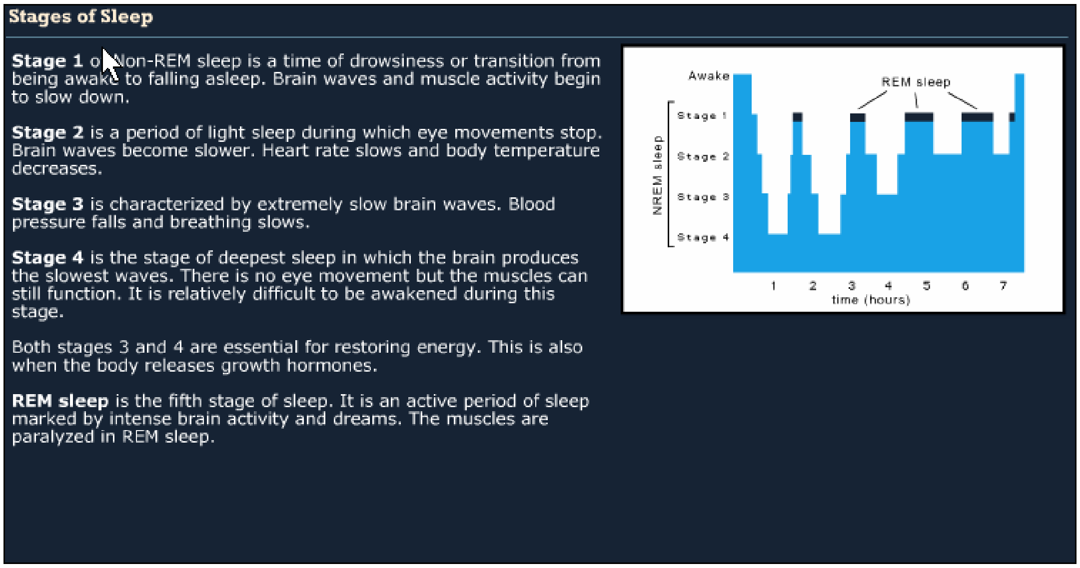
STAGES OF SLEEP

Studies of human sleep have established five well-defined stages, according to electroencephalographic (EEG) recordings and polysomnography (Figure 5). Each stage may have a distinct physiological function. The body rests during sleep; however, the brain remains active, recharges and still controls many bodily functions, including breathing. When we sleep, we typically move between two sleep states, REM (rapid eye movement) and non-REM, in 90-minute cycles. Non-REM sleep has four stages with distinct features, ranging from stage one drowsiness, when one can be easily awakened, to "deep sleep" stages three and four, when awakenings are more difficult and where the most positive and restorative effects of sleep occur. However, even in the deepest non-REM sleep, our minds can still process information. REM sleep is an active sleep where dreams occur, breathing and heart rate increase and become irregular, muscles relax and eyes move back and forth under the eyelids. (National Sleep Foundation, 2006).



The sleep process goes from Stage I through IV and then to stage II to III and then to Stage I in a gradual and continuous process in a rested person, repeating every 90-100 minutes throughout the night (Figure 6). The four stages of non-REM sleep occupy the first 50 to 70 minutes of sleep. The EEG pattern is then reactivated to the faster frequency and low-voltage pattern of Stage I REM where dreams occur in sleep. Understanding sleep by studying EEG patterns became more widespread by the early 1950's during which new findings once again changed the view of sleep. Until then,

Figure 5. Sleep Stages. With permission from the National Sleep Foundation, 2007.



EEG patterns during sleep were considered to be less active than when compared to those of awake persons. In 1953, Dr Eugene Aserinsky found clear evidence to the contrary while working with eye movements and arousal in children (Meyers, 2004). He went on to pursue a career in REM studies and is considered one of the fathers of modern sleep research. During REM sleep, EEG patterns are as active as an awake person, and respiratory and heart rates also increase.

Non-REM sleep accounts for 75-80 percent of total sleep time (Hobson, 1989). Stage 1 has a near-disappearance of the alpha waves seen in awake states and theta waves appear for the first time. This stage is sometimes referred to as somnolence, or drowsy sleep. It begins at sleep onset (as it is mostly a transition state into Stage 2). In this period, humans lose some muscle tone, and conscious awareness of the external environment; Stage 1 can be thought of as a gateway state between wake and sleep. Stage 2 of sleep has "sleep spindles" (12–16 Hz) and "K-complexes." The EMG lowers, and conscious awareness of the external environment all but disappears. This stage occupies 45-55% of total sleep. Stage 3, with delta waves, also called *delta rhythms* (1–2 Hz), functions primarily as a transition into stage 4. Overall, Stage 3 occupies three to eight percent of total sleep time. Stage 4 is true delta sleep. It predominates in the first third of the night and accounts for 10-15% of total sleep time. This is often described as the deepest stage

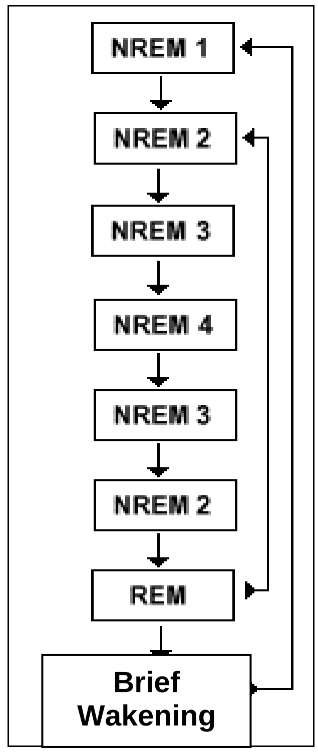


Figure 6. REM Cycle.

of sleep; it is exceedingly difficult to wake a subject in this state. This is the stage in which night-terrors and sleepwalking occur. Stage 5, or rapid eye movement (REM) sleep, is associated with dreaming, especially bizarre, visual, and seemingly random dreams. REM sleep is predominant in the final third of a sleep period, its timing linked to circadian rhythm and body temperature. The EEG in this period is aroused and looks similar to Stage 1, and sometimes includes beta waves. Drugs such as alcohol and some sleeping pills can suppress certain stages of sleep, resulting in sleep that exhibits loss of consciousness but does not fulfill its physiological functions (Hobson, 1989).

Several current theories exist on what restorative processes occur with sleep. Sleep is a dynamic time of healing and growth for organisms. For example, during Stages 3 and 4, or slow-wave sleep, growth hormone levels increase, and changes in immune function occur (Hobson, 1989). One process known to be highly dependent on sleep is memory. REM sleep appears to help with the consolidation of spatial and procedural memory, while slow-wave sleep helps with the consolidation of declarative memories. When experimental subjects are given academic material to learn, especially if it involves organized, systematic thought, their retention is markedly increased after a night's sleep. Mere rote memorization is retained similarly well with or without an intervening period of sleep (Hobson, 1989).

Non-REM sleep is an anabolic state marked by physiological processes of growth and rejuvenation of the organism's immune, nervous, muscular and skeletal systems. Sleep also restores neurons and increases production of brain proteins and certain hormones. Wakefulness may perhaps be viewed as a cyclical, temporary and hyperactive catabolic state during which the organism acquires nourishment and procreates (Hobson, 1989).

Some scientists feel that sleep serves as an adaptive function. It protects the individual during that portion of the 24-hour day in which being awake, and hence roaming around, would place the individual at greatest risk. Organisms do not require 24 hours to feed themselves and meet other necessities. From this perspective of adaptation, organisms are safer by staying out of harm's way where potentially they could be prey to other stronger organisms. They sleep at times that maximize their safety, given their physical capacities and their habitats (Hobson, 1989).

Another interesting view is that the function of sleep is for memory processing. This theory argues that saving memory directly into the long-term memory is a slow and an error-prone process. Thus, some have proposed that the memory formed during waking time is not saved directly into long-term memory; instead it is saved into a temporary memory store first. The function of sleep is to process, encode and transfer the data from the temporary memory store to the long-term memory store (Zhang, 2004).

Regardless of the theory, these processes, each influenced by hormonal, neurological, and environmental factors, underlie sleep regulation. The homeostatic process determined by prior sleep and wakefulness, determining "sleep need." The circadian process determining periods of high and low sleep propensity, and high and low rapid eye movement (REM) sleep propensity. The 1960's were the dawn of work in neuromodulators and understanding that the neurotrasmitters serotonin and norepinephrine tended to inhibit the cells they contacted. Another neurotransmitter, called acetylcholine was also suspected to play a role in sleep (Hobson, 1989). From here work was done to isolate REM-on and REM-off cells by Hobson and McCarley (Hobson, 1989). They proposed a push-pull transmitter model for sleep. A mathematical description has been used to help explain the mechanism and nature of dreaming as well as provide a unified structure for comprehending the genesis of sleep and sleep disorders (Hobson, 1989). Disruption to circadian rhythms usually has an immediate negative effect in the short term. Many travelers have experienced the condition known as *jet lag* with its associated symptoms of fatigue disorientation and insomnia. A number of other sleep disorders are associated with irregular or pathological functioning of the circadian rhythms. More will be discussed on this later.

SLEEP NADIR

Based on biological rhythms, it is normal to feel sleepy between 1 P.M. and 4 P.M. and between 2 AM and 6 AM. That afternoon lull, during which many Americans reach for caffeine, is siesta time in many countries. An hour-long afternoon nap would be a far healthier choice. That sleep time would also go a long way toward conquering the national sleep debt. Even 15 or 20 minutes of sleep at midday can contribute to restored alertness and efficiency. Napping is a key tool to address sleep debt and will be discussed further in other chapters including the countermeasures chapter. In one study on napping, multiple naps occurred throughout 24 hours, and many subjects exhibited polyphasic sleep similar to that observed in nonhuman species. Such spontaneous naps do not recur randomly throughout the day. Rather, their striking regularity encourages speculation on the existence of an ultradian 4-hour component of the sleep-wake cycle that may be superimposed on the more robust circadian and mid-afternoon components. In fact, 4-hour cycles in sleep propensity have been found in many studies conducted in unstructured environments and come as no surprise to investigators familiar with the 4-hour sleep-wake pattern observed in infants (Hobson, 1989). Extensive study has been done in the area of sleep nadir and its applications. It exceeds scope of this overview work.

SLEEP REQUIREMENTS

The general public has many prevailing beliefs and myths that persist concerning sleep, and it is important to address these. One common misperception is that everyone needs eight hours of sleep. The amount of sleep needed is individually and biologically different for each person. Some people can do with six hours of sleep, others need nine. However, as a general rule, eight hours is recommended. Probably the only effective way to determine what an individual sleep requirement is to place them in an isolated location with no little to no external stimuli such as sunlight and interruptions and let them sleep repeatedly until they awake. Anecdotal accounts of this happen at remote sites in the Artic and South Pole where darkness lasts for months and research has been performed on this issue. Humans appear to operate in a cycle that is slightly longer than a 24-hour day. Humans have a rise in core temperature in the evenings which is linked to our sleep cycle. Figure 7 demonstrates the relationship between body temperature and sleep. This temperature nadir has been investigated extensively and generally taught at almost all core sleep physiology courses including those at aerospace medicine residencies, the FAA and NASA (Jennings, 2006b; Jones, 2007).

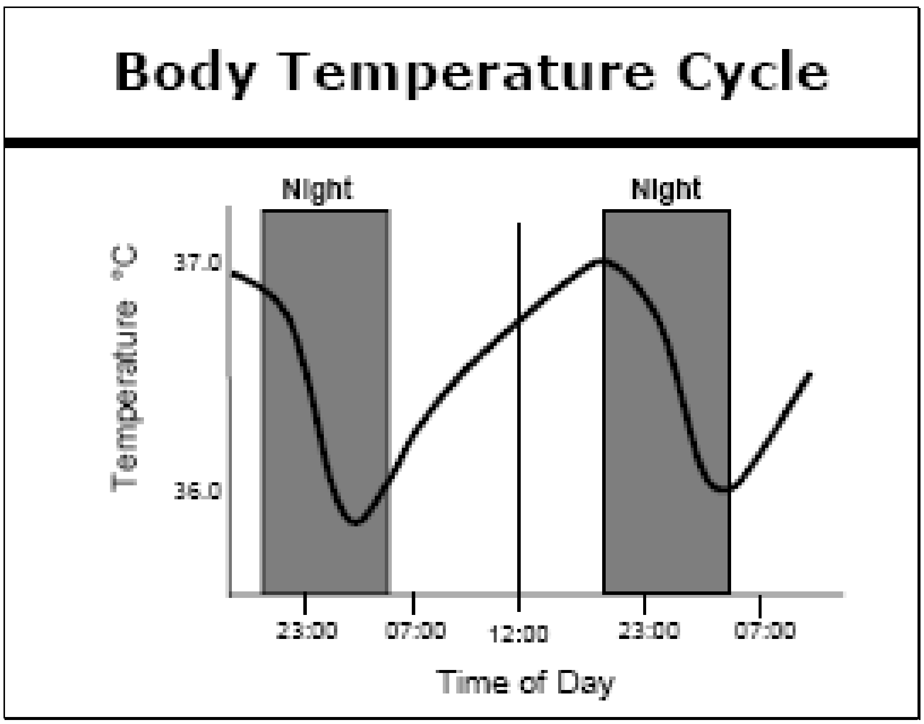


Figure 7. Body Temperature Cycle.

The idea that you can catch up on sleep is another common myth. As late as the early 21st century people thought that “paying back the sleep debt” could negate too little sleep. However, recent studies have shown this to be false (Coren, 1996). Sleep experts state that you cannot "store" sleep by sleeping more on the weekends in preparation for the normal workweek. The amount of sleep deprivation which could lead to death in humans is unknown. The longest recorded period of wakefulness occurred in 1964 for the San Diego Science Fair. Seventeen-year-old student, Randy Gardner, stayed awake for 264 hours (11 days) and set a Guinness Book record (Coren, 1996). His feat drew the attention of the media and researchers. Another commonly held view is that the amount of sleep one requires decreases as one ages, but this is not necessarily the case. The ability to sleep, rather than the need for sleep, appears to decrease when people get older. Before widespread use of the light bulb in the early 1900's, and before distractions like television and the Internet, the average adult slept about nine hours a night. Recent studies have shown that when all cues to time are removed and people are permitted to sleep as much as they choose, they sleep 10.3 hours out of every 24, just as monkeys and apes do (Coren, 1996).

It appears that sleep rhythm is linked to the light-dark cycle. Animals kept in total darkness for extended periods eventually function with a "free-running" rhythm. Free-running rhythms of diurnal animals are close to 25 hours. Free running organisms still have a consolidated sleep-wake cycle when in environments shielded from external cues, but the rhythm is not entrained and may become out of phase with other circadian or ultradian rhythms such as temperature and digestion. This knowledge has influenced the design of spacecraft environments, as systems that mimic the light/dark cycle have been found to be highly beneficial to astronauts (Jennings, 2006b).

FATIGUE IMPACTS

In sleep-deprived states humans display irritability, impaired cognitive function and poor judgment. Experiments on sleep-deprived medical trainees, for example, have shown them less able to interpret EKGs and x-rays than their well-rested peers. Experimental studies have shown that sustained wakefulness (SW) impairs several components of performance, including hand-eye coordination, decision making, memory and visual search performance (Babkoff, Mikulincer, Caspy, Kempinski & Sing, 1988; Linde & Bergstrom, 1992,), slowed cognition (Angus, Heslegrave & Myles, 1985), diminished memory (Babkoff et al., 1988) and impaired speed and accuracy of response (Linde & Bergstrom, 1992). In addition to the cognitive factors, affective components of behavior such as motivation and mood are altered as the duration of SW increases (Babkoff et al., 1988). Thus, research has consistently produced a clear general consensus that cognitive psychomotor performance is impaired by sleep disruption and extended wakefulness associated with shift work (Monk, 1994; Akerstedt, 2003). Although this impaired performance is associated with increased risk of accidents, there is a clear disconnect between the evidence for fatigue related performance decrements, and the perception, understanding and awareness of the implications of sleep deprivation by the general public and policy makers.

Fatigue comes in many forms and from many sources, not just lack of sleep. Individuals who perform continuous strenuous physical activity develop lactic acid accumulation in the muscles as a result of oxygen debt. Endurance sporting activities (e.g., running marathons) demonstrate that well-trained, physically fit, highly motivated people can endure 10-15 hours of sustained aerobic physical effort (Coren, 1996). However, most disaster crews arriving to aid in disaster relief are not ultra marathoners and will typically be very physically and emotionally challenged by schedules that easily exceed 15-hour workdays, especially for EMS, police and rescue staff. February 2006 discussions with numerous pilots and service members from the Army and the U.S. Coast Guard at The

Operational Aeromedical Problems Course in Galveston, Texas found anecdotal reports that the helicopter crews and rescue swimmers were extremely fatigued by day two of Katrina Rescue Operations. Discussions continued stating that the initial response period the crews continued to fly daily missions with crews averaging 16-18 hour days and trying to sleep on what was "the world's busiest helicopter airfield" (Jennings 2006a).
In a series of MSNBC News articles entitled "How We Work: Punching the Clock in the New Economy," the point was made that the unprecedented blurring of the lines between work time and leisure time is threatening productivity and health while leaving personnel increasingly tired almost every day of the week (Caldwell & Caldwell, 2007). Duty-related fatigue can affect home life and leisure time as well. On-the-job fatigue reduces mission readiness at work, but then carries over to off-duty hours. Many fatigue-related car accidents occur when the drowsy, over-taxed, worn-out service member simply tries to get home after a long duty cycle (Caldwell & Caldwell, 2007).
The topic of fatigue and sleep's contribution can become very complex, demonstrated by the vast number of publications on the issue. Searches using the National Library of Medicine as well as PUBMED reveal nine current U.S. medical journals and one fatigue journal dedicated to the field of sleep and fatigue. Immense volumes of data are available on this topic; there are literally hundreds of textbooks on the topic. There are even several hundred sleep centers located at medical centers around the country.
Frustratingly, even with all of this science and data, the knowledge is not getting out to the public at-large. The problem of sleep deprivation and fatigue is real. An April, 2006, *Institute of Medicine* (IOM) Report, requested by the National Institute of Health (NIH), states that sleep deprivation is an unmet public health need (Colten and Altevogt, 2006) and far more advancement is needed in this area. The IOM report identified concerns and

goals to address this public health issue to include more coordinated sleep centers with combined academic research and medical sleep centers to further the advancement of medical and safety concerns regarding the impact of sleep deprivation and fatigue (Colten and Altevogt, 2006). The need to address the occupational, health, and safety impact of fatigue seems obvious. The public's attention and awareness of the deleterious effects of fatigue is in stark contrast to their concern about other safety policy regulations.

SIGNIFICANCE

To emphasize the importance of understanding sleep deprivation and fatigue for disaster response teams, it is instructive to place these factors within a measurable context. An excellent frame of reference utilizes the approach of comparing the impact of alcohol intoxication to fatigue effects, an area that has been extensively studied. Starting in the 1970's, Klien and colleagues determined that sleep deprivation is qualitatively similar to the effects of moderate alcohol intoxication (Colten and Altevogt, 2006). Since then, the much cited "Fatigue, alcohol and performance impairment" (Dawson & Reid, 1997) experiment tracked 28 hours of cognitive psychomotor performance involving two experimental conditions, SW and an alcohol condition.

In the alcohol condition, subjects were served alcohol in a controlled environment and then tested. Then subjects were tested without ingesting alcohol but under a condition of sustained wakefulness lasting 28 hours. The results showed that between 18-27 hours of SW subjects' performance decreased to an equivalent blood alcohol level (BAL) of greater than 0.05% (Dawson & Reid, 1997). The report also showed that the longer the wakefulness, the greater the impairment. A 2003 *Journal of Sleep Research* study looking at the impact of sleep loss on cognitive effects found that after days of sleep restriction, while subjects thought that they had adapted to the sleep restriction, the results indicated quite differently (van Dongen & Dinges). The results showed that the sleep deprived subjects were completely unaware of the impact sleep deprivation was having on them, rating themselves as unaffected when in fact their performance of cognitive tasks were severely impacted. This misperception is actually very common across studies and while accepted as common knowledge among the sleep research community now, the lay public is still largely unaware of the extent of the propensity for inaccurate self-appraisal in this regard to this data (Carskadon and Roth, 1991; van Dongen and Dinges, 2003). Similarly, Jewett et al. found that total loss of sleep time becomes the predominant predictor in performance decreases (Jewett et al., 1999).

ALCOHOL COMPARISON

Applying the comparison of alcohol impairment to disaster response teams gives us a way to assess the potential negative adverse effects crews are likely to experience because we simply have no direct data on fatigue impacts on disaster response personnel. There have been no specific studies that assess disaster participant fatigue and performance during live disasters or even during training events. Furthermore, currently this issue is only minimally recognized as a significant threat to the health and well being of disaster relief personnel.

Given the likelihood that the first night of reporting to a disaster is characterized by individuals who have been traveling from all over the country after planning and packing while making hurried arrangements with work and family before deploying, disaster response members often arrive already in a state of early sleep deprivation. Arriving with a 16-18-hour day already behind them, they then start working. Anecdotal stories have been obtained from persons who have deployed to hurricanes, tornados and terrorist events. The first duty shift (8-12 hours) of responding essentially involves staffs that are already sleep deprived and will have been awake for up to 30 hours by the end of that shift. Applying the BAL equivalencies to this scenario, we can then expect performance impairments equivalent to a BAL > 0.05%.

When all clues to time are removed and people are permitted to sleep as much as they choose, they sleep 10.3 hours out of every 24, just as primates such as monkeys and apes (Coren, 1996). Of adults in the United States surveyed in 2002, 37% report that they are so sleepy that it interferes with their daily activities a few days per month or more. In addition, 16% experience this level of daytime sleepiness at least a few days a week or more (National Sleep Foundation, 2006). Due to the chaos of the first few days of an operation with personnel arriving, unclear situations on the ground, housing shortages, food and transportation challenges, it is also likely staff are not getting much *quality* sleep after their first shift. The problem of sleep deprivation is therefore endemic, persistent and substantive for teams and individuals.

SUMMARY

Given that sleep is required and biologically determined, it is clear that it is chronically grossly abused, with most people only getting 6-7 hours of sleep a night, whereas before widespread use of the light bulb in the early 1900's and before distractions like television and the Internet, the average adult slept nine hours a night. Sleep cannot be stored up nor can daytime sleepiness be eliminated during the work-week by sleeping more on the weekends.

In the beginning of this chapter the similarities between the impact of alcohol and fatigue were presented as a relevant analogy to quantify performance impacts from fatigue. The etiology, performance decrements, and reduced alertness of fatigue have all been reviewed. No businessperson or responsible leader would allow or tolerate staff arriving to work impaired by alcohol; that same reasoning should exist for workers displaying fatigue. Humans simply were not designed, from an evolutionary standpoint, to function without sleep. Disaster management and relief is a complex process. It is already complicated enough without the loss of sleep and fatigue that can occur during trying times. Leaders need to have an understanding of sleep physiology and the implications of the loss of sleep if they are to be able to establish and conduct a fatigue management program that is effective and has organizational support. The following chapters will provide examples of how other organizations have studied fatigue and implemented processes to mitigate its impacts. Disaster response teams, through reviewing work hours, shift work, night work, and jet lag and other areas fatigue related topics, can develop a rational, sustained approach to work-rest cycles for a more productive and safe process.

CHAPTER 2: FATIGUE AND THE MILITARY

Everyone has remarked that increasing fatigue means a general diminished quality and quantity of work. It is also widely recognized that a fatigued group, is as a rule, one in which discontent prevails, and there is apt to be lowered morale. In war there is perhaps no general condition, which is more liable to produce a large crop of nervous and mental disorders than a state of prolonged and great fatigue. For these reasons the study of fatigue, how it is caused, what are its results and how it may be counteracted: is a matter of very great concern for every officer.

F.C. Bartlett

From: Psychology and the Soldier, 1927

(Australian Defense Force Publishing)

In the July 2005 edition of *Aviation, Space and Environmental Medicine*, Major General (Dr.) Lester Martinez stated, “Warfighters experience mental and physical demands well beyond those seen in peacetime environments. During a typical combat deployment, they face stressors such as temperature and weather extremes, muscular fatigue, sleep deprivation, information overload, and emotional strain through exposure to horrific injuries and death, and anxiety for the welfare of families at home. Enabling our troops to succeed in the most demanding of combat environments is of foremost importance." (Martinez, 2005).

OVERVIEW

Whether expressed from a military psychologist’s position, such as the Australian physician Dr. Bartlett in the 1920's, or the current perspective of Dr. Martinez, the military medical community knows that fatigue has a significant impact on the execution of military operations. History has born out this lesson time and again. The various military services of the United States (U.S.) have similar approaches to teaching, training, tracking and mitigating fatigue. The Department of Defense (DoD) has vast experience in fatigue management. The losses due to human factors and fatigue are not new to training or combat. Likewise, the demands of extended operations and contingency operations, as well as disaster response, are not likely to change regardless of the amount of experience accrued over time. However, the mitigation of those demands can be better dealt with through sound, scientifically supported and tested fatigue management procedures. In this respect, the DoD does fund many experts to study fatigue, help develop policy and help leverage all the options available in fatigue countermeasures. Leaders in disaster management can garner valuable information from the varied DoD approaches to fatigue.

This chapter will 1) provide an overview of some of the practices that the various DoD services use to teach, implement and regulate fatigue; 2) highlight the efficacy of combining fatigue with safety and the organizational embracement of safety as a corporate culture; 3) describe the various safety centers and some current pertinent research on fatigue; and 4) introduce the topic of medicinal countermeasures.

The military approach to fatigue highlights training, publications, manuals, policies and research concerning fatigue. In the forward to the *Army Leader's Guide to Crew Endurance*, Brigadier General Konitzer states that military leaders must have a clear understanding of decreases in performance resulting from human endurance limitations. The guide helps leaders to recognize the detrimental effects of stress, fatigue, and sleep deprivation on soldier performance and the need to control these hazards (Comperatore, Caldwell & Caldwell, 1997).

The current conflict in the Middle East has emphasized this point quite effectively. Military leaders believe all branches of service are in a state of chronic fatigue of epidemic proportions (Caldwell & Caldwell 2005). The military community paradigm of "24/7" schedules are often essential for effective mission completion. The Air Force Chief of Staff noted that "persistent and sustained operations 24 hours a day, 7 days a week are essential to attaining U.S. Victory in today's battle space" (Caldwell & Caldwell, 2005). It is this exact ability to conduct relentless, precise and lethal warfare that makes our military so effective. But with the military's success comes the high price of soldier fatigue. An executive paper to Washington from September 2000 outlined surprising data on the services operational work tempo (Spencer, 2000). U.S. forces had been decreased by 28%, with a 16-fold increase in deployments of the nominal pace from 1960-1991. The final staggering figure was the overall increase in operations, a 352% increase comparatively (Spencer, 2000). A 2002 Report to Congress found that number had increased to 400% (Zapanta et al., 2002). These figures do not include the last five years of sustained combat in two separate geographic areas of operation.

SAFETY CULTURE

All the branches address training their leaders in matters related to fatigue. The topic is approached from multiple venues and is supported and stressed as a key safety issue from the top leadership down. It also is embedded in day-to-day operations, as safety is everyone's job. This process starts early in the careers of officers and non-commissioned officers (NCOs). Fatigue has a direct link to inadequate sleep and stress. This process is linked to mankind's patterns of sleep as addressed in Chapter One. Military operations are continuous and often take the form of shift-work. Shift-work alone, without the context of extended operations, is a problem. As such, all U.S. military branches have leadership guides for crew endurance. In particular, the field of aviation stresses the lessons learned from fatigue, as a pilot operating under such duress is extremely dangerous. The various branches may change the terms, e.g., "crew resource management" or "crew endurance management," but whatever the term they have guides that clearly define crew rest periods to combat fatigue which are easily obtainable through the internet. This is done as doctrine, well knowing that warfare does not always go as planned and contingency operations must be expected. Crew rest is always examined as a potential factor in mishaps. Each branch has a safety center where monthly publications with articles on this topic and write-ups on accidents are printed and made available. The Department of the Army (Army) has one publication called *Countermeasures* (1992), which focuses on ground risk-management information. Another deals with Army aviation risk-management (2006). Each focuses on the commander's attention to his unit's work endurance and their balance of work, rest and combat effectiveness. Expanding on the importance of this, the military defines the issue, teaches it and seeks to actively mitigate the impacts of fatigue. Similarly solidifying this concept of training fatigue into the minds of all leaders in the disaster field is imperative. The reason that the services go to this trouble is because the military knows that fatigue impacts mission operations, costs money, damages equipment and people and gets people killed.

TEACHING THAT FATIGUE KILLS

Military aviation is probably the best example of the emphasis placed on teaching, training and even testing service members on fatigue. All aviation branches in the military teach flight crews and personnel on flight status the importance of fatigue. The very first class taught in the Navy Aviation Primary Instruction (API) course is on fatigue. API is where every future pilot and flight officer starts his or her aviation career. The first lecture taught during the first day of the API is a one-hour block of instruction on fatigue and sleep impact on the Navy, on aviation, on safety and on how individuals fatigue level specifically impact test taking. Lectures of similar scope are taught to all new officers and the training is repeated. One theme that every branch incorporates is the education and re-education of leaders on safety and fatigue. Before they learn any basic aviation principles, aerodynamics or weather, the Navy teaches about fatigue and the physiology of circadian rhythms and endurance to future aviators. Fatigue kills aviators. The number two cause of aircraft mishaps resulting in death is fatigue, second only to spatial disorientation (Figure 8) (Bohrens, 2006). The aviation component of each branch now teaches crew resource management (CRM) and operational risk management (ORM). ORM and CRM are different but complement each other and both courses are focused on safety. They also both reinforce the risks of sleep deprivation and fatigue at the crew level and at the larger operational level. More will be discussed on this in a later chapter.

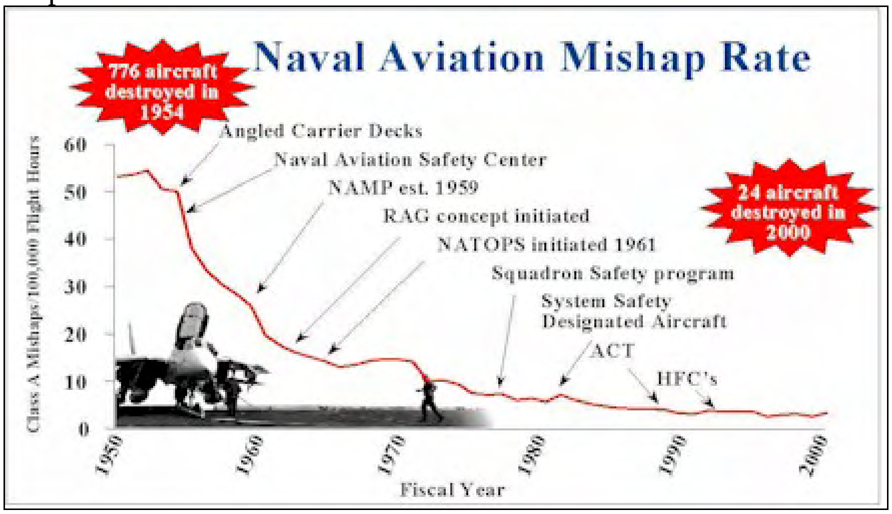


Figure 8. Naval Aviation Mishap Rate. With permission from Capt. Davenport.

THE ARMY LEADERS GUIDE

The Army Leaders Guide to Crew Endurance states that fatigue is well known to decrease attention and to decrease audiovisual monitoring patterns. It also causes an increase in reaction times and a decrease in memory (Comperatore et al, 1997). The guide is extensive and focuses on the use of an organized program to ensure sleep when possible, as well as the use of strategic napping, bright light therapy, clocks, scheduling of meals and a sound understanding of sleep, stress and circadian rhythm. Each branch of service teaches these basics principals because fatigue affects ground and sea personnel as well. Many military branches in the U.S. and abroad have similar such guides. The quotation from the Dr. Bartlett comes from the Australian Army Australian Defence (sic) Force *Fatigue Management During Operations: A Commander's Guide* composed in 2002 (Murphy). The Australians, like the United States Department of Defense and many other nations, have whole military departments and centers that study fatigue to promote safety.

As an example of how fatigue impacts a specific occupational group, let us consider personnel on flight status a little more in-depth. Due to the risks of increased reaction times, aviators obtain far greater doctrinal training and regulation of fatigue. Acute or chronic fatigue in sustained or continuous military flight operations is often a reality. Understanding the associated poor flight performance and increased safety risks allows commanders to mitigate the problem, and each branch of service has means to address this challenge. In one of the primary aviation regulations, the Army defines fatigue in its flight accident prevention regulation AR 385-95 as "a state of feeling drowsy or sleepy resulting from a number of factors to include prolonged mental or physical work, exposure to harsh environments, extended periods of anxiety, loss of sleep, or monotonous tasks" (1999). All of these states may be present in the aviation operational environment. Fatigue interrupts attention and causes slow and inaccurate performance, with a greater tolerance for error on the part of the individual. Lapses of attention and failure of crew coordination stemming from fatigue has been shown to cause mishaps in the high task-load environment of the cockpit (Army, 1999).

In the Army flight community, a vigorous program emphasizing non-pharmacological measures to optimize crew rest is found in the guidelines of the Army flight regulations AR 95-1, Flight Regulations, Table 3-1 (2006a). This guide further instills a sense of command responsibility for the issue. The commander is tasked to develop and monitor a unit crew rest policy (Army, 1999) in accordance with published policy. So that leader is held responsible for his or her unit crew's rest policy. This level of focus and responsibility could not be found in disaster management in literature searches by this author and a research librarian at the Naval Operational Medical Institute. In fact, hardly even any comment could be found in summary reports and lessons learned. This issue will be returned to later.

LEADERSHIP RESPONSIBILITY

In the Army, unit commanders are required to ensure that subordinate personnel are trained to standards, and these standards are enforced. Fatigue in the military falls under the standard of safety. Army units will organize a safety day, typically once per year. They also brief soldiers on travel and fatigue risks before all holidays. One way commanders accomplish this standard of safety is to make this a unit mission and responsibility. All Army units are required to assign safety officers and non-commissioned officers (NCOs), whether they are an aviation unit, ground unit or other. The Air Force and Navy have similar processes. During each iteration of training events at Navy schools, the instructors are required to remind the group that at any time, anyone can call a safety time-out. This applies to obvious safety concerns but also is indoctrinated for all training—whether at a school or at the unit level. If a junior aircrew member thinks the senior pilot is tired and not rested they can, and are supposed to bring up the issue right then and there. This is a significant paradigm shift compared to even ten years ago. This focus on safety and not seniority or rank is now seen in both civil and military aviation. Do disaster response teams promote this type of attitude or culture? Disaster recovery brings together large numbers of agencies. Does FEMA promote a fatigue policy or guidance to these agencies?

SAFETY CENTERS

The military branches also have designated safety centers to train safety officers and other leaders, as well as to develop policies and promote safety within the forces. The Army Safety Center is located at Fort Rucker, Alabama. It is no mistake that Fort Rucker is also the home of Army Aviation. The Air Force and the Navy both have their safety centers located with their initial flight training centers. Each center among other things teaches and trains what is known as operational risk management or ORM. The fundamental goal of risk management is to “enhance mission effectiveness at all levels while preserving assets and safeguarding health and welfare” (Davenport, 2006). The ORM process anticipates and manages risk by planning. All military safety centers also sponsor avid research and employ many of the nation’s experts in fatigue management. Do the lead agencies in disaster preparedness have centers for safety excellence and do they sponsor research?

MISHAPS

Captain Nicholas Davenport is an ER physician and Navy Flight Surgeon who is one of the primary Navy experts on fatigue. Dr. Davenport currently instructs in Pensacola at numerous courses including Naval Aviation Safety Officer Course, the Flight Surgeon Course, advance pilot courses, Navy leadership and many other venues including briefs to many of the brand new Navy and Marine Corp pilot applicants on fatigue. He also works with the Navy Safety Center (NSC) collecting data on fatigue and mishaps. Figure 9 shows how fatigue plays a significant role in Navy mishaps. Fatigue is the number two cause of loss of life in Navy aviation mishaps. The military accident investigation systems are non-punitive and treated as privileged information and this allows the services to get objective information free of the fear of reprisals thus. This is done to promote safety and allow for the prevention of future mishaps.

Mishaps are divided in to three types, A, B and C. Class A mishaps are the loss of the aircraft or life or in excess of $250,000. A Class B mishap is rated from $20,000 to $250,000 or serious bodily harm and Class C includes the remaining smaller losses to include missed work. The branches of the military use essentially the same mishap system. The Navy, Marines and the Air Force use Human Factors Committees in mishap investigations along with locally organized investigations teams and one or two advisors from the Safety Center. The Army uses a centralized mishap team from the Safety Center and may task local support. What is common across the services is that fatigue is a significant contributor to crashes and mishaps. In fact in the Navy it is the number two cause. The image below clearly defines that point. All the services have similar findings.

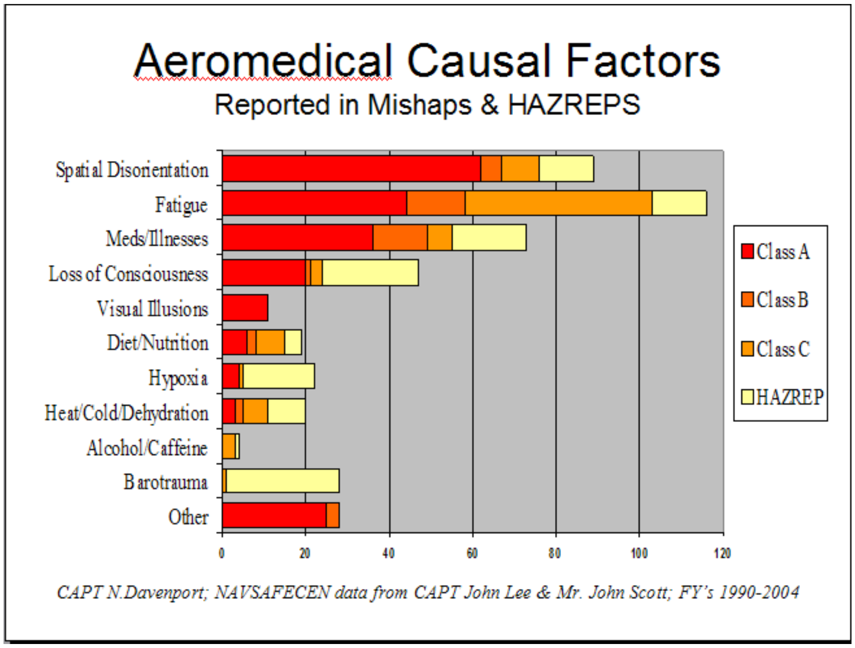


Figure 9. Aeromedical Causal Factors. With permission from Dr. Nick Davenport.

Of all USN/USMC aviation Class A mishaps over the last five years, four out of five involve human error. Every hand that flies, fixes or supports aircraft has the opportunity to introduce human error. The human error problem is very difficult to control, compared to the technological and programmatic challenges of the past 40 years. It is less predictable and harder to analyze and correct than an equipment or procedural issue (Davenport, 2006). Figure 10 is a plot of only Class A's over the prior 15 years. On the right side of the figure, the four leading causal categories of fatigue that have contributed to mishaps are listed; the number one cause is inadequate rest and sleep deprivation and the second leading cause is circadian rhythm disruption. The four categories are stacked from most to least frequent (Davenport, 2006). Figure 10 lists fatigue as a causal factor of Class A accidents, with FY 2003 showing that there were nine Class A's where fatigue was mentioned as a "why" causal factor or one of the primary reasons for the accident

(Davenport, 2006). Dr. Davenport notes that the rate seems to drop off in 2004, but he suspects that's because the Naval Safety Center coders may be behind on classifying and entering mishap causal factors into the database (Davenport, 2006).

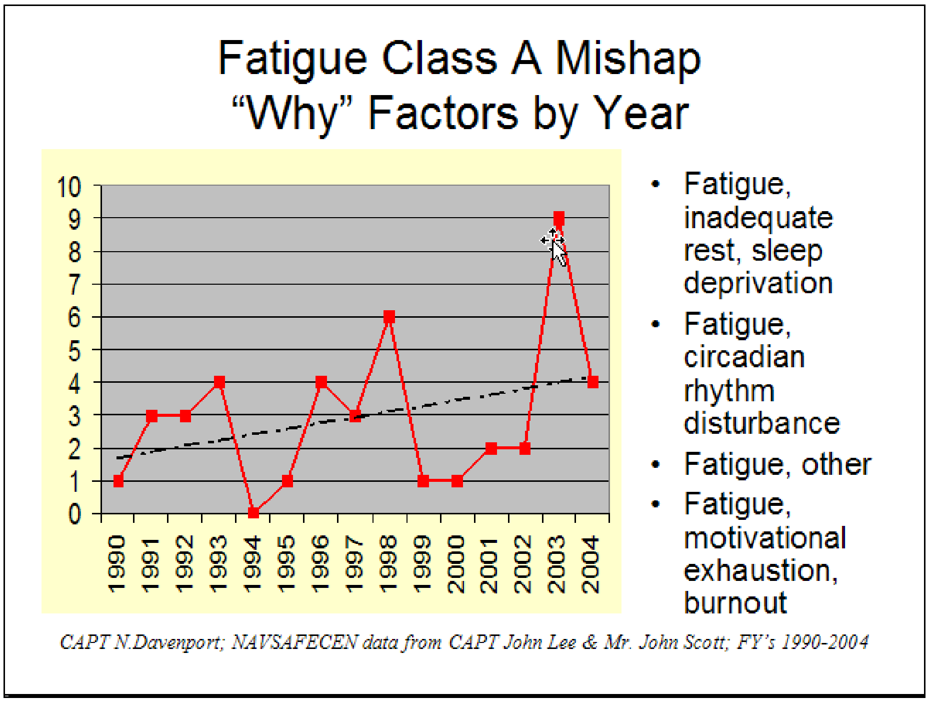


Figure 10. Fatigue Class A Mishaps and Top Four Causes. With permission from Dr. Nick Davenport. From the Fall 2006 Naval Aviation Safety Officers Course.

HUMAN FACTORS: CRM AND ORM

In fact, the Navy attributes the implementation of its Safety Center and focusing on human factors as the key for it's ability to reduce its mishap rate from 776 in 1954 to 20 in 2000, (Figure 8) (Davenport, 2006). Through mandating education processes on risks and countermeasures, such as crew resource management (CRM) and operational risks management (ORM), the Navy and all the armed services have done incredible jobs in making flying safer. These tools incorporate the risk of fatigue and built systems that help identify the risk to the crew and, equally as important, encourage all to address fatigue verse regret a mishap later.

ARMY V CORPS EXAMPLE

Taking a closer look at a specific unit will highlight the importance of this topic. The following example from a safety approach 5th Corps U.S. Army. The memo states that commanders will complete a deliberate risk assessment upon occupying an area. Then he or she will provide a daily risk assessment and report it to the next higher-level command. This risk assessment is taken quite seriously. For new training and even for real-world missions commanders often send in key leaders to do a site survey to determine if a location is suitable and safe. Establishing sleeping areas for this site is determined, planning on the quietest possible areas for flight crews to rest.

In the *5th Corps Command Training Guide* for fiscal year 2005-6, under the subject section of "Safety," the guide requires all V Corps commanders to measure and report risk. Among many requirements, it lists such obvious measures as requiring a fire evacuation and response plan, even for tents. The guide states that plans will be published and exercised for each area. The stance is firm and simple: make, have and teach the safety plans. Under the section "Occupational Safety and Health", leaders are required to develop a "Directed Sleep Management Plan", referring leaders to *The Leader's Guide to Crew Endurance* as a reminder of where to review this topic (Army, 2006b). The guide is very clear and instructs leaders to develop a Directed Sleep Management Plan to ensure fatigue does not hinder mission. Fatigue is a known causal factor in many mishaps. After 48-72 hours without sleep, personnel become ineffective. The training guide lists factors other than sleep that impact fatigue, such as water consumption, diet, physical condition, stress, and hygiene" (Army, 2006b). The military holds commanders ultimately responsible for the safety of their soldiers, sailors, marines and airmen. This V Corps example saliently stresses the need for leadership to focus on fatigue management, to have a policy, a plan and to provide a daily risk assessment of fatigue. Whether for aviation, ground or sea units, fatigue management is real and has consequences. Certainly consideration of sleep plans and fatigue mitigation would seem prudent to disaster leaders preparing for or responding to events.

COAST GUARD

Coast Guard personnel can be exposed to rigorous work schedules. A 1996 United States Coast Guard (USCG) analysis of 279 incidents showed that fatigue contributed to 16% of critical vessel casualties and 33% of personal injuries (McCallum, Raby, & Rothblum, 1996). Like the Army, the Coast Guard has a Research and Development Center with a specific team called the Crew Endurance Management Team. This team, located in Groton Connecticut, has a program basis that is to implement systems and attitudes that help companies and ships' crews to enhance their current efforts toward maintaining high levels of crew endurance and safety. The consistent use of the processes allows company and ship management staff, as well as crewmembers, to use objective methods to constantly improve the work plan, safety and personnel endurance. Figure 11 is from the crewmembers endurance management system (CMEMS) program and shows factors effecting crew endurance (Comperatore, 2003).

In 1999, the National Transportation Safety Board (NTSB) issued Recommendation M-99-1 to the Coast Guard for the establishment of scientifically based hours-of-service regulations that set limits on hours of service, provided predictable work and rest schedules and considered circadian rhythms and human sleep requirements (NTSB, 2001). In response, the Coast Guard collaborated with the Army Safety Center and developed the regulations. One regulation system resulting from that initiative is the CMEMS program. It does not prescribe specific schedules, but it does provide a process

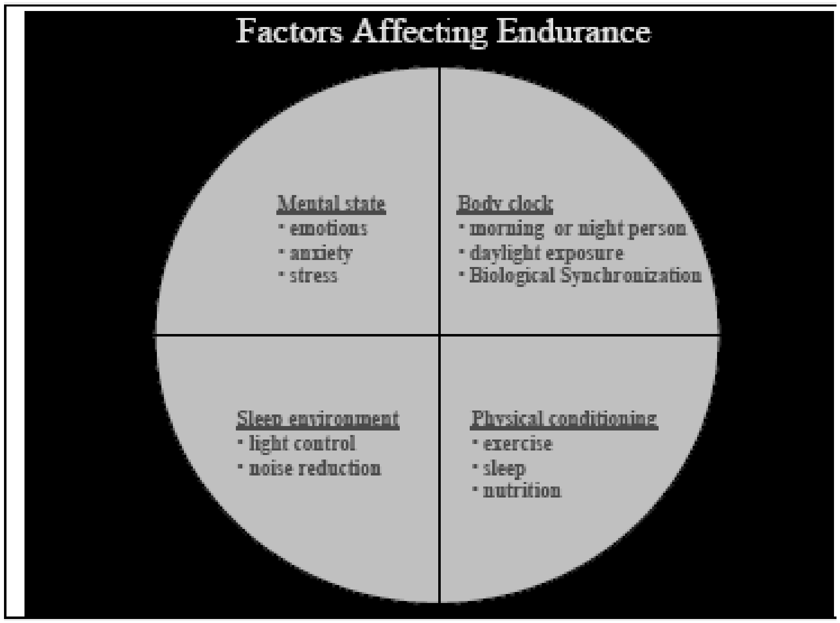


Figure 11. Factors Affecting Crew Endurance. Adapted from the CMEMS Program.

by which to maintain endurance, prevent fatigue and burnout and enhance the safety of overall operations. Like Army safety officers and NCOs, Coast Guard members can become champions of the endurance plan aboard a commercial vessel and contribute to the maintenance of crew endurance. Figure 12 shows how the CMEMS program teaches alertness as a function of time of day.

Assigning and training unit level experts on safety is the recurring theme. Maritime systems such as CMEMS and other processes have been developed by experts and are grounded in science. Expanding on the information introduced in the first chapter, endurance levels are affected by the interaction of factors such as physiological, psychological and environmental issues (Table 1). Changes in the body's timing mechanism for restorative processes affect the alignment of daily peaks and troughs of

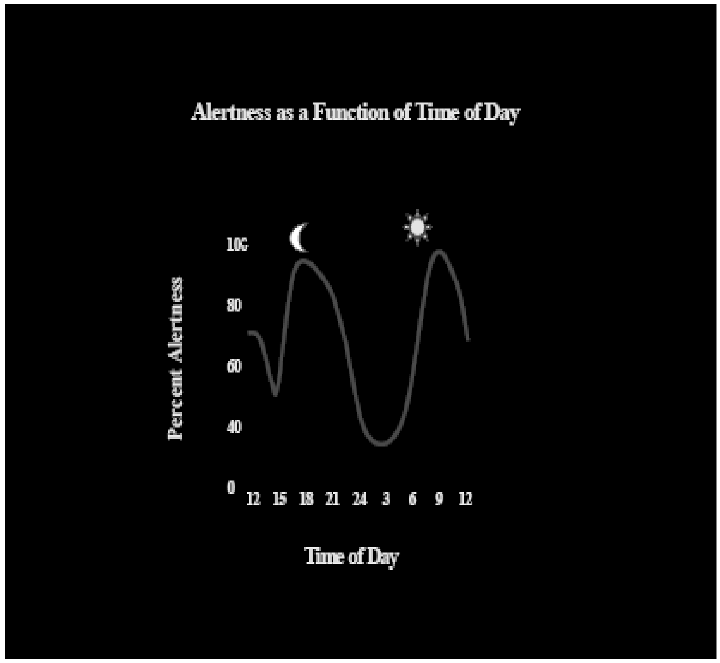


Figure 12. Alertness as a Function of Time of Day. Adapted from the CMEMS Program.

other physiological events such as core body temperature, cellular metabolism, and production and release of hormones and neurotransmitters. In general, the biological clock system requires approximately three days to re-adjust to a new input, such as a two-hour advance in daylight exposure time due to earlier wake-up times (Comperatore, 2003). This re-adjustment will take place if the new sleep/wake schedule is consistent from day to day. However, if the inputs are inconsistent, the clock's timing can become disorganized in such a way that the physiological rhythms under its control will no longer be expressed in a predictable pattern.

The individual impact results in sleepiness, insomnia and performance degradation in mental and motor tasks. Inconsistent inputs to the biological clock are common when personnel work nighttime shifts (Comperatore, 2003). Dr. Comperatore, one of the lead researchers on the project and a well respected expert, explained, “Personnel exposed to regular work schedules that allow for consistency from day to day enjoy the benefits of a well-synchronized biological clock. This allows their daily energy restorative cycles to

Mental State	**Emotions**	**Anxiety**	**Stress**
Body Clock	AM/PM person	Daylight exposure	Biological Synchronization
Sleep Environment	Light control	Noise reduction	
Physical Conditions	Exercise	Sleep	Nutrition

Table 1. Fatigue Factors: Physiological, Psychological and Environmental.

take place regularly. In contrast, older work schedules that impose frequent transitions from daytime to nighttime duty hours, and long duration shifts disrupt energy restorative processes and induce fatigue” (Comperatore and Kingsley, 2005). Thus, experts from scientific study have developed maritime systems such as CMEMS and other processes. Because of the NTSB recommendation, Coast Guard members now have more effective systems that are organized and mitigate fatigue and mishaps. The Coast Guard has gone to great lengths to ensure its crews are rested so they can accomplish their mission.

AIR FORCE

As noted, all the services focus on fatigue mitigation. The Air Force Research Lab Human Effectiveness Directorate studies fatigue in aviation operations of the Air Force.

Other centers have done intense study and development of effective countermeasures for ground-based personnel, the outcomes being the leadership guides and training for ground and sea forces. The Air Force lab researchers found relatively little research at overcoming fatigue in the aviation environment (Caldwell, 2006a). All of these environments, flight or ground, have similar overlaps with managing disaster work schedules.

RESEARCH AND FAST

The comprehensive efforts in the Human Effectiveness Directorate have focused on maximizing alertness and endurance in air operations. The researchers at the lab have developed a computer application called the Fatigue Avoidance Scheduling Tool (FAST™) to help mission planners devise the best possible duty schedules, given operational constraints. The application runs under Microsoft® Windows® and integrates information about circadian rhythms, performance decline associated with sleep loss, recovery rates associated with sleep, and temporary performance effects associated with post-sleep grogginess. FAST™ allows planners to estimate the average effects of various schedules on crew performance and determine which schedules will maximize performance under specific operational circumstances (Caldwell, 2006a). This is an exciting new approach to this age-old problem, and it would be encouraging to see this adopted in the disaster management arena as it includes air, ground and often even sea operations. Currently the FAST program is taught to Navy leaders as well as the Navy flight surgeons course and to aviators attending CRM to become unit CRM proponents. It is an excellent tool that will show leaders graphically what to expect as risk from fatigue based on the real time schedules of their staff.

LONG RANGE BOMBERS

The aviation environment itself poses an obvious threat to safety and effectiveness. The Human Effectiveness Directorate has studied many areas and made sound impacts in fatigue operations. In one example from Operation Iraqi Freedom, pilots flew the B-2 bomber to targets in Iraq from one of two airfields. Sortie durations were long (16.9 h) from one field and very long (35.3 h) from the other. A retrospective analysis of 75 pilots who performed 94 combat sorties was performed. The study examined the prevalence of the pilot's decision to use dextroamphetamine, caffeine and in-flight sleep during combat. Pilots on shorter missions used dextroamphetamine for 97% of the time and in-flight naps for 13% of sorties. Those on longer missions used dextroamphetamine on 58% and naps on 94% of sorties (Kenagy and Bird, 2004). Now procurement and deployment of the B-2 bomber has paved the way for nonstop, intercontinental flights in which a 2-person crew can remain in the cockpit for up to 44 continuous hours. These examples show the importance in the military environment to teach, implement and encourage a fatigue plan from the command down. They also stress the need to know and have a plan with available scientifically proven options for use during continuous operations (Caldwell, Smythe, LeDuc, & Caldwell, 2000).

The bottom line is that poor performance is the outcome of sleep deprivation. Many journals detail studies to confirm that sleep deprived personnel lose approximately 25-30% of their ability to perform useful mental work with each 24 hr period of sleep loss (Caldwell and Caldwell, 2005). The search for solutions often leads to dead-end. The services have investigated various strategies to mitigate fatigue that ultimately did not work. These include limiting the time on task, ensuring high levels of physical fitness and providing brief periods of exercise (Ahasan, Lewko, Campbell, & Salmoni, 2001;

Akerstedt, 2003). One common myth is that rolling the window down during driving and changing the temperature have repeatedly been proven to have little benefit as well. Of course bombers don't have roll down windows, but the emphasis is that leaders in disaster management can leverage and benefit from the research investments already made by the military. Disasters are not unlike combat or at least very aggressive, intense training exercises–filled with unknowns, broken communications, people in need, destruction, hunger, fatigue and even death. All involved would agree this creates high levels of stress. Current military research in fatigue covers a broad range of topics. The following few key areas are chosen to further highlight and explore fatigue in an operational context.

HIGH LEVELS OF STRESS

Military exercises are known to generate high levels of stress in order to simulate combat, providing a unique opportunity to examine cognitive and physiologic responses of normal humans to acute stress. A recent 2005 study re-examined this area. Cognitive and physiologic markers of stress were evaluated before, during and after an intense training exercise conducted for 53 hours in the heat. Cognitive performance, mood, physical activity, sleep, body composition, hydration, and saliva cortisol, testosterone and melatonin were assessed. Thirty-one male U.S. Army officer volunteers from an elite unit, aged 31.6 +/- .4 years were tested. The results documented that soldiers slept only 3.0 +/- .3 hours during the exercise and were active throughout. Volunteers lost 4.1 +/- .2 kg ($p < .001$) of weight, predominately water (3.1 +/- .3 L) ($p < .001$). Substantial degradation in cognitive function occurred. Vigilance, reaction time, attention, memory and reasoning were impaired ($p < .001$). Mood, including vigor ($p < .001$), fatigue ($p < .001$), confusion ($p < .001$), depression ($p < .001$) and tension ($p < .002$), assessed by a questionnaire, deteriorated, with the highest cortisol and testosterone levels observed before the exercise. The study did an excellent job quantifying the adverse impact of multiple stressors on cognitive performance, mood and physiologic parameters during a continuous but brief military exercise conducted by highly motivated, well-trained officers (Lieberman et al., 2005). This example certainly should be able to serve as a model for what happens to most well trained, well-intended and highly motivated disaster units responding to a natural disaster, e.g., hurricanes, tornadoes, earthquakes. The knowledge that 18-20 hours of continuous wakefulness results in 25% decline in cognitive abilities could change the expectations of leaders for team members during the initial few days of a response.

WALTER REED

The Walter Reed Army Institute of Research (WRAIR) in Silver Spring, MD, has long done research in the area of sleep and fatigue, having studied these topics since World War II. Recently it has examined how sleep deprivation affects cognitive performance in people undergoing chronic cumulative restricted or total sleep loss (Horne, 1978; Angus and Pigeau, 1992). “We know that sleep deprivation decreases metabolism in the area of the brain called the pre-frontal cortex,” explains Dr. Nancy Wesensten, supervisory scientist and researcher at WRAIR. “The whole brain is deactivated by sleep deprivation but that area is more deactivated than any other area of the brain. This is the same area that governs executive functioning and higher order cognitive functions. Sleep deprivation impairs executive functioning. Measuring executive functions can be difficult because some of these are one-time tasks, yet executive functions are the most operationally relevant.” Walter Reed researchers are developing new methods of testing executive functions to discover the scope of what is affected by sleep deprivation using computer programs and Functional Magnetic Resonance Imaging (MRI) machines with imaging techniques that look at how the brain is functional in real-time (N. Wesensten, personal communication, March 15, 2006).

PHARMACEUTICAL RESEARCH

The Air Force research lab, as well as Naval research sites and Army labs, at places such as Walter Reed Army Medical Center and the U.S. Army Research Lab at Fort Rucker, in collaboration with civilian research partners have all been collecting large amounts of data on medications to extend the war fighters when no other options exist. The Cold War brought about policies by the Air Force for use in strategic and military air command groups for long-range bombers and other aircraft. These extended air lift missions set the precedent for research in fatigue. The longest continuous operations record comes from the B-2 bomber. It paved the way for nonstop, intercontinental flights in which a two-person crew can remain in the cockpit for up to 44 continuous hours (Gander, Nguyen, Rosekind, & Connell, 1993).

The goal has been to sustain performance when no other options will work. The U.S. military began use of pharmacological stimulants to support operations in WWII. Many of the experts already cited in this review have worked or currently work with various branches of the department of defense in fatigue management. Dr. John and Dr. Lynn Caldwell are two experts and well-known authors in the field of fatigue. They have both worked full time for the Army Safety Center, spoken nationally and administer projects for NASA. Currently they are doing full time research for the Air Force. One of their areas of expertise and research is pharmacological countermeasures and they have provided a very recent overview of U.S. Military approved pharmacological countermeasures. The Caldwell team conducted an extensive overview of U.S. Military approved pharmacological countermeasures for fatigue and concluded that sleep is often difficult to obtain in operational contexts, even in situations where efforts have been made to ensure the existence of adequate sleep opportunities. (Cornum, Caldwell and Caldwell, 1997; Caldwell and Caldwell, 2005).

In an article focusing on stimulant use in extended flight operations, they outlined the categories of approved military countermeasure medicines into two primary areas, hypnotics and stimulants. The branches of service have studied and approved stimulants agents from ranging from caffeine, Modafinil and Dexedrine (Table 2) to sleep agents such as Ambien, Restoril and Sonata (Table 3). Modafinil is a relatively new product and is effective as an intermediate-term (up to 40 h) maintenance medicine. Dexedrine is effective as a long-term agent, but must be closely monitored (Caldwell and Caldwell, 2005). It is worth noting that caffeine has repeatedly been proven to be an effective short to medium time range agent to combat fatigue. While most people know this, adjustments must be made due to tolerance seen in regular users.

Med	**Dose (mg)**	**T1/2**	**Uses**	**Cautions**
Modafinil (Provigil)	100-200	15	Up to 40h of alertness	Off label use
Dextroamphetamine (Dexadrine)	5-10	10	Long term alertness	History of abuse, avoid HTN or cardiac problems
Caffeine	50-300mg	5	Short term alertness requirement	Tolerance exists in regular users

Table 2: Stimulants used in Fatigue.

In the military, administration of rest agents to assist in circadian cycling and ensuring adequate sleep or stimulant agents for continued mission execution in sustained operations is an additional measure or option to consider for managing fatigue and maintaining aircrew performance after non-pharmacological measures have been considered and deemed inadequate. This process is closely regulated, monitored and executed by the flight surgeon in conjunction with the immediate commanders and the unit commander, as well as the safety officer. With the growth of televised advertisement of medications, the use of rest agents is increasing in the public and certainly in the international business travel population.

Med	**Dose (mg)**	**T1/2 (h)**	**Uses**	**Cautions**
Temazepam (Restoril)	15-30	9	Sleep maintenance, daytime sleep, jet lag, travel west	Need 8h sleep period
Zolpidem (Ambien)	5-10	2.5	Sleep Initiation Early onset sleep Medium naps Travel East	Need 4-6h sleep
Zaleplon (Sonata)	5-10	1	Sleep Initiation Short naps Early bed times	

Table 3. Sleep Aid Hypnotics

In the Army, no waiver is required for use in a short-term capacity. Use must be well documented and is typically discussed in mission planning. Stimulants or rest agents should only be used in combat or during exceptional ("fly or die") circumstances of operational necessity. Use of these agents and medication accountability must be under the direct supervision of the flight surgeon and must be authorized by the local commander (Army, 1994; Army, 1998; Army, 2000; Army, 1988; Comperatore, et al., 1997). Note that five documents, not just one, play a role in this process. Again, fatigue countermeasures are usually employed by a relatively small number of military members engaged in sustained or continuous operations when sleep is not an option. Prescribed stimulant medications, in-flight sleep, and self-medication with caffeine can mitigate fatigue for military aviation crews. Often in aviation the flight crews refer to these medications as “Go and No-Go Meds.” Each branch has strict policies and protocols similar to the Army policy noted above.

Pharmaceutical countermeasures, especially the use of stimulants, evoke controversy in the public and military. It does this because of a paucity of combat data regarding the efficacy of stimulant use over sustained operations.

There certainly is no doubt that fatigue among warriors can jeopardize mission success. In the realm of pharmaceutical countermeasures, stimulant use has been and continues to be the largest area of controversy. The development of sophisticated systems such as night vision goggles and other battlefield technologies, allowing military forces to fight through the night and into the next day, have produced continuous operations CONOPS (fighting around the clock), and sustained operations SUSOPS, (working steadily for long periods without relief). Some special operations military teams work mostly during darkness and rest during the day, accumulating sleep debt as a result of scattered, interrupted, and fragmented sleep.

Sustained workloads combined with fatigue, especially after one or more nights of complete sleep loss or longer periods of reduced or fragmented sleep, degrade performance, productivity, safety, and mission effectiveness (Krueger, & Obal, 2002). Sleep loss interacts with workload, resulting in reduced reaction time, decreased vigilance, perceptual and cognitive distortions, and changes in affect, all of which vary according to circadian rhythm time-of-day effects. (Krueger, & Obal, 2002). Frequently during CONOPS, small teams of combatants engage simultaneously in sustained operations (SUSOPS). In SUSOPS, individuals work until the objective is reached. If the mission goes as scheduled, the intent is that the mission duration falls within the range of human safety endurance. But if the plan changes, they will not be relieved or get an opportunity for sleep. This description accurately and succinctly applies to disaster response teams as well. Having persons in peak physical condition, well trained, and equipped with the right tools helps, but unlike most disaster response teams, military teams also have contingency plans for SUSOPS. In the military, this includes being trained and prepared to use pharmaceuticals.

The future use of such agents in a sustained disaster setting may occur but first extensive further research and then education of the human assets implementing the option would need to occur. While this paper is not advocating the general use of prescription medications as countermeasures during disaster recovery operations, there are some pharmacological findings that could be of use e.g., the strategic use of caffeine. The significant parallels in operations between continuous and sustained operational military units and disaster response teams warrant a serious consideration of these countermeasures for the future. The use of prescription medications is a complicated and highly regulated process used rarely in some areas of DoD. It has been debated and discussed at the NTSB for air, ground and sea carriers but no action was taken. Similarly, the possible use of stimulants is available, trained and prepared for but rarely implemented in special operations communities. Strict protocols including screening by physicians, a trial dose, command over-site and inventory audits are conditions placed on the use of these medicines. Other coalition countries have similar proceedings and equally strict protocols.

JET LAG

The military continues to study the area of fatigue countermeasures, constantly looking at multiple areas of focus. Perhaps the selective use of sleep aids in the future may be a viable option for small groups of early-entry disaster recovery teams. Before that happens, the field of disaster management needs to establish guidelines and to implement teaching, training and tracking of sleep and fatigue. Passengers, following rapid transmeridian travel, routinely complain of jet lag, which includes transient disturbances in sleep patterns, alertness, appetite and mood. The literature in this area is rapidly expanding, as fatigue management becomes a concern for an every broader spectrum of the population (Ehret and Scanlon, 1983; Nicholson, 1986; Graeber, 1994). For example, a study reviewed the success of the use of Zolpidem to reduce sleep deprivation in jet lag. This has an economic and social impact on travelers(Jamieson, Zammit, Walsh, Davis, & Rosenberg, 2001). Another sought via a multi-center, double blind, randomized, placebo-controlled, parallel-groups to determine if seasoned travelers received improvement in sleep following rapid transmeridian travel (Suhner et al., 2001). The study found that the first night with Zolpidem after travel had longer sleep time and reduced number of awakenings and improved sleep quality. It did not show an improvement in sleep latency.

The focus on fatigue in aerospace medicine is illustrated by its recurrence as a feature subject at the premier aeromedical conferences in the United States. The Introduction to Aerospace Medicine Course, sponsored by the Army and the University of Texas Medical Branch (Jennings, 2006a) featured keynote speaker Dr. David Dinges, a renowned expert in fatigue and sleep as well as countermeasures and consultant to NASA (Dinges, 2006). One of the May 2006 Aerospace Medical Associations workshop speakers, Dr. Caldwell, also spoke on fatigue (Caldwell, 2006b). Participants in these conferences include physicians and staff from NASA, from the aviation industry, the military, the FAA and many foreign governments. The problem of fatigue, its awareness, appreciation, and respect for its impact require education and training to leaders and health care experts.

SUMMARY

For now, the military will continue to support disaster relief both in the U.S. and globally. Northern Command is a new joint military command that was established after 9/11; one of its functions is to respond to disasters - natural and terrorist. Nearly 60 agencies have representatives in the command center in the Northern Command's headquarters, which was packed to standing-room-only for 42 straight days last year as Katrina and Rita battered the Gulf. These agencies are predominantly government departments. Northern Command, along with FEMA, are logical spearhead agencies to establish disaster fatigue protocols and countermeasures for disaster response teams. They could start a process to ensure the best possible outcomes for all staff responding to disasters.

Practices that the various DoD services use to teach, implement and regulate fatigue have been reviewed. The combining of fatigue with safety and the organizational embracement of safety as a corporate culture within the military have been highlighted. Along with that, a discussion of the various safety centers and some current research from them and other locations was performed. Finally, the topic of pharmaceutical countermeasures was reviewed. At this time the levels of disaster management, with its mix of local, state, federal and charitable organizations are not trained, equipped or ready to consider the use of stimulants. The use of sleep agents with medical over-site may not be that far off. The larger take-home concept is the need to establish a corporate or organizational culture of fatigue awareness and disaster leadership ownership of fatigue. Accidents and the hazards of fatigue can become some of the greatest threats to disaster staff working long shifts under adverse conditions while in a sleep-deprived state. Teaching, training and assessing the risks of fatigue to staff are paramount. Studying the impact of fatigue in disasters also should be considered. Perhaps FEMA and NORTHCOM can join forces with a safety center or the CDC and perform a study on the impact of fatigue during disaster training and later during disasters. Whether combating aircrew fatigue, training new military leadership or teaching fatigue to disaster teams, the concepts and understanding the basics of sleep/fatigue awareness is critically important. A quotation from *The Fundamentals of Land Warfare* probably best sums up the issue of fatigue in the military: "Continuous high-tempo operations cause great demands on sustainment systems, and severely test the endurance of land forces. Sleep deprivation causes physical and psychological stress, reducing the endurance and resilience of soldiers and their commanders. The requirement to conduct protracted, continuous operations requires the refinement of organizational processes and procedures that enable commanders and their staffs to maintain the tempo of operations while sustaining battle proficiency and high morale." (Department of Defence (sic), 1998).

CHAPTER 3: MEDICINE AND FATIGUE

I'm not asleep…but that doesn't mean I'm awake.

Author Unknown

OVERVIEW

The long hours and grueling work schedule of a doctor in training has been well documented in everything from academic papers to popular television shows. Ironically the career field that focuses on health and well being is historically one of the largest abusers of sleep. The literature suggests that sleep deprivation causes substantial detriments in a physician's performance of discrete neurocognitive and simulated clinical tasks (Gaba and Howard, 2002; Weinger and Ancoli-Israel, 2002). The problem is so pervasive that the American College of Graduate Medical Education (ACGME) finally set national standards of a maximum of 80 hours per week in 2003 (Landrigan, Barger, Cade, Ayas, & Czeisler, 2006). The medical community was slow to embrace these reforms, and many programs averaged 110-120 hours per week before the regulatory change (Landrigan et al., 2006). Over the last two hundred years, current medical training has notoriously involved so many hours on the job that the term "resident" implied that the training physician "resided" or lived in the hospital. Changing these attitudes toward the need for sleep required a culture shift. This chapter will review current literature on fatigue impacts in medical training. Many laboratory and field studies show that sleep deprivation has a negative effect on the performance of resident physicians (Gaba and Howard 2002). Reduced performance due to sleep deprivation has been clearly associated with increased errors (Fletcher et al., 2005) and contribution to adverse patient events when fatigued staff care for patients (Landrigan et al., 2004). In a 2003 national survey, out of 3,604 first and second year physicians-in-training, those who averaged more than 80 work hours per week were more likely to be involved in serious conflict with other staff members, more likely to be involved in a personal accident or injury, and more likely to make a significant medical error (Baldwin & Daugherty, 2004). Subsequently, changes to the policies addressing these issues resulted in the imposition by the ACGME of an 80-hour per week limitation on work hours and a 30-hour limitation on continuous work hour periods. The United States Congress subsequently enacted legislation and implemented the ACGME requirement (Landrigan et al., 2006) . Such work-hour limitations were imposed to help decrease sleep deprivation, which in turn may decrease medical errors and improve patient safety. Overview of the impact of fatigue in medical training is a valuable lesson for leaders in disaster preparedness as the paradigm shift in medicine has resulted in improved patient care and safety margins for the employee.

HISTORY OF OVERWORKING

Disaster relief and all extended operations are similar to practicing medicine; toughing it out has always been a rite of passage and is expected. In fact, it was not until the 1990's that the possible effects of sleep deprivation and fatigue on the performance and well-being of physician residents received consistent scientific examination. Interestingly, Samkoff stated that no reviews on this topic had been published since 1970 (Samkoff and Jacques, 1991). In a 1981 study he determined that some medical house officers were found to have symptoms of "episodic cognitive impairment, chronic anger, pervasive cynicism, family discord, depression, substance abuse, suicidal ideation and suicide." This syndrome was so pervasive it was identified as House Officer Stress Syndrome (Small, 1981). For over twenty years, medical administration and leadership ignored the topic. Reviews from the time dealt partly with residents' moods and attitudes, as well as demonstrating the deleterious effects of sleep deprivation and fatigue; however, since these reviews did not account for the important factor of excessive work hours, they only offered partial conclusions (see e.g., Wolf, Richardson, & Czeisler, 1991). Samkoff's later reviews analyzed residents' acuity on performance tests requiring prolonged vigilance and found that attention tended to deteriorate with acute sleep loss. These reviews also tried to evaluate residents' performances with brief psychomotor tests meant to measure manual dexterity, reaction times, and short-term recall—all of which were not adversely affected. The conclusion was unfortunate: residents could continue to operate under such extreme circumstances.

Despite this finding, the authors concurred with the recommendation of the Executive Council of the Association of American Medical Colleges that the total working hours for residents should not exceed 80 hours per week, averaged over four weeks. This study and others, coupled with litigation, led to a national institutional change in how American doctors are trained and the number of hours they can work (Beckes, 2003). Sadly, the change did not occur for another eleven years.

CATALYST FOR CHANGE

As in other fields, the catalyst for dramatic change in work hours for physicians-in-training did not come from evidence-based medicine (Asch, 1988) but from the legal system. In this particular case, the landmark litigation over the death of a young New York woman, Libby Zion, was responsible for a chain of events leading to the institution of work-hour limitations for physician trainees in New York hospitals (Holzman & Barnett, 2000). The patient's death was attributed, in part, to the long work hours and sleep deprivation imposed by the medical profession on the physicians-in-training. Disaster leadership need not make the same mistakes waiting for a publicized accident to force a fatigue policy.

MEDICAL ERRORS

An excellent recent study by Landrigan performed at the Division of Sleep Medicine in Brigham and Women's Hospital in Boston helps to clarify just how serious such "medical errors" can be. Physician researchers conducted a prospective, randomized study comparing the rates of serious medical errors made by interns while working a traditional schedule with extended (24 hours or more) work shifts every other shift (an "every third night" call schedule), and interns working an intervention schedule that eliminated extended work shifts and reduced the number of hours worked per week. A multidisciplinary, four-pronged approach that included direct, continuous observation to determine incidents was utilized. Two physicians who were unaware of the interns' schedule assignments independently rated each incident. During a total of 2,203 patient-days involving 634 admissions, interns made 35.9% more serious medical errors during the traditional schedule than during the intervention schedule (136.0 vs. 100.1 per 1000 patient-days, $p<0.001$), including 56.6% more non-intercepted serious errors ($p<0.001$). The total rate of serious errors on the critical care units was 22.0% higher during the traditional schedule than during the intervention schedule (193.2 vs. 158.4 per 1000 patient-days, $p<0.001$)(Landrigan et al., 2004). The study also found that interns made 20.8% more serious medication errors during the traditional schedule than during the intervention schedule (99.7 vs. 82.5 per 1,000 patient-days, $p=0.03$). Finally, interns made 5.6 times as many serious diagnostic errors during the traditional schedule as during the intervention schedule (18.6 vs. 3.3 per 1,000 patient-days, $p<0.001$) (Landrigan et al., 2004).

80 Hour Weeks

Similarly, Lockley et al. conducted a study demonstrating that modest changes in an 80-hour schedule produced an approximate 50% decrease in attention failures in interns (2004). Twenty interns were studied during two three-week rotations in intensive care units, each during both the traditional and the intervention schedule. Subjects completed daily sleep logs validated with regular weekly episodes (72 to 96 hours) of continuous polysomnography ($r=0.94$) and work logs validated by means of direct observation by study staff ($r=0.98$). The study results show 17 of 20 interns worked more than 80 hours per week during the traditional schedule (mean, 84.9; range, 74.2 to 92.1). All interns worked less than 80 hours per week during the intervention schedule (mean, 65.4; range, 57.6 to 76.3). On average, interns worked 19.5 hours less per week ($p<0.001$), slept 5.8 hours more per week ($p<0.001$), slept more in the 24 hours preceding each working hour ($p<0.001$), and had less than half the rate of attention failures while working during on-call nights ($p=0.02$) on the intervention schedule as compared with the traditional schedule (Lockley et al., 2004). The remarkable results confirm the assertion of this paper that managing sleep is the correct and safer approach and produces positive outcomes.

Acute sleep deprivation is typically defined as zero to four hours of sleep in a twenty-four hour period. Sleep debt (less than eight hours in a twenty-four hour period) must be made up in the next sleep cycle to prevent the development of chronic sleep deprivation. Chronic or partial sleep deprivation is repetitive daily sleep of less than seven to eight hours in twenty-four hours. The results of the Landrigan et al. and Lockley et al. studies clearly show that work shifts of 24 hours or more and every third night call schedules are dangerous. While data is not available, most people would agree that disasters put far worse strains on medical systems resulting in even longer than normal “traditional work schedules.”

Although many studies now show the need for altering resident training schedules, no studies were found on work schedule comparisons and fatigue during disaster training or real world disasters despite multiple search protocols. Since no such similar research involving disaster management exists, the goal is to learn from the medical field and extrapolate the medical findings into the various fields of work required during disaster responses, all of which require attention, focus and often precision. Evidence that eliminating extended work shifts and reducing the number of hours interns work per week can reduce serious medical errors in an intensive care unit (Landrigan et al., 2004) has direct relevance for disaster relief efforts as well. During disaster relief efforts and training events, disaster relief management and medical facilities often do not have clearly defined sleep schedules.

MEDICAL PARADIGM FOR DISASTERS

Disasters can increase the demand for healthcare and limit the ability to provide it. In an editorial in *Critical Care Medicine* entitled “A time to work and a time to rest,” Carolyn Bekes cited numerous relevant articles outlining the situation in a high operational, real-world training environment (2003). This is an excellent paradigm for disaster leaders to study. She found emergency medicine residents admitted to being involved in a higher number of motor vehicle crashes and near crashes after working night shifts compared with other shifts (Steele, Ma and Watson, 1999). Another article found that, by the fifth month of internship, trainees demonstrate significantly increased levels of depression-dejection, anger-hostility and fatigue-inertia (Bellini, Baime and Shea, 2002). While relief efforts do not typically last for similar durations, recent disasters, e.g., the Bali tsunami and Hurricane Katrina, exemplify disasters that have required prolonged disaster relief demands. Even a year after these events, recovery efforts still continued for both disasters. Surprisingly, studies from spring 2006 literature searches did not identify any fatigue management case studies generated by these extensive disaster management events. In fact, research during actual disasters appears emaciated at best and limited to anecdote (Vankawala, 2005). Organized and mandated sleep as a leader-driven requirement and intervention has proven effective in medicine and certainly would be applicable in disaster management.

DRIVING AFTER WORK

It is worthwhile to highlight a few final areas of research derived from fatigue in medical training. It is not just the dangerous and potentially adverse cognitive errors at work that impact training physicians. One of the most substantiated hazards of sleep deprivation and fatigue is driving while fatigued. Table 4 graphically demonstrates the serious outcomes of sleep deprivation for any member of a team, be they doctor or disaster responder. These results came from a 1996 study of pediatric physician residents prior to the mandatory ACGME work hours (Marcus, 1996).

A similar emergency resident study looked at automobile accidents and established the prevalence rate for collisions and sleep deprivation up to eight percent; of note, 74% of these accidents followed working a night shift. The prevalence rates of near-miss accidents rose to 58%; again most would-be accidents (80%) occurred after a night shift (See Table 4). Incidentally, this group of residents reported a “tolerance to shift work and the ability to adapt to drowsiness" (Steele et al., 2005). Tolerance and adaptation to sleep loss is a common misconception among many affected workers, physicians included.

Outcomes	**Residents**	**Faculty**	
Average hours sleep	2.7 +/- 0.9	6.5 +/- 0.8	
Falling asleep at the wheel:	49%	13%	p<00.1%
Traffic Citations:	25%	18%	
Motor Vehicle Accidents	20%	11%	
Feel asleep at stop light	44%	12.5%	p<00.1
Falling asleep while driving	23%	8%	NS
Nearly all accidents for residents occurred post call			

Table 4. Automobile Accidents and Pediatric Residents and Physicians. Adapted from Marcus, 1996.

The third landmark medical study of this type reported the effect of the extended-duration work hours on driving safety in interns (Barger et al., 2005). In 2,737 participants who completed 17,003 monthly reports, the odds of encountering a traffic accident or a near-miss incident after extended work shift was two-fold and six-fold greater than the risk following a regular shift. The investigators demonstrated a dose-effect relation between the number of extended work hour rotations in a month and the risk for a motor vehicle crash during the same month. The authors concluded that current ACGME regulations allow residents to work 30 consecutive hours during a shift, and that further restriction of work hours is sorely needed.

Figure 13 shows cognitive performance by residents on awakening from sleep compared with subsequent sleep deprivation. The group mean (horizontal dotted line) across the sleep inertia period and 26-hour awake period has been added to the deviation from the mean scores for the number of correct responses in 2 minutes to permit overall assessment of the magnitude of performance impairment (Wertz, 2006). The results show that, even at one night of sleep deprivation, cognitive performance decreases by almost 20% from 25 to 21 (Wertz, 2006).

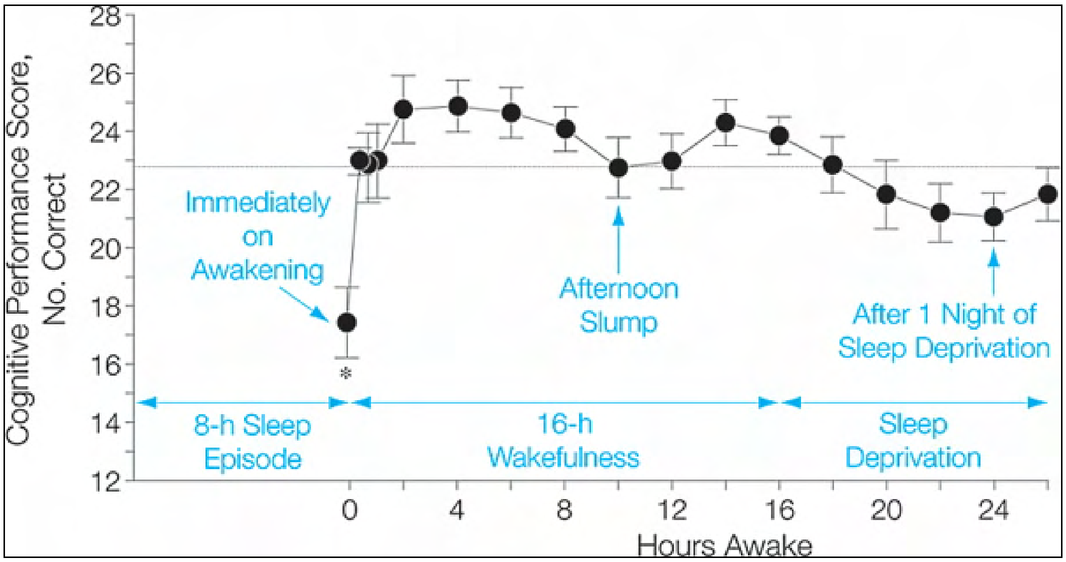


Figure 13. Cognitive Performance Score. Adapted from Wertz 2006.

Table 4 and Figure 13 help to highlight the serious risks of having any persons work excessive hours and the impact of 24 hours awake on cognitive performance. There can also be significant individual-to-individual variation in the level of impairment at given degrees of sleep deprivation, but humans have not been found able to predict their own cognitive impairment due to sleep deprivation (Dinges & Kribbs, 1991). That theme will be revisited later.

AMERICAN ACADEMY OF SLEEP MEDICINE

Medicine has made vast improvements in studying the science of sleep and embracing the ideas set forth by studies involving sleep management, but this has been a century-long progress. However, some important contributions did occur during the decades of sleep abuse, e.g., the establishment of the American Academy of Sleep Medicine (AASM). AASM is the professional organization representing sleep specialists and accredited sleep centers. AASM was a sponsoring organizations for the Institute of Medicine (IOM) report, "Sleep Disorders and Sleep Deprivation: An Unmet Public Health Problem" released April 4, 2006 (Colten & Altevogt, 2006). AASM recognized that sleep medicine is an independent specialty of medicine that is interdisciplinary in nature but requires specialized training (Rosen and Zozula, 2000). The IOM report shed more light on the problem of the large numbers of people with unrecognized and undiagnosed sleep disorders that adversely affect health and performance. The major obstacle to people getting appropriate care is the public's lack of awareness of the importance of avoiding sleep deprivation and detecting sleep disorders (National Commission on Sleep Disorders Research, 1993).

SUMMARY

Awareness of the burden of sleep loss must be increased, among both the general public and health care/disaster management professionals. Knowledge of sleep science and sleep medicine needs to be increased at all levels and in all fields of medical training and leadership training. The need for increased investment in sleep research to develop adequate sleep/work requirement calls for continuing development of the field and development of new technologies to deal with the challenge of managing fatigue, especially during critical times like disaster recovery.

CHAPTER 4: FATIGUE IN THE TRANSPORTATION INDUSTRY

There is no evidence that excessive hours are necessary for competitive success, but somehow we've gotten in our minds that the way to succeed in this world is to work yourself to death.

Thomas Paine (1737-1809)

While the economic benefits of industrialization and shift work are known, they also bring social and health costs (Milter et al., 1988). Research over the last 30 years has clearly identified shift work as an occupational health and safety risk factor. Thomas Paine's quotation is still applicable today. Such a mindset exacerbates the levels of fatigue that threaten personal safety, both at work and at home (Caldwell, 2001).

OVERVIEW

The basic manifestations of fatigue and disrupted circadian rhythm has been clearly linked to health and safety problems, involving decrements in psychophysical and physiological functions, plus subjective complaints (Ahasan, Lewko, Campbell & Salmoni, 2001). Extended wakefulness and sleep disruption are generally considered to be the major risk factors associated with shift work related accidents (Leger, 1994; Akerstedt, Czeisler, Dinges & Horne, 1994; Mitler et al., 1988). Previous chapters have dealt with fatigue concerns and management approaches in areas such as the military and in medicine. This chapter addresses fatigue in various areas of commerce, focusing specifically on those that involve transportation and the impact of fatigue on driving as a work-related activity.

THE COST OF SLEEP DEBT

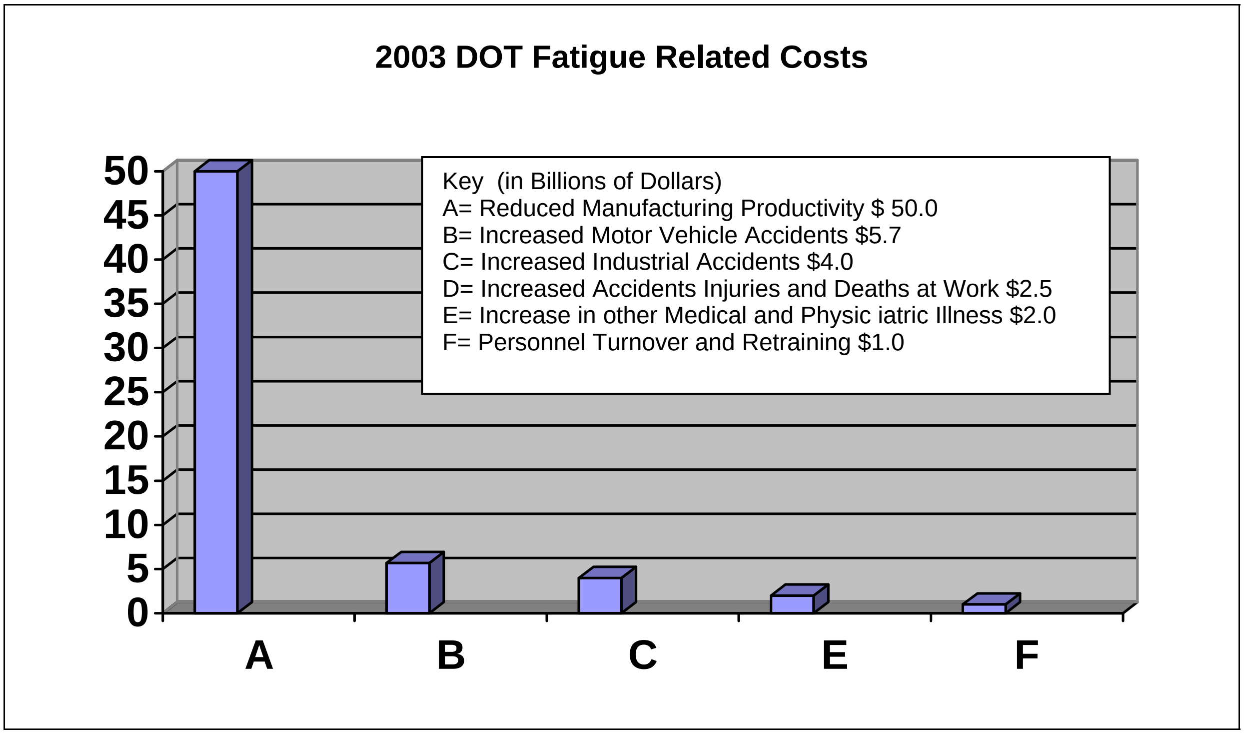
Each year sleep related accidents and errors cost the United States over $56 billion, cause 25,000 deaths and result in over 2.5 million disabling deaths (Coren, 1996). Insurance studies have found on average a seven percent increase in automobile accidents occurring in the week following the onset of Daylight Savings Time, due to the one-hour sleep debt incurred by people who are running on a seven to eight hour sleep pattern (Coren, 1996). In a mid 1990’s study conducted by the National Transportation Safety Board (NTSB), 23% of drivers admitted to falling asleep at the wheel in the past twelve months (2001). The National Highway Traffic Safety Administration estimates that drowsy drivers are responsible for 100,000 crashes, 1,500 vehicular deaths and 71,000 fall-asleep injuries each year (NTSB, 2001; Knippling and Wang, 1995). With regard to off-duty injuries and deaths, the NTSB estimates that each year nearly 100,000 motor vehicle crashes (about 1.5% of all crashes) are principally caused by driver fatigue (NTSB, 2001). Conservatively, it has been estimated that fatigue is responsible for 4% of all traffic crash fatalities (Coren, 1996). The annual total cost of these crashes has been estimated at $12.5 billion (Caldwell, 2001).

INTERNATIONAL SCOPE

Driving impairments are not unique to the United States. A United Kingdom study found that falling asleep while driving accounts for up to 30% of vehicle accidents that occur during monotonous driving conditions (Feyer, 2001). Many of these accidents are related to work: for example, drivers of trucks, goods vehicles and company cars. Time of day (circadian) effects on the driver are profound, with sleepiness being particularly evident during night shift work or driving home after work (Feyer, 2001). Circadian factors are as important in determining driver sleepiness as is drive duration, but only duration of the drive is built into legislation protecting professional drivers (Horne & Reyner, 1996). Unintended sleep episodes occur during the sleep nadir period also. A survey of car drivers in the United Kingdom found that 29% admitted to having felt close to falling asleep while driving in the previous year (Feyer, 2001). The pattern of reported driving incidents is consistent in both the UK and US. Among a study of New York drivers, about a quarter reported having at some time fallen asleep at the wheel (Feyer, 2001). Around a third of truck drivers responding to a national survey in Australia reported that fatigue was a substantial problem (Dawson & Anderson, 2001). A comparison of the effects of sleep deprivation and alcohol intoxication found that after 17-19 hours without sleep, starting from waking at about 0600 hours, individuals' performance was equivalent to or worse than at 0.05% blood alcohol concentration (Williamson & Feyer, 2000). This relationship between the impacts of fatigue and alcohol blood levels is probably the best analogy available. Most people can grasp the safety risk of driving while under the influence of alcohol and the analogy is highly effective. The U.S. Navy teaches this comparison to flight surgeons, pilot applicants, and safety officers at command safety courses (Cantrell, 2006). This measure of impact may be the best way for leaders to approach this problem.

DOT

The Department of Transportation (DOT) is very interested in fatigue and fatigue related impacts to the economy. The DOT has developed safety and educational guides on fatigue. It has a Human Factors Committee. Data from 2003 was compiled in a 45 slide presentation entitled *“Towards a Comprehensive Approach of Fatigue Management: The Operator Fatigue Management Program.”* The work is designed to educate the operator and management on the history of the problem, factors, the costs and solutions to the problem. The costs are impressive: $50 billion in reduced industrial productivity and $4 billion in industrial accidents (Graph 1) (Coplen et al., 2003).



Graph 1. DOT Fatigue Related Costs, 2003. Adapted from Transportation Research Board, 2003.

The presentation of the DOT Human Factors Committee states that leadership appear to treat all hours of the day the same, have regulations independent of job task and workload, do not consider the sociological and schedule proximal tasks and finally that little or no responsibility placed on worker concerning fatigue (Coplen et al., 2003). The authors also state that transportation work is characterized by: shift lengths that are often greater than eight hours per day; often significant mental and physical stress; varying high and low workloads; required night time shift rotations and the occurrence of irregular work/rest patterns (Coplen et al., 2003). Certainly this sounds just like a disaster relief work scenario. It has a nicely organized fatigue "puzzle" that outlines many of the variables that multimodal transportations balance (Figure 14).

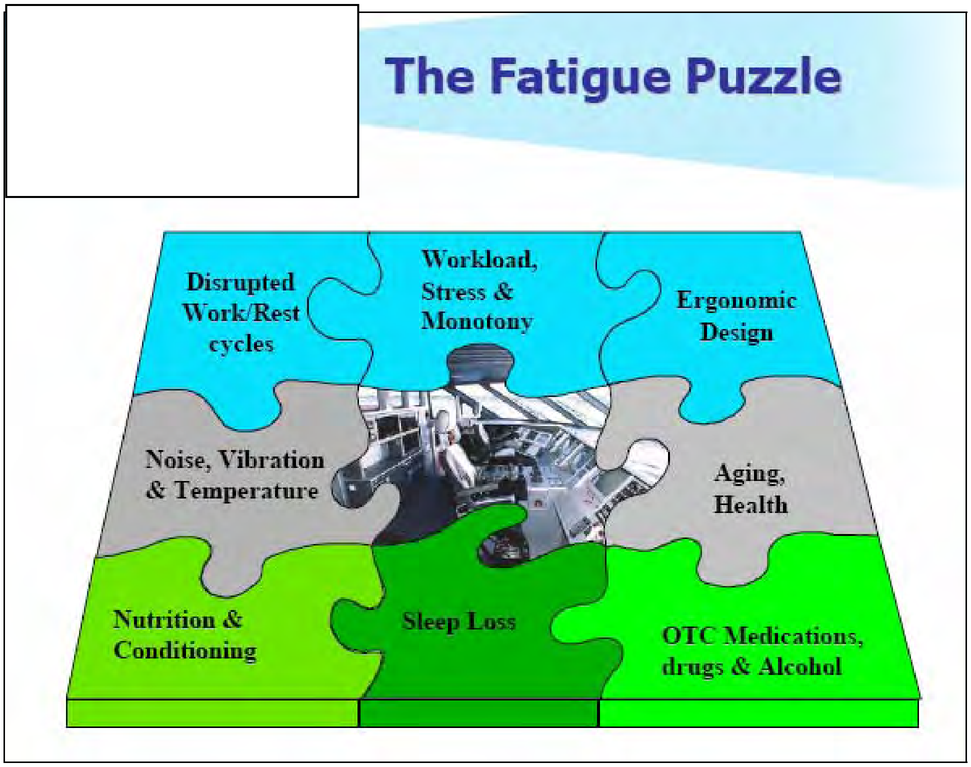


Figure 14. DOT Fatigue Puzzle. Adapted from Coplen et al., 2003.

The work concludes with many recommendations. Of note it uniquely stresses the following specific concepts not seen in any other data reviewed for this capstone. It advocates for the establishment of a cross-government working group of program managers to develop research-based procedures for establishing a curriculum and credentials for work schedule managers, with the goal to confer professional status and advanced training to individuals with similar job descriptions and responsibilities for staffing, schedule design and management of work schedules. This DOT fatigue training guide is well done and brings up a truly relevant issue. This work is worth reviewing by any person in a leadership or disaster staffing positions.

HISTORY OF HOURS-OF-SERVICE REGULATIONS

Commonly experienced levels of sleep deprivation equivalent to one extended day for a well-rested individual have a profound effect on performance. At around 2230-2430, well before reaching the circadian trough in alertness, performance levels are low enough to be considered incompatible with safe driving in many countries (Feyer, 2001). The current hours-of-service regulations in transportation vary quite differently from mode to mode. The motor carrier hours-of-service regulations were developed in 1937 and have remained essentially unchanged up to the late 1990's (NTSB, 2001). The Railroad Hours of Service Act was first enacted in 1907, substantially revised in 1969, and amended again in 1976 and 1988. Aviation limits were addressed in the Civil Aeronautics Act of 1938 and the Federal Aviation Act of 1958 (NTSB, 2001).

In 1985, domestic flight limitations and some commuter limitations were updated; flag and supplemental operations were not. The work-hour regulations for marine operations are specified in Title 46 *United States Code* (U.S.C.) 8104 and date back to the early part of the 20th century. The Oil Pollution Act of 1990 contained work-hour limitations for tank personnel of 15 hours per 24 hours and 36 hours per 72 hours (NTSB, 2001). The legislation agencies, regulatory agencies and enforcing agencies differ and as a result make this a complex process for achieving rapid change.

A 2001 NTSB report titled Evaluation of U.S. Department of Transportation Efforts in the 1990's to Address Operator Fatigue provided an update on the activities and efforts by the DOT and the modal administrations to address operator fatigue. That report also provides some background information on current hours-of-service regulations, fatigue and the effects of fatigue on transportation safety (NTSB, 2001).

The NTSB safety report made 70 recommendations to the DOT, states, industry, and industry associations to reduce the incidence of fatigue-relate accidents (2001). As a result, the National Transportation Safety Board issued new safety recommendations to the U.S. Department of Transportation, the Federal Aviation Administration, the Federal Highway Administration, the Federal Railroad Administration, the Research and Special Programs Administration, and the United States Coast Guard. One can start to see how this becomes complex, as these various groups have to implement policy change, regulate and enforce these recommendations.

Fatigue research of this type really came of age in the 1980's. An excellent chapter in a British study entitled *Fatigue and Accidents: A Comparison Across Modes of Transportation* reviews research data from the 1980's and breaks them down into patterns of accident rates. The chapter is quite thorough and cites articles supporting increased accident rates in multi-transport modes in the following categories: time of work, night work, disruption of sleep, second circadian peak, cumulative fatigue and extended rest. The key points are: 1) drivers with shifts exceeding fourteen hours have shown nearly three times the accident rate of those less than ten hours; 2) naval mishaps show a marked diurnal distribution with the lowest rate from 0900 to 1800; 3) the earlier the morning start time, the higher the rates of accidents; 4) there appears to be a second early afternoon circadian peak of accidents, particularly in those who have been at work for long periods; 5) cumulative fatigue effect has not yet been extensively studied, but working a week or longer are important factors, due to a pattern of prolonged work and inadequate rest and sleep. (McDonald, Fuller and White, 2006).

THE COST OF SLEEP DEBT

Stanley Coren is a Canadian professor of psychology at UBC who draws together strong evidence that we, as a society, do not sleep as much as we used to or probably need to. His investigations shed light onto many areas of fatigue in industry and transportation. He started off with a history lesson on Thomas Edison, who hated sleep so much that he invented the light bulb. By this, Edison hoped to render sleep obsolete. Instead, light bulbs and the demands of a modern industrialized society have all modern people likely more fatigued. Coren examines the lives of many work-areas, such as those of truck drivers, shift workers and airplane pilots. His goal was to see what happens when sleep is disrupted or limited in these areas. He argues that running up sleep debt is very expensive and that each year sleep related accidents and errors cost the United States over $56 billion, cause 25,000 deaths and result in over 2.5 million disabling deaths (Coren, 1996). His book is an advised resource for leaders interested in fatigue.

THE NTSB

In the United States the NTSB is tasked to investigate accidents in specific areas of transportation commerce including the aviation, highway and marine accidents that involved operator fatigue. Following years of accident investigations, the NTSB Safety Board in 1989 issued three recommendations to the U.S. Department of Transportation (DOT) addressing needed research, education, and revisions to hours-of-service regulations (NTSB,1995). It was these recommendations that then led to the ten year follow up and many of the statistics noted at the beginning of this chapter.

Moving to a new light/dark schedule, such as a shift to nightwork or a time zone change, can create internal and external desynchronization. These involve an internal desynchrony among circadian rhythms and a discrepancy between internal circadian timing and external/environmental cues, respectively. The internal clock can take from several days to weeks for adjustment or, in some circumstances, not fully resynchronize at all. Scientific studies have demonstrated these findings in the laboratory and in field studies conducted during actual transportation operations (Kryger, 1994; Minors & Waterhouse, 1985; Dijik et al., 1992). Since 1989, the NTSB Safety Board has issued many fatigue-related safety recommendations, the result of major accident investigations, special investigations, or safety studies that identified operator fatigue as a factor. Table 5 summarizes these findings and includes 11 accident reports or studies in aviation regarding air tours and operations conducted under Parts 91, 121, and 135; seven in highway regarding bus drivers and truck drivers; three in marine regarding passenger vessels and tank ships; four in railroad regarding freight trains, passenger trains, and rail transit operations; and one in pipeline regarding pipeline controllers (NTSB, 1990, 1991, 1994, 1995, 2001).

A 1990 safety study that examined the causes of 182 accidents that were fatal to the driver of heavy trucks found that fatigue was involved in 31% of the fatal-to-the-truck driver accidents (NTSB, 1995). A 1995 study of 107 accidents (62 of which were fatigue related) examined the factors that affect fatigue in heavy truck accidents. The Board found that the three most critical factors that predicted a fatigue-related accident were duration of sleep in the last sleep period, the total hours of sleep obtained during the 24 hours prior to the accident, and the presence of split sleep periods (NTSB, 1995).

FATIGUE RELATED ACCIDENT DATA

Location of NTSB accident or topic of study that identified fatigue-related issues	**Accident date**	**NTSB report number**
Accident Investigation: Aviation		
Molikai, HI	10/28/89	AAR-90/05
Brunswick, GA	04/05/901	AAR-92/03
Pine Bluff, AR	04/29/93	AAR-94/01/
Guantanamo Bay, Cuba	08/18/93	AAR-94/04
Kansas City, MO	02/16/95	AAR-95/06
Cheyenne, WY	04/11/96	AAR-97/02
Everglades, FL	05/11/96	AAR-97/06
Special Investigation:		
Commercial space launch, Cape Canaveral, FL	08/17/93	SIR-93/D2
Safety Study:		
Flight crew-involved accidents	02/03/94	SS-94/01
Commuter airline safety	11/30/94	SS-94/02
Aviation Safety in AK	12/01/95	SS-95/03
Accident Investigations: Highway		
Sutton, WV	07/26/90	HAR-91/01
Donegal, PA and Caroline, NY	06/26/91, 08/03/91	HAR-92/01
Evergreen, AL	05/19/93	HAR-94/02
White Plains, NY	07/27/94	HAR-95/02
Special Investigations:		
Selective motorcoach issues	02/26/99	SIR-99/01
Safety Study:		
Accidents fatal to the truck driver	04/04/90	SIR-90/01
Truck driver fatigue	02/07/95	SS-95/01
Accident Investigation: Marine		
Valdez, AK	03/24/89	MAR-90/04
Santa Catalina Island, CA	06/14/89	MAR-90/05
Lynn Canal, AK	06/23/95	MAR-97/02

Table 5: NTSB Fatigue Related Accident Data. Adapted from NTSB, 2001.

Impact of fatigue in the aviation industry has been noted earlier. However, the following maritime industry example will give the reader an idea of the data seen in this landmark NTSB report. A 1996 United States Coast Guard (USCG) analysis of 279 incidents showed that fatigue contributed to 16% of critical vessel casualties and 33% of personal injuries (McCallum, Raby and Rothblum, 1996). Looking at a specific maritime transportation incident is helpful. On May 26, 2002, a river towboat pilot at the controls of the towboat M/V Robert Love pushing barges fell asleep or lost consciousness, hitting the Webber Falls, Oklahoma I-40 Arkansas River Bridge. Fourteen motorists who drove off the collapsed bridge into the Arkansas River lost their lives (NTSB, 2001). Towboats operate 24 hours a day on the inland rivers and waterways of this nation. These boats push barges under bridges supporting roadways traveled by thousands of people every day. Towboats are manned 24 hours a day, 365 days a year. Each towboat operates with multiple crew changes on a scheduled interval set by the river transportation company that owns or leases the boat.

As with truck drivers, a federal law is supposed to protect the public from overtired towboat crews: 46 U.S.C. 8104 (h) (river men call it the 12 hour rule). Tragically, this federal fatigue code is not enforced on American inland waterways. It has been ignored by most river transportation companies because the federal government policy allows towboat companies police themselves. The Coast Guard is the federal agency that is supposed to provide safety on the inland rivers of this nation and enforce safety laws like the 12-hour rule (United States Coast guard, 2006).

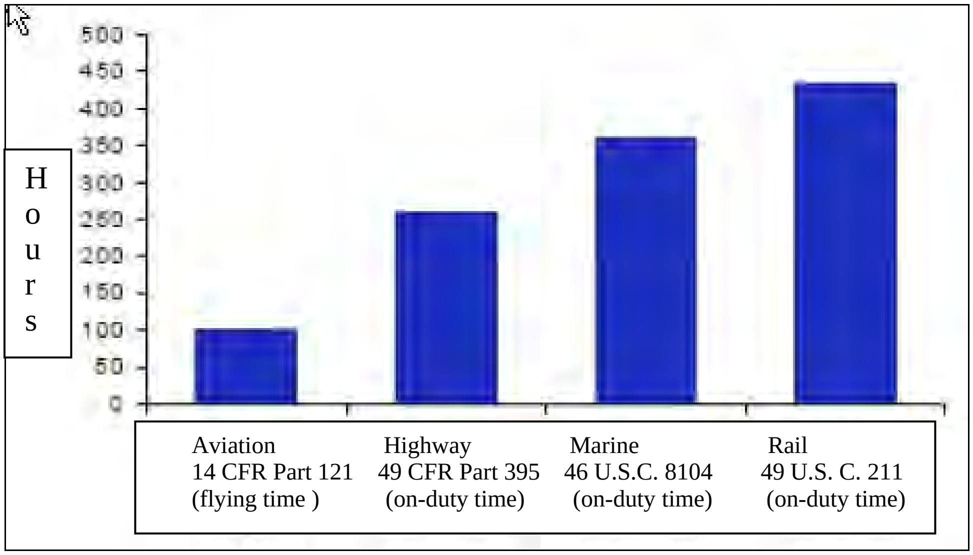
Work of this type by the NTSB has had positive impacts and, as in the military, the truck transportation industry has taken a proactive stance in training employees and designating safety officers. Starting in 1996, the Federal Motor Carrier Safety Administration and the

American Trucking Associations have co-sponsored and conducted “train-the-trainer” fatigue management courses for over 3,700 safety and risk managers in the trucking industry. The goal is to provide training material to safety officers, which they can use to foster alertness and implement fatigue management programs in their companies. The program offers a 19-minute family-oriented VHS video on driver fatigue, accompanying helpful booklets and pamphlets, a set of over 50 PowerPoint slides, and a comprehensive lecture to accompany the course.

The course, “Mastering Alertness and Managing Commercial Driver Fatigue,” covers topics as: the importance of obtaining adequate rest and sleep, body and sleep physiology, circadian rhythm effects, shift-lag influences from rotating work schedules, sleep disorders, the influences of chemical substances, a list of drowsy driver warning signals and a set of fatigue countermeasures (McCallum, Sandquist, Mitler, & Krueger, 2003). Certainly the trucking industry has not been cured of its fatigue-related problems, but proactive guidance and regulation has helped to limit risk to the workers and society.

CODE OF FEDERAL REGULATIONS FOR MAXIMUM WORK HOURS

One of the outcomes of this type of work has been further regulation on the mandatory number of hours workers can function in certain types of transportation jobs (Graph 2). The regulations for aviation, highway, and some marine vessel types impose weekly work and rest limits. Only the aviation mode has monthly and annual limits as well. The maximum number of hours an employee of each mode is permitted to work in the course of a 30-day period is shown in the chart. A scheduled air carrier pilot may fly up to 100 hours per month; a truck driver may be on duty up to about 260 hours per month; licensed individuals on an oceangoing vessel or coastwise vessel of not more than 100 gross tons (GT) may operate up to 360 hours per month when at sea; and locomotive engineers may operate a train up to 432 hours per month (NTSB, 2001).



Graph 2 Code of Federal Regulations for Maximum Work Hours in a 30-day Period. Adapted from NTSB, 2001.

The adverse effects of sleep deprivation and fatigue on public safety have been recognized, not only in truck drivers, but in other workers as well, e.g., workers on offshore oil rigs (Mitler, Miller and Lipsitz, 1997). The list of occupations and industries that employ counter fatigue business models is extensive. Suffice it to say that most successful businesses with extended work hours employ policies to effectively limit accidents from fatigue. Whether at work or while driving, even a microsleep event, lasting 10 to 60 seconds, provides ample time to get into a serious and possibly fatal accident. These events occur with little or no warning. Certainly, drowsiness can also result in industrial accidents, decreased productivity and interpersonal problems (Dinges, 1990). Commercial aviators, industrial workers and plant operators have long had opportunities to acquire fatigue-management training focused on their safety and productivity needs, and this training has proven quite effective. Interestingly, some of the early comprehensive training programs on how to manage fatigue within the specialized setting of military aviation operations came from reviews of industry "Best Practices" (Cantrell, 2006).

BEST PRACTICES

The Navy did this very thing in its efforts to reduce human related error and accidents in aviation (Cantrell, 2006). As seen in the military, industry, government and even medicine take this topic quite seriously. More importantly, it is obvious that many organizations study what other groups do and learn from them.

The transportation industry is concerned about fatigue on multiple levels. Fatigue related accidents are expensive both in fines and in sheer operating costs. Fatigue is a continued challenge that is recognized in the transportation operations since they frequently require around-the-clock operations, sometimes globally. The National Transportation Safety Board has found fatigue to be causal or contributory in accidents in every mode of transportation, and has issued almost 80 fatigue-related safety recommendations since 1972 (NASA, 2006).

Probably one of the most comprehensive and respected transportation countermeasures programs is that developed by the National Aeronautics and Space Administration (NASA) Ames Fatigue Countermeasures group. One of the things that NASA Ames has done is collaborated with the NTSB to create a multimodal symposium, *Managing Fatigue in Transportation: Promoting Safety and Productivity* (NASA, 2006). NASA Ames has addressed fatigue in aviation through research and other activities since 1980 (NTSB, 2001). NASA's work will be addressed in more depth in the aviation chapter.

Based on expertise from 15 years of field research, the Ames program has developed a comprehensive approach to managing fatigue in aviation, which can be generalized to managing fatigue in all modes of transportation. The work has allowed the transportation industry to recognize that fatigue is a major factor in accidents. It has taken decades of research and teaching to get industry to legitimately accept this. NASA Ames supported this process; they repeatedly demonstrated impacts of fatigue in NTSB Safety Board’s symposiums like the one in 1995 (NTSB, 2001). Further, the NTSB and NASA Ames Safety Board’s in-depth investigations have clearly demonstrated that fatigue is a major factor in transportation accidents (NTSB, 2001).

GLOBAL APPROACHES

Fatigue in transportation is a global problem and the steady progress of researchers and science in the field of sleep has been provided dividends. Many countries now have national programs to mitigate driver fatigue and fatigue in general. They track statistics and develop programs to counter the hazards of road fatigue. Figure 15 is from a product developed by the Road Transportation Administration (RTA) of New South Wales. The program is called Road Safety 2010: Driver Fatigue Management Action Plan 2002-2004. It shows the road fatality statistics from fatigue from 1986 to 2001 for New South Wales (RTA, 2004).

They also advertise to educate the public. In Australia one can see road campaigns of semi trailers with images such as a soft drink can labeled “Sleep” and the phrase “The only quick fix for fatigue!” (Figure 16).

In England the deadly consequences of falling asleep at the wheel are being highlighted in a hard-hitting road safety campaign. Signs on motorways urge drivers to "Think Don't Drive Tired." Many countries stress that falling asleep when driving can be a factor in

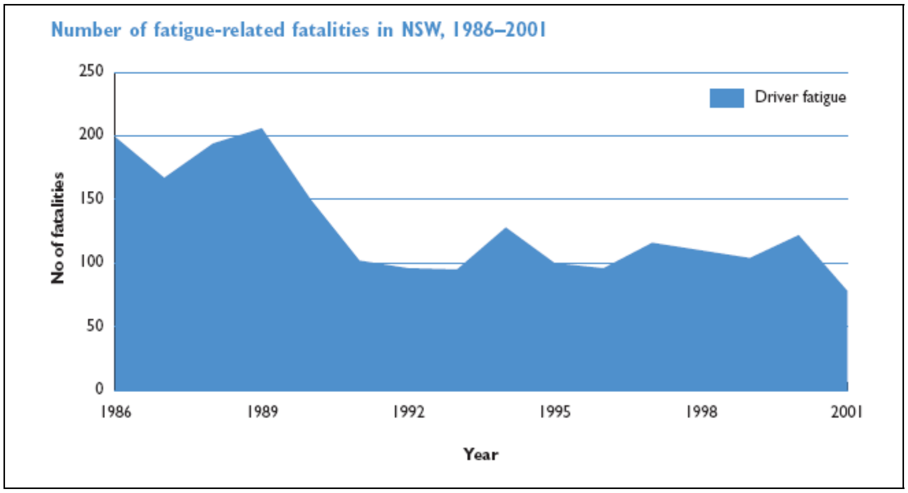


Figure 15. Australian New South Wales Drive Fatigue Fatalities. Adapted from RTA, 2004.

serious accidents. The 2001 Selby train crash in England, in which ten people died, brought the issue center stage globally. That automobile driver was jailed for five years after falling asleep and veering into an oncoming train (Campaign, 2002). It is likely that as public awareness grows and the analogy of fatigue to alcohol consumption is promoted, the U.S., will start to see increased liability litigation and court sentences for fatigue related accidents. The Road Safety Minister of Britain says that "Sleepy drivers kill 300 people a year in the UK; 90% of motorists admit driving when too tired; 50% of motorists would drive for 10 hours a day and that 10% of road accidents are linked to falling asleep" (Campaign, 2002).

The United States has seen a change for the better towards educating the public on this transportation issue as well. Driving is a shared experienced by many and it is the link between educating the public as well as those in the trucking industry. The National

Figure 16. Australian New South Wales Driver Fatigue Safety Program Images.
Adapted from RTA, 2004.

Sleep Foundation (NSF) is the organizer and sponsor of National Sleep Awareness Week ® (NSAW), an annual public education, information and awareness campaign. Now in its ninth year, this nationwide effort is the cornerstone for multiple initiatives designed to make sleep consciousness a part of every person's lifestyle. This year's theme is "Sleep: As Important as Diet and Exercise (Only Easier!)." Each year, the timing of the campaign coincides with the return to Daylight Saving Time, when clocks "spring forward" at 2:00 a.m. on the second Sunday in March – a time when most Americans lose an hour of sleep confirming Cohen's 1996 admonition about the risk of Daylight Savings time.

Nearly 100 federal and state agencies, nonprofit organizations and associations work in support of NSAW as Sleep Awareness Co-Sponsors, tapping their own membership and communications networks to help spread the word about the importance of sleep to health, safety and well-being. Among 2007's co-sponsors are the American College of Chest Physicians; Centers for Disease Control and Prevention; Federal Aviation Administration; Federal Railroad Administration; Federal Motor Carrier Safety Administration; National Association of Secondary School Principals; National Association of Student Councils and the National Transportation Safety Board (National Sleep Foundation, 2006).

Fatigue research in transportation as in most other fatigue fields has a major hurdle; there is no gold standard for measuring or monitoring fatigue. There are currently a growing number of technologies that purport to help drivers manage fatigue and drowsy driving. The DOT has an obvious interest in this area. As an example, Dr. David Dinges and colleagues conducted a study called "The Fatigue Management Technologies Pilot Test." It was sponsored by the Federal Motor Carrier Safety Administration (FMCSA) and Transport Canada (TC), in cooperation with the American Transportation Research Institute (ATRI). In addition to finding an objective test for fatigue, there is a critical need to determine whether feedback from such technologies during driving could affect the behavior or alertness of commercial motor vehicle operators (Dinges, 2004).

Building on previous work at the U.S. Department of Transportation, the study examined the effects of feedback from a group of fatigue management technologies (FMT) bundled as a single intervention. The study was tasked to develop an experimental design and instrumentation plan and conduct a pilot test of commercial truck drivers' reactions to a combination of FMT, under current Federally-mandated hours-of-service in both Canada and the U.S. Since it was neither cost-effective nor practical to conduct a separate study of each individual technology, the selected technologies were combined and tested as a set within in a single field trial that had two phases – one completed in Canada and a second phase completed in the U.S.

The project involved an extensive over-the-road test of the combined set of FMT. It compared *SleepWatch®* a wrist worn actigraphic monitoring device; *CoPilot®* an infrared-based retinal reflectance monitor for eye closure detection; SafeTRAC® a technology selected for providing feedback to drivers on their lane tracking, lane drifting, and weaving; and finally a technology selected for reducing the physical work of controlling vehicle stability while driving called the *Howard Power Center Steering® (HPCS)* system. Unlike the other FMT technologies that were designed to provide feedback to drivers on their behavioral alertness relative to fatigue based in sleep and circadian biology, the *HPCS* system was designed to lessen physical fatigue associated with drivers "fighting" the steering wheel in cross winds. The objective was to determine how drivers, engaged in over-the-road trucking operations, reacted to FMT, and whether the technologies would improve the alertness and fatigue awareness of commercial truck drivers by providing them with information feedback about changes in sleep need, in drowsiness, and in driving performance during their routine driving schedules (Dinges, 2004).

CONSENSUS STATEMENT

Understanding the problem of fatigue has certainly not been resolved in the transportation industry, but it has made strides and has even evolved into national awareness campaigns. However, industry is broad-based and a final summary from experts seems appropriate. In 2000 The Journal of Sleep Research published a consensus statement from an international group of scientists who study human performance, safety and prevention of accidents associated with work schedules, night activity, and inadequate sleep and made the following six points: 1) the 24 hour society, with around the clock operational demands in all transport modes, challenges the powerful and vital need for sleep. Sleep, alertness and performance are fundamentally linked to the 24-hour biological clock. 2) The major causes of fatigue are: (a) the time of day of the transport operation (e.g. night/early morning), (b) a long duration of wakefulness, (c) inadequate sleep, (d) pathological sleepiness (sleep apnea, etc) and (e) prolonged work hours (not necessarily while operating a vehicle). 3) Fatigue (sleepiness, tiredness) is the largest identifiable and preventable cause of accidents in transport operations (between 15 and 20% of all accidents), surpassing that of alcohol or drug related incidents in all modes of transportation (Akerstedt, 2000). Official statistics often underestimate this contribution. 4) Underestimation of the impact of fatigue can lead to the under-utilization of important countermeasures. 5) Public and environmental safety, health and productivity are compromised by fatigue and sleepiness, with substantial financial costs to individuals and society. 6) Fatigue related risk may be reduced through a variety of interventions, that include education (about sleep, the biological clock, sleep disorders, and fatigue countermeasures), improved scheduling of work hours and the judicial use of strategies and technologies (Akerstedt, 2000).

The commerce industry and, specifically, transportation offers valuable lessons to leaders, the greatest being that education and sound practices pay off. Patterns and countermeasures to mitigate fatigue hazards during disasters can be drawn from the experience of the fields noted in this work. Other superb examples in industry, such as power companies and production plants, exist. What is surprising is that an extensive literature search through the literature could not locate a rest policy for emergency providers. In addition, informal discussions with law enforcement and EMS staff did not find any common policies among the groups. A visit to the Emergency Operations Center at the CDC in January 2006 resulted in the same outcome: no consistent practice or policy on fatigue management (Noah, 2006).

SUMMARY

Secretary Norman Mineta, former director of the Department of Transportation (DOT) stated in 2004 “Our top priorities at DOT are to keep the traveling public safe and secure, increase their mobility, and have our transportation system contribute to the nation’s economic growth.” Transportation as an industry in the United States is overall a safe part of our economy. The industry and government have taken measures to reduce the risk of fatigue and educate the transportation work force to ensure that and work continues to improve that safety record. Fatigue is a complex state characterized by a lack of alertness and reduced mental and physical performance, often accompanied by drowsiness, which has no place in an vehicle operator of any type, be that boat, ship, truck or train. All of these transportation modalities are utilized in a response to disasters.

NTSB progress made in the 1990's to implement change has served the public well. These fatigue-related recommendations and the information on current hours-of-service regulations, fatigue and the effects of fatigue on transportation safety could rapidly be implemented into a FEMA and homeland security policy for staff responding to disasters. Disaster management is organized, funded and executed by an alphabet soup of governmental agencies. Having a common consensus statement of fatigue and common rules for fatigue guidance would seem obvious in this day and age.

CHAPTER 5: CIVILIAN AVIATION AND FATIGUE

(Regarding the pilot's environment) *Modern mechanisms have brought man within sight of his natural boundaries…It is possible to devise artificial aids to greatly enlarge these boundaries.*

Wing Commander G.S. Marshall, 1933

G.S. Marshall was not off the mark when he said this in 1933. The aviation field has been the lead industry in recognizing the hazards of fatigue and in mitigating it with both federal requirements and industry standards. Pilot fatigue is a significant safety issue in aviation. Fatigue is not a simple mental state that can be willed away or overcome through motivation or discipline. It is rooted in physiological mechanisms related to sleep, sleep loss, and circadian rhythms. These mechanisms are at work in flight crews no less than in others who need to remain vigilant despite long duty days, traveling, or working at night when the body is programmed for sleep.

OVERVIEW

Several examples of excellence in fatigue management in aviation were noted in the Military chapter; here the whole chapter will be devoted to aviation related fatigue topics. Pilot fatigue has been a key safety issue throughout the history of civil aviation. Its causation is complex, especially when one attempts to determine how variations in work scheduling may affect the overall level of pilot fatigue. However, it has often been difficult to establish fatigue as a sole cause of aviation accidents, even when the presence of fatigue may have appeared probable. Fatigue is felt to have a likely role in many accidents. It is cited as a cause in the disastrous Little Rock plane crash of June 1, 1999 (NTSB, 2001). A brief history of man and flight will be provided. How the area of safety and fatigue developed with the progresses in aviation and aspects of fatigue and human factors will be highlighted. Current research and policy factors will be noted with relevance to the FAA and the NTSB. Finally, a summary of NASA contributions to fatigue management in the aviation field will be provided. This chapter will continue to enhance fatigue definitions; the measurement/assessment of fatigue and the performance, mood and safety problems associated with fatigue in the aviation operational setting will be highlighted.

HISTORY OF FLIGHT

Mankind's fascination with flight has gone on for some five thousand years of recorded history.   The gods and heroes of Roman and Greek myth and legend were set apart from ordinary people because many of them could fly. Mythology from the Vikings to the Aztecs includes deities that fly. The Egyptian goddess Queen Isis had wings of a falcon and each year she brought spring to the land (Welcome, 2003).

Probably the best-known mythological story of an aviation mishap is the father and son Greek story of Daedalus and Icarus. The pair escaped from Crete by flying with wings made of feathers, twine and wax. After the escape the father told his son Icarus not to fly too close to the sun. But Icarus did not listen. The sun melted the wax and his wings came apart. He drowned in the Aegean Sea. From a modern perspective, this story of flying near the sun encompasses artificial aids that enhanced the boundaries of Greek men flying but exceeded the natural boundaries of wax in a solid state!

Ancient Mediterranean cultures are not the only source of fascination with flight. Garuda are bird-like divine creatures seen in Indian and Asian cultures. Thailand and Indonesia have the Garuda as their national symbols; the Indonesian national airline is Garuda Indonesia. In Thailand Garuda is known as Krut. Garuda is the Malay form of the Phoenix. The Japanese also know the bird-like divine creature Garuda. They call it the Karura. In Buddhist mythology, the Garuda are a race of bird-like divine creatures. Garuda are one of the three principal animal deities in the Hindu mythology.

The history of aviation is fascinating, extensive and can't be fully covered here. Suffice it to say the Chinese started flying kites over 2000 years ago. Kites led the way to the design of early gliders. Pioneer fliers such as the Englishmen Percy Pilcher, German Otto Lilienthal and the American Wright brothers began the dawn of true modern aviation (Welcome, 2003). Through the centuries, humans have tried to copy the mechanics of birds. Early aviation fatalities resulted from man's flawed attempts to jump from towers and heights with elaborate wings made of feathers. The desperate flapping of arms was to no avail during the plummet. Humans are too heavy and our muscles are not strong enough to fly. The first known recorded survivor was the Scotsman John Damian who survived a leap from a castle wall in 1507 (Welcome, 2003). Damian blamed it on the chicken wings! The real rate limiting factor is that human hearts cannot pump blood fast enough to meet the oxygen demands of wing flapping. A sparrow's heart beats at 800 beats per minute (Welcome, 2003). Just like flapping our arms has limits, humans in flight have fatigue factors too.

The use of hot air balloons allowed humans to stay in flight for long durations starting in the late 1700's. Fatigue related aviation mishaps probably first occurred in the late 1800's. In 1897, three explorers vanished trying to reach the North Pole in a balloon (Welcome, 2003). Certainly hypoxia and hypothermia may have contributed but eventually fatigue would have taken its toll on the three as well. Early ballooning also brought about the dawn of early physiology. Professor Gay-Lussac and Professor Charles gave the world their gas law and in 1793 invented the hydrogen balloon. The dawn of modern physiology began and names such as Etienne Robertson, Claude Bernard and Paul Bert (considered the father of aviation medicine) went on to pioneer many aspects of modern physiology (Dehart, 1996). Little to no mention of fatigue has been found during this era. It is not surprising as attitudes impact the acceptance of science.

The following is an example of how perception and attitudes impact mission conduct and "policy". The German Naval Airship Division conducted nuisance bombing over London during World War I. They flew at 16,400 to 20,000 feet for eight hours flights, causing severe hypoxia. At the time hypoxia was known to cause dizziness, headache, fatigue, impact judgment, and impair movement (Dehart, 1996). Aviation units also knew that hypoxia was relieved by oxygen. However the crewmembers and commanders would not use oxygen even though it relieved their symptoms. They were reluctant to use oxygen because it was considered a sign of weakness (Dehart, 1996). Fatigue management in the first half of the 21st century has been the "oxygen use" of early WWI. By the end of the war the need for oxygen delivery at high altitude was recognized and published in many most war departments (Dehart, 1996).

Duration of fixed wing flight during the first half of the century was mostly limited to the amount of fuel aircraft could carry. Of course one can speculate about fatigue playing a role. American Cal Rodgers survived five crashes to be the first person to fly across the country. It took him 84 days in 1911 (Welcome, 2003)! In 1927 Charles Lindberg flew across the Atlantic. By this point anecdotal pilot comments on boredom and fatigue due to long flights were common. The keynote speaker at the May 2006 Aerospace Medical

Association was Polly Vacher. She is a British woman in her 60's who developed a passion for flying and flew solo around the world. She stated that fatigue was a key issue that she focused on in planning her trip. With her modified plane, she was able to fly 14-hour stretches, seated and unable to leave the cockpit. Like many of the amazing aviation pioneers before her she commented in her presentation several times on the impact of fatigue during her long flight legs (Vacher, 2006).

Modern aviation can be a very complex field of employment. Some Boeing 747 cockpits contain 971 instruments and controls (Welcome, 2003). With the rollout of the Global Express and certification of the Gulfstream V aircrafts, the advent of long-range business jets now allow even smaller aircraft to fly globally (Lwin & Wirtz, 2001). Flight crews face lengthy duty days and long-duration flights while crossing many time zones. How does the aviation industry handle fatigue? How many 16-hour days can crews fly? Do flight departments have a fatigue management program? These end up being complex questions with complex answers.

TYPES OF PILOTS

Three types of pilot licenses are issued in the United States: class 1, 2 and 3. A person with a private pilot license flies under Part 91 rules and has a class three medical certificate (Code of Federal Regulations [CFR], 2007a). That pilot can fly a private plane for personal use. A different set of rules applies for a commercial pilot with a class two certificate. That pilot can fly cargo or be seated as a co-pilot with a pilot. Scheduled passengers fly on scheduled commercial flights and fall under Part 121 (CFR, 2007b). This area is actually far more complicated; for instance a chartered aircraft uses Part 135 because it is a non-RPT flight or a non-regular public transport flight that is conducted for revenue (CFR, 2007b). As an example, oil companies may have scheduled charter flights that go to their oil fields. Chartered flights can be helicopters, small planes with one or two passengers or large jets. A pilot can fly in with passengers to the field and fly out alone and fall under different FAA rules and rest requirements. A class one pilot certificate is what most people think of when they see a commercial pilot flying a commercial jet out of a large airport. That pilot is an ATP or airline transport pilot who falls under Part 121. Basically Part 91 has no specific rest guidelines, and Parts 121 and 135 are notably restrictive for demanding operations. Part 91, 121, and 135 are Federal Aviation Administration (FAA) Regulations that govern flight work hours (CFR 2007a, 2007b, 2007c). It is easy to see that this can rapidly become very complex and impact business.

Workloads taken on by pilots and the rapidly changing erratic schedules have disastrous effects on our circadian rhythms and natural sleep patterns. Dr Stanley Coren interviewed one NTSB accident investigator and was told that human error was the underlying cause of about 60% of all transport accidents with human error contributing to another 25% of accidents (Coren, 1996). The aviation safety industry and accident investigation organizations are well aware of the human factors and fatigue problem.

NTSB AND HUMAN FACTORS

The NTSB uses human factors to evaluate the demands of the aviation environment and the human realities such as fatigue faced by civilian pilots in flight. During accident investigations, they apply human factor principles to the specific accident crash or mishap. The goal is to determine the contribution of human variables to accidents. They review work schedules, logbooks, hours of sleep and rest, alcohol levels and many other factors to make such determinations. Human factors committees work retroactively to evaluate a crash and proactively to prevent future ones.

EASTERN AIRLINES FLIGHT 212

Dr. Coren provided the mishap example of Eastern Airlines Flight 212 from Charleston to Charlotte, North Carolina on 11 September, 1974. The flight crashed killing the three crew and 68 passengers. The official report blamed the crash on "pilot error." In 1974 pilots worked under flight scheduling rules introduced in 1934. These rules remained essentially unchanged until the 1990's (Coren, 1996). The rules also worked in a system of accident investigation that did not allow immunity, thus limiting the candid responses of accident flight crews. Thirty minutes prior to the Flight 212 accident, the pilot checked in with a control tower and his recorded voice sounded tired and depressed. He said, "Rest. That's what I need is rest. I don't need all this damned flying." The pilot's schedule the week before the crash started with awaking a 04:15 am with five flights in one day, then the next day starting work at 4:45 pm with three flights. Day three started at 3:30 pm with a series of four flights. Day four was off. Then the captain returned to early morning flights, he was up at 06:45 am with four flights. Day six was off but he was up at 07:00. The day of the crash he was up at 03:30 a.m. A person could hardly pick a more scrambled circadian schedule; sadly the pilot had picked part of it because he wanted to get his flying done early in the month (Coren, 1996).

PEGASUS EXPENDABLE LAUNCH VEHICLE

The NTSB can cite fatigue as a cause of or contributing factor to an accident. It is thought that mishaps aspects of the Space Shuttle Challenger accident are related to fatigue. The procedural anomaly that occurred during the launch sequence of the Orbital Sciences Corporation Pegasus expendable launch vehicle on February 9, 1993 is one such example of fatigue and space flight. The NTSB/SS-94/01 report cited the accident as having a high probability that fatigue caused by the disruption of the circadian rhythms and sleep loss adversely affected the performance of some critical personnel during the launch. As a condition for license for commercial space launches, as a minimum, the company applying for the license must provide for an adequate and specified time period for uninterrupted sleep and include in its license application a provision for mandatory rest periods before the launch for key participants. The quantitative criteria for such rest periods are supposed to be developed by appropriate human performance experts to ensure applicability to the assigned tasks (NTSB, 2001).

Coren's book, Sleep Thieves, gives further examples of pilot fatigue, jet lag and struggles with FAA rules. He notes that many pilots on long haul flights would admit to napping even though prior to the writing of the book that law had not changed (1996). In the 1980's NASA and the Ames Research Center were studying napping in the cockpit on long haul flights (Rosekind, Gander, & Dinges, 1991). The aviation industry has struggled with implementing current flight rules in a safe and cost effective manner to provide flights to the public. Corporate aviation crews have equally challenging if not harder jobs with these new rules. They fly for private business, which is still required to prepare for flying long duty days on their own as their crew duty limits typically fall under Part 91 operators, unless flying more than ten passengers (then Part 121 applies). The result is that they are the least monitored and therefore potentially at greatest risk. The key is that corporate jets fly with under ten passengers; otherwise, Part 121 rules apply.

FAA RULES

The rules governing how and what types of flights pilots fly change rarely and slowly due to concerns of lobby groups, politics, industry and safety. The aviation industry is big business, which has powerful lobby groups. Laws and rules that impact the industry are closely monitored, including those that impact fatigue. One example of a lobby group is the National Business Aviation Association (NBAA). The NBAA represents the aviation interests of over 4,200 companies, which own or operate general aviation aircraft as an aid to the conduct of their business, or are involved with business aviation. NBAA Member Companies globally earn annual revenues in excess of $3 trillion - about half the U.S. gross national product – and employs more than 16 million people worldwide National Business Aviation Association [NBAA], 2006). The industry is concerned with how fatigue mishaps are classified and evaluated by the NTSB as well as how the rules regulate the industry concerning pilot flight hours/duty and rest schedules. The result is that fatigue management is a very hot topic in the industry and in aviation related medicine.

For example, during the 1990's corporate aviation crews started to fall under new Part 91 rules. These flight operators were largely unregulated. This presented a potentially dangerous situation for the industry. Aircrew fatigue can be an insidious threat to the safety and effectiveness of air operations. The advances of modern flight operations involved multiple time zone changes and extended irregular schedules (Gander, 1994; Graeber, 1986). These factors can result in sleep loss, circadian disruption, and fatigue with subsequent effects on pilot performance (Gander, 1994; Graeber, 1986). Experts collaborated to find solutions and many business symposiums were held on the topic that included members of industry, NASA, government and aviation.

One example is a fatigue panel discussion that consisted of representatives from business aviation, including fatigue researcher Dr. Mark Rosekind of NASA Ames Research Center, Ted Mendenhall of Gulfstream Aircraft, Mert Pellegrin of Entergy Services, Patricia Andrews of Mobil, Bob Vandel of Flight Safety Foundation (FSF), and several other business aviation representatives from both small and large flight departments (NBAA, 2006). Panels Efforts like this helped to combine policy with research on effective fatigue countermeasures to try and safely optimize effectiveness in various aviation environments at that time. This theme of fatigue education and fatigue panels is highly effective and popular.

On the aviation medical side of the industry fatigue has been equally as popular. The 2006 Army Operational Problems Course, the 2007 Naval Operations Problems Course and the 2006 Aerospace Medical Association (ASMA) conference all had keynote speakers on fatigue topics (Davenport, 2006; Dinges, 2007). During the medical monthly grand round seminar series at Johnson Space Center in 2005 and 2006 Dr. David Dinges spoke to the NASA physicians on fatigue. This 2007 ASMA conference is hosting a whole extra day symposium on fatigue topics. Interestingly aviation fatigue medical experts were able to get the FAA to change rest rules before the AMA (American Medical Association) finally changed sleep rules in 2003.

Federal Aviation Administration (FAA) regulations used to allow pilots to work a maximum of 16-hour days. To put this in perspective, this would be equivalent to the average worker showing up at 9 a.m. and leaving at 1 a.m. The FAA report of a 2004 commuter plane crash in Missouri noted the flight crew had been on duty for 14½ hours and cited fatigue as a factor (Levin, 2006). However, it does leave one asking the question “Who in their right mind would stand for those work rules or even be able to perform competently?” Experts in clinical aviation medicine who where closely involved with companies, off the record, have said that many practical useful guides on fatigue have existed over the years, but sadly, were never read by those to whom it should really matter and who needed to read it, i.e., aviation management, scheduling and those who make work rosters (Slack and Davis, 2006). That has changed and aviation fatigue countermeasures are now implemented by federal policy in America and other countries. These experts often ended up investigating a "fatigue accident" and making strategy recommendations.

AVIATION FLIGHT LIMITS PART 121 AND 135

Aviation flight limits were addressed in the Civil Aeronautics Act of 1938 and the Federal Aviation Act of 1958. In 1985, domestic flight limitations and some commuter limitations were updated; flag and supplemental operations were not (NTSB, 1999). The current standards are displayed in Table 6. As mentioned previously in the mid 1990s pilots could still fly up to 16 hours a day. Since March 20, 1997, aircraft with 10 or more seats used in scheduled passenger service have been operated under Title 14 of the Code of Federal Regulations (CFR) Part 121 (CFR, 2007b).

FAA regulations now allow flight duty of from 16 hours to 12 hours for pilots, depending on the departure time of their flights. In 1995 the agency proposed reducing those limits, dropping the maximum time of continuous duty to 14 hours. In her 2003 book, Aircraft Safety: Accident Investigations, Analyses, and Applications, Dr. Shari Krause discusses research that found a tired pilot is two to four times more likely to have an accident. Literature and documents such as this were generated from the work being conducted on this topic in the 1990's to document the problem. The critics, including a former chairman of the National Transportation Safety Board, stated "a change in the regulations is long overdue" (Slack and Davis, 2006).

What might seem odd is that despite intense study and development of effective countermeasures for ground-based personnel (in shift work), researchers had performed relatively little research at overcoming fatigue in the aviation environment. A

CODE of FEDERAL REGULATIONS: TITLE 14 AVIATION: PART 121 and PART 135
Pilots flying domestic Part 121 operations may fly up to 20 hrs per week, 100 hrs per month, and 1000 hours per year
Pilots flying domestic Part 135 operations may fly up to 34 hrs per week, 120 hrs per months and 1200 hours per year
If the scheduled flight time is less than 8 hrs, the minimum rest period in the 24 hrs preceding the scheduled completion of the flight segment is 9 hrs. This time may be reduced to 8hrs if the following rest period, to begin no later than 24 hrs after the commencement of the reduced rest period, is reduced to 10 hrs.
If the scheduled flight time is 8-9 hrs, the minimum rest period in the 24 hrs preceding the scheduled completion of the flight is 10 hrs. This time may be reduced to 8 hrs if the following rest period, to begin no later than 24 hrs after the commencement of the reduced rest period, is increased to 10 hrs.
If the scheduled flight time is equal to or greater than 9 hrs, the minimum rest period in the 24 hrs preceding the scheduled completion of the flight segment is 11 hrs. This time may be reduced to 9 hrs if the following rest period, to begin no later than 24hs after the commencement of the reduced rest period, is increased to 12 hrs.

Table 6: Code of Federal Regulations, Title 14 FAA Rules, Part 121 and 135. Modified from CFR, 2007b and 2007c.

comprehensive effort was performed from the late 1980’s to the 2001. One of the goals was to maximizing alertness and endurance for safer air operations. The basic causes of aircrew fatigue are the same for other groups noted earlier: insufficient sleep, disruptions to the body's clock, and extended duty periods. Technological aviation advances and a

Number of pilots	Duty period hours	Flight time hours	Minimum rest hours	Reduced rest hours[a]	Rest hours following reduced rest (compensatory)	Extended duty period hours[b]
1 (Part 135)	No more than 14.	No more than 8.	10	9, May only be reduced if duty period has not exceeded 14.	11	Up to 16 only if due to operational delays.
2	No more than 14.	No more than 10.	10	9, May only be reduced if duty period has not exceeded 14.	11	Up to 16 only if due to operational delays.
3	No more than 16.	No more than 12.	14	12, May only be reduced if duty period has not exceeded 16.	16	Up to 18 only if due to operational delays.
3 Each pilot must have sleep opportunity, and approved sleeping quarters must be available.	More than 16, but no more than 18.	No more than 16.	18	16, May only be reduced if duty period has not exceeded 18.	20	Up to 20 only if due to operational delays.
4 Each pilot must have sleep opportunity, and approved sleeping quarters must be available.[c]	More than 18 but no more than 24.	No more than 18.	22	20, May only be reduced if duty period has not exceeded 24.	24	Up to 26 only if due to operational delays.

[a] Rest periods may be reduced only when the actual duty period does not exceed the maximum scheduled duty period for that crew composition and if the pilot is provided a compensatory rest period. This compensatory rest period must be scheduled to begin no later than 24 hours after the beginning of the reduced rest period.

[b] The flights to which the pilot is assigned must at block out time be expected to reach their destination within the extended duty period.

[c] Applies only to duty periods with one or more flights that land or take off outside the 48 contiguous States and the District of Columbia.

Table 6. Part 135 Duty Hours. Adapted from CFR, 2007c

global flight reach make long-range, continuous operations a way of life for today's aviation industry. The current Part 135 rules are listed. The number of hours that can be flown is related to the number of pilots in the aircraft and now rest periods are allotted to these pilots after extended duty days. The aviation industry has probably come further

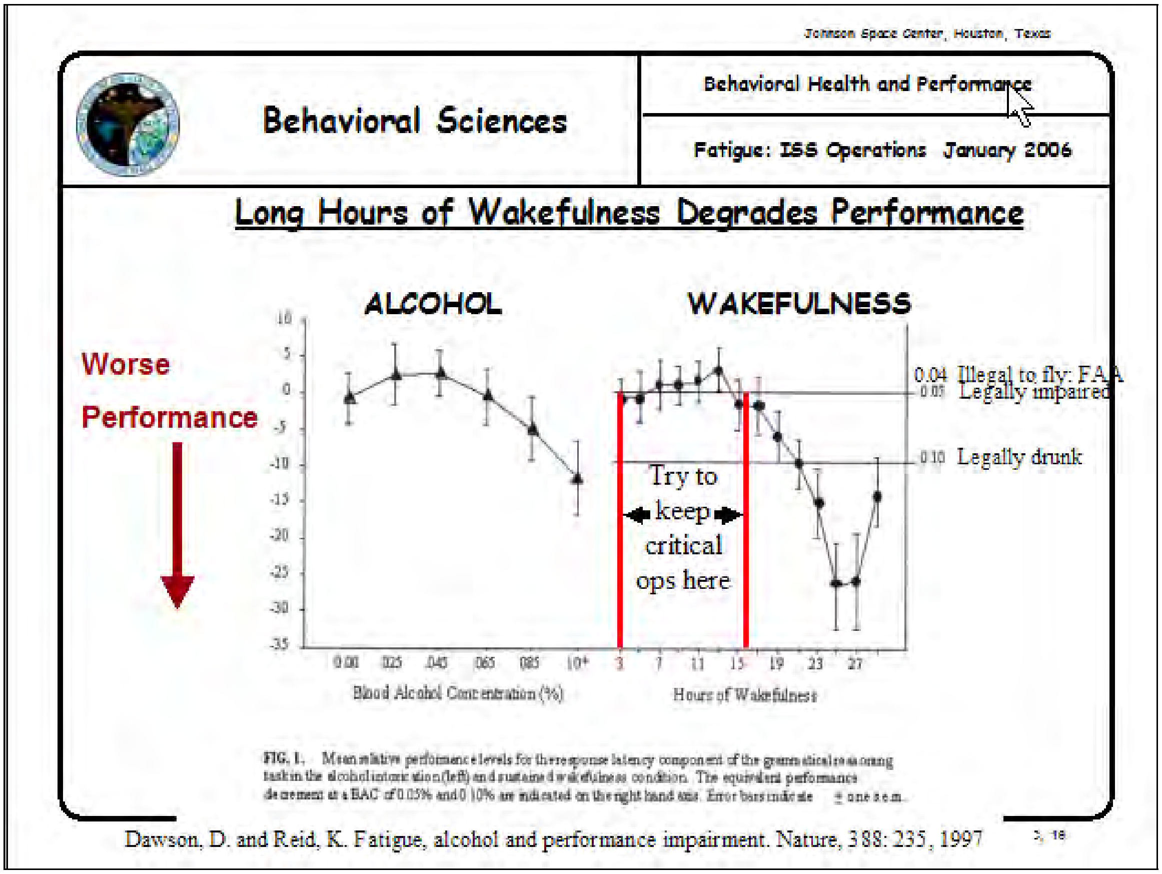


Figure 17. Performance: Alcohol Versus Hours of Wakefulness. Adapted from Dinges, 2006a

then any other field to appreciate, teach and study the effects of sleep loss. Science has proven that people lose approximately 25% of their higher-level cognitive capacity with each 24 hours of sleep loss (Dawson & Reid, 1997). That type of loss cannot occur in any flight situation, a complicated flight deck or a private antique aircraft. Stated differently, just 18 to 21 continuous hours without sleep leads to performance impairments like those seen with blood alcohol concentrations of 0.05 to 0.08%—beyond the legal limit of intoxication in every state in the U.S. (Dawson & Reid, 1997) (Figure 17). This is something that taught to NASA flight surgeons. The following is adapted from a slide presentation in 2006 at Johnson Space Center on this very topic.

NUMBER ONE HAZARD

The risks associated with fatigue in the aircraft simply cannot be allowed in such an already hazardous environment. Aviation fatigue and associated fatigue issues cannot be over looked like the "German Oxygen of WWI". The good news is modern flight crews are well educated on lengthy duty days and long-duration flights while crossing many time zones. As such they are actually some of the most versed persons in sleep deprivation and now work in a world where they can even tell the boss they are too tired to fly. But the hazard is still there. The former NTSB chairman stated "It's (fatigue) probably the number one hazard that we have not effectively addressed in all forms of transportation. We put in place programs to address alcohol and drugs, yet we leave fatigue hanging out there with nothing done," he said. "It's not something we can say we don't have the information to do something about. The information exists, and lives are being lost because we are failing to take action" (Slack & Davis, 2004). The leaders in the aviation industry understand the issue as well. "There is no question that pilot fatigue is present in our commercial airline operations," the current president of the Air Line Pilots Association, told a House subcommittee in 1999 (Slack & Davis, 2004).

FATIGUE EDUCATION

The FAA has a division known as CAMI, the Civilian Aeromedical Institute. CAMI studies aviation human factor issues and other medical topics for civil aviation in the United States. Dr. Melcor runs the department and is a well known speaker on aviation and aviation fatigue. He teaches fatigue at FAA courses for pilots and doctors, to aerospace medicine residents and lectures at conferences. His department offers free CDs on human factors to airmen related to flight including a specific presentation on fatigue (Dinges, 2006b). Dr. Melcor often uses examples from the military and NASA studies on fatigue to stress his points to audiences, again underscoring that educating persons in the field is step one in addressing the topic.

Government and industry organizations including the Federal Aviation Administration (FAA), the National Transportation Safety Board (NTSB), Air Transport Association (ATA), the Air Line Pilots Association (ALPA), and even National Aeronautics and Space Administration (NASA) have collaborated to make significant improvements in fatigue and modern aviation. Fatigue has had an “important” negative effect on aviation. The National Transportation Safety Board has cited pilot fatigue as a factor present in several adverse aviation incidents.

During the 1990’s the FAA began an update of limitation of pilot flight hours. Original proposed regulation began in 1995 and did not end until 1999 (CFR, 2007a, 2007b, 2007c). The Airline Pilots Association (ALPA) recognized fatigue as a significant aviation safety issue and collaborated to improve the situation. Industry abuses of pilot scheduling practices have been evident per their 1999 report to the Aviation Sub-committee to the House of Representatives in 1999 (Primo & Cobb, 2003). Despite major advances in the aviation in the past half-century, the regulatory framework has not been significantly improved.

POLITICS AND BIG BUSINESS

This was an intense time for aviation fatigue regulation. Some political games were played; ALPA used the NTSB mishap system to its advantage and claimed that fatigue has never been officially documented as the primary cause of an aviation incident. The key word has always been “primary.” They did correctly point out that scientific evidence has not been appropriately applied to the current regulatory debate (Primo & Cobb, 2003). As a business entity, their point was taken; as inappropriately formulated regulations could result in needless cost, while not actually yielding any increase in aviation safety. They stressed that it is important to avoid a "one-size-fits-all" approach to regulations covering a wide variety of aviation environments and circumstances. That point was actually correct. As a result of the congressional hearings in the 1990’s the FAA worked with NASA on using real scientific data to further update the rules and educate the industry.

The result of the hearings was a success and education became the primary tool for spreading the word. In the early 1990s, NASA developed an education and training module entitled “Alertness Management in Flight Operations.” The module focused on three primary objectives: to explain (1) the current state of knowledge about the physiological mechanisms that underlie fatigue; (2) misconceptions about fatigue; and (3) fatigue countermeasures (NASA, 2007). NASA and the FAA have cosponsored many courses to educate pilots for a large segment of the major U.S. air carriers as well as for corporate management. The Federal Rail Administration (FRA), Federal Transit Administration (FTA) along with other industry organizations has used the NASA countermeasures training module as the basis for training modules in the other modes of transportation.

People in general are not aware of when they are tired and how it affects them. Data from an international study of flight crews reported that the highest subjective rating of alertness occurred at a time when physiologically the individual was falling asleep within 6 minutes (an indicator of severe sleepiness) (Sasaki, Mori, & Endo, 1986). Likewise, subjective and physiological self-assessment of performance can differ significantly. The operational relevance of this phenomenon is clear. For example, an individual might report a low level of sleepiness or fatigue but could be carrying an accumulated sleep debt with a high level of associated physiological sleepiness. Fatigue is a topic that is simply not taught to the public. It is commonly misunderstood. Educating aviation leaders and flight crews as the industry was able to do with the help of Congress, the FAA and NASA has been critical to successfully beginning to manage fatigue within the aviation industry..\

Probably the best reasons for education is that while the FAA sets regulatory guidance regarding issues such as limitation of pilot flight hours and setting minimum rest times, the responsibility to implement these regulations ultimately falls upon the airlines and the pilots. They have to understand the issue to take it seriously. The aviation industry well knows that fatigue in transportation operations has been on the NTSB's list of most wanted safety recommendations since the inception of the list in 1990. The NTSB has cited pilot fatigue as a long-term and pervasive problem for aviation safety (NTSB, 1994). The NTSB first began making recommendations regarding fatigue in the early 1970’s, asking FAA to revise regulations accordingly (NTSB, 1994).

NASA AMES FATIGUE/JET LAG PROGRAM

In 1980, responding to a Congressional request, NASA Ames Research Center created a program to examine whether "there is a safety problem of uncertain magnitude, due to transmeridian flying and a potential problem due to fatigue in association with various factors found in air transport operations." The NASA Ames Fatigue/Jet Lag Program was created to collect systematic, scientific information on fatigue, sleep, circadian rhythms, and performance in flight operations. It involved the origination of multiple research studies. The FAA jointly funded the program. Three program goals were established and continue to guide research efforts: to determine the extent of fatigue, sleep loss and circadian disruption in flight operations to determine the impact of these factors on flight crew performance to develop and evaluate countermeasures to mitigate the adverse effects of these factors and maximize flight crew performance and alertness (NASA, 2006). This is probably the largest and most comprehensive fatigue research project ever conducted.

So in responding to that Congressional request, NASA Ames Research Center created a program to examine whether "there is a safety problem of uncertain magnitude, due to transmeridian flying and a potential problem due to fatigue in association with various factors found in air transport operations." The NASA Ames Program was created to collect systematic, scientific information on fatigue, sleep, circadian rhythms, and performance in flight operations. Three program goals were established and continue to guide research efforts: to determine the extent of fatigue, sleep loss and circadian disruption in flight operations to determine the impact of these factors on flight crew performance to develop and evaluate countermeasures to mitigate the adverse effects of these factors and maximize flight crew performance and alertness (NASA, 2006).

The program was very extensive involving years of multiple studies from sleep logs, to studying short haul, long haul with researchers in the cockpits, to jet lag, napping, and circadian disruption to name several areas and resulted in hundreds of pages of data. It was known that fatigue is caused by a number of different factors in commercial flight, both in schedules involving very long flights and in those involving multiple short flights. The aviation field truly led the way in fatigue management in regards to fatigue research. The study is by far one of the best if not the best work of its type in fatigue.

In brief, the NASA Ames Fatigue/Jet Lag Program used evidence regarding the existence and extent of fatigue in aviation gathered from several different sources and environments, including aviation operations, laboratory studies, high-fidelity simulations, and surveys pertaining to information on fatigue, sleep, performance in flight operations, and circadian rhythms—the biological "time clock" that regulates the body's daily sleep-wake patterns.

By that point many studies had consistently shown that fatigue is an issue with complex, diverse causes and potentially critical consequences. Field studies specific to different aviation environments and using a range of measures (e.g., performance, physiology, and behavior) revealed a number of factors related to fatigue. For example, in long-haul operations, the non-24-hr duty/rest cycles, the circadian desynchronization associated with transmeridian flights, and the sleep loss accompanying nighttime flying are all associated with fatigue (Gander et al., 1991; Neri et al., 1995; Rosekind, Gander, Connell & Co, 2001a; NASA, 2006). For short-haul operations, long duty days, sleep loss as a result of short nighttime layovers, and shortened sleep episodes due to progressively earlier report times across trips serve to create flight crew fatigue (Gander et al., 1992; Gander et al., 1994; Dinges, 1992). In overnight cargo crews, even regular nighttime flying often results in incomplete circadian adaptation. Additionally, duty periods ending in the morning hours lead to sleep loss due to an increasing signal for wakefulness from the biological clock during this time. The problem is compounded by daytime layovers that can sometimes be too short for an adequate sleep opportunity (Gander et al., 1991; NASA, 2006).

Other evidence of fatigue has been obtained from flight crew surveys and researcher observations in the field (Rosekind et al., 1991, 1994, 1996, 2001a). Flight crews routinely respond that fatigue is a concern, often admitting to having nodded off during a flight and/or arranging for one pilot to nap in the cockpit seat. Flight crews have acknowledged the presence of fatigue for many years. Fatigue continued to show up in reports in NASA's Aviation Safety Reporting System (ASRS), which operates under FAA funding (ASRS, 1998). ASRS database reports for FAR 121 and FAR 91/135 operating environments (ASRS, 1998).

Despite the widespread evidence that fatigue occurs frequently enough to be a significant aviation issue, it remains difficult to detect reliably and counteract effectively. Consequently, detection and countermeasures were two areas of active research by the Fatigue Countermeasures Program. For example, NASA researchers collaborated with NTSB investigators in assessing whether fatigue was present in the 1993 crash of a U.S. DC-8 freighter in Guantanamo Bay, Cuba (NTSB, 1994). Three core physiological factors related to fatigue were identified (cumulative sleep loss, continuous hours of wakefulness, and circadian time of day). All three crewmembers were loaded on these fatigue factors. The NTSB implicated fatigue as a probable cause; the first time fatigue had been so identified in an aviation accident (NTSB, 1994). This approach now represents a means of looking for the presence of fatigue in accidents or incidents across all transportation modes and other work environments as well.

Throughout the course of this outstanding research program, it was evident that pilot fatigue is a significant safety issue in aviation. Rather than simply being a mental state that can be willed away or overcome through motivation or discipline, fatigue is rooted in physiological mechanisms related to sleep, sleep loss, and circadian rhythms (NASA, 2006). These mechanisms are at work in flight crews no less than others who need to remain vigilant despite long duty days, transmeridian travel, and working at night when the body is programmed for sleep (NASA, 2006).

One specific study empirically demonstrated the effectiveness of a planned cockpit rest period in improving performance and alertness in long-haul flight operations (Rosekind et al., 1994). Flight crews who were provided a planned 40-minute nap opportunity (resulting in an average of 26 minutes of sleep) subsequently exhibited improved physiological alertness and performance compared to flight crews not receiving the nap opportunity (Rosekind et al., 1994). The crewmembers napped one at a time in a three-person cockpit with minimal disruption to normal flight operations and no reported or identified concerns regarding safety. The benefits of the nap were observed throughout the critical descent and landing phases of flight. The planned nap appeared to provide effective and acute relief from significant sleepiness experienced by crews in three-person non-augmented flight operations (Rosekind et al., 1994). Following this study, the Fatigue Countermeasures Program submitted a draft advisory circular to the FAA in January 1993 on "Controlled Rest on the Flight Deck." Regulatory provisions that would sanction the appropriate use of planned cockpit rest remain under review. Most long haul carriers implemented the procedure.

The initial aspects of the NASA AMES research proved that fatigue is a safety issue in aviation. The next logical question was how to address it. Unfortunately, there is no one simple solution. Fatigue is a problem with diverse causes, requiring a multi-faceted and comprehensive yet integrated approach. Based on current research the NASA Ames study advised that an approach should have at least the following components: (a) education and training, (b) hours of service, (c) sound scheduling practices, (d) effective countermeasures, (e) incorporation of appropriate design and technologies, and (f) research (Rosekind et al., 1996).

FAA AND NASA AMES EDUCATION

Education was noted earlier. It establishes the knowledge base necessary for the successful implementation and acceptance of all other activities. The NASA Ames program advised that educational materials should include information on the physiological mechanisms underlying fatigue and what can be done to manage fatigue in operational settings. In 1994 the Fatigue Countermeasures Program, in collaboration with the FAA, developed an education and training module on alertness management in flight operations. The module is a 1-2 hour live presentation covering physiological mechanisms, misconceptions, and fatigue countermeasures. The presentation is supported by a NASA/FAA publication that includes the presentation slides, explanatory text, and appendices on NASA studies, sleeping pills, sleep disorders, and additional reading. The module and publication are distributed to the aviation industry primarily through two-day train-the-trainer workshops held at NASA Ames Research Center. The goal is to train the trainers.

A 1998 survey of participants indicated that the module was in use at 149 organizations reaching more than 116,000 flight crewmembers and others in the industry (Rosekind, et al., 2001b). The FAA continues to educate current and new pilots and Aeromedical examiners in fatigue (AME). The most recent AME course in Oklahoma City provided a lecture that included fatigue and offered further materials in CD and pamphlet form (Jones, 2007). That material is taught during refresher courses required for pilots and Ames at the FAA and at courses the FAA teaches regionally (Jones, 2007).

The NASA Ames study did advised all programs should have an “Hours of Service” or work area section. Each operational environment should be encouraged to develop principles and guidelines for duty and rest scheduling that reflect the demands of that particular work setting. The aviation industry has many different shifts and types of flight with rules that apply to each. Appropriate guidelines would need to incorporate and reflect the latest scientific research on fatigue yet allow sufficient operational flexibility to meet often unique operational demands. In response to a request from the FAA for operational input, NASA assembled an international team of scientists and produced a principles and guidelines document based on the latest scientific information on fatigue (Dinges, Graeber, Rosekind., Samel & Wegmann, 1996). This document at the time served as one of several inputs to an FAA rule-making team that subsequently drafted a new flight/duty/rest regulation putting the research into action. The Part 135 Duty Hours, Graph 6, is a result of that work.

SCHEDULING PRACTICES

The area of scheduling practices was a large collaborative effort made with international partners, industry, academia and the military. The group effort co-sponsored (with the National Space Biomedical Research Institute and the Air Force Office of Scientific Research) a Workshop on Biomathematical Models of Circadian Rhythmicity, Sleep Regulation and Neurobehavioral Function in Humans. Organized by scientists from

Harvard University and the University of Zurich, the workshop brought together basic and applied researchers from around the world to compare, integrate, and publish current models of circadian, sleep and human neurobehavioral system (Proceedings, 1999). The workshop advised scheduling practices include scientific information about sleep, fatigue, and circadian rhythms, in addition to other factors, in creating and evaluating flight crew schedules. It promoted further research by advising the acceleration of the development of models that can predict neurobehavioral functioning. These key work areas led into the area of countermeasures.

The program advised using countermeasure strategies, implementing them proactively in a preventive fashion, such as before duty and on layovers to reduce the effects of fatigue, sleep loss, and circadian disruption during flight operations. They can also be used operationally, employed in flight to maintain alertness and performance. The Fatigue Countermeasures Program examined several strategies to counteract the effects of fatigue. In addition to the study on in-flight cockpit napping, the program conducted a study of the effectiveness of brief in-flight activity breaks on alertness and performance (Neri, Mallis, Oyung, and Dinges, 1999). Flight crews were advised to receive brief hourly activity breaks (involving mild physical activity and social interaction) showed improved physiological alertness for at least 15 minutes relative to a control group, while reporting significantly greater alertness for up to 25 minutes post-break. The effect of the breaks was especially pronounced during the portion of the flight when it is most difficult to remain vigilant; the early morning hours associated with the nadir in the circadian rhythm of body temperature performance (Neri et al., 1999).

The study program advised that good system design incorporates information about human physiology, its limitations and strengths, early in the process. Technological approaches that use this information can take many forms, including flight crew scheduling algorithms (i.e., the methodology of choosing flight crews) and alertness monitoring/management systems (Proceedings, 1999). Fatigue Program work in this area included a project examining on-board crew rest facilities to determine the quantity and quality of sleep obtained and the factors that promote or reduce good sleep in the bunk (Rosekind et al, 1997). Onboard bunks are used in operations with extra (augmented) flight crewmembers onboard so that crews can rotate through flight deck positions and non-flying crew can obtain sleep during long flights.

NASA has contributed far more to the aviation industry than just this specific program from the 1990's. In fact, many technologies such as light therapy and circadian shifting used by NASA areas are becoming mainstream. NASA closely tracks and monitors astronauts sleep and work schedules to optimize performances of the astronauts. A visit to mission control in Houston will show in the upper left hand corner of the massive screen in the flight control room the "awake times" and "time to sleep" of astronauts on shuttle missions and on the international space station down to the minute. Down to the minute might not be required for disaster relief but tracking the hours is not a bad idea for leadership.

Great strides in aviation fatigue management have been made in the last century. The NASA AMES study final area to be addressed was the challenge of the appropriate application of current research to the operational aviation environment. Given the recent development of technologies claiming to be able to detect fatigue, focused research is needed to ascertain the sensitivity, reliability, and validity of these devices (Dinges, 2001). Research also needs to continue to address regulatory, scheduling and countermeasure questions. The area of fatigue is plagued by misconceptions about its causes and characteristics. There is no substitute for valid empirical data gather through research to guide decision-making and policy.

NASA's highest priority in aeronautics is aviation safety. Extensive research has been performed in the context of the Fatigue Countermeasures Program at the NASA Ames Research Center (Proceedings, 1999). Field studies in a variety of flight environments revealed that fatigue occurs with sufficient frequency to constitute a significant threat to aviation safety (Proceedings, 1999). NASA has research fatigue detection and control methods (Proceedings, 1999). On the basis of currently available scientific evidence, the program advises the following components should be considered as part of a multi-dimensional solution to the problem of fatigue: education and training control of work hours, sound scheduling practices, effective countermeasures, appropriate design and technologies, and research (Proceedings, 1999).

SUMMARY

Without a doubt the aviation field has been the lead industry in recognizing the hazards of fatigue and in mitigating it with both federal requirements and company standards. Man's early fascination of flying is now more than a reality it is a part of modern life. The evolution of the field has certainly seen its share of hazards. Early aviation was limited by the length of time that aircraft could stay in the air. That is no longer the case, man can fly far longer then the body can stay alert. Thankfully the last century has brought about improvements to the hazard of human fatigue in aviation. The areas of regulation, research and industry have collaborated to make fatigue be a manageable factor in the safe conduct of flight, making flying a safer activity than driving (NTSB, 2001; Jones, 2007). Such collaboration can teach disaster teams and disaster leadership a lot about how to tackle the complex issues of fatigue in disaster relief. The next chapter will directly address that issue.

CHAPTER 6: FATIGUE COUNTERMEASURES

Those that expect to reap the benefits of freedom must, like men, undergo the fatigue of supporting it

Thomas Paine

OVERVIEW

Nationally there is not an all-encompassing disaster management policy to encourage or implement nationwide and no requirements relating to fatigue management during disaster responses, yet year after year we are stuck by tornados, hurricanes, industry accidents and even terrorist events. Because of disasters such as Three Mile Island, Hurricane Katrina or the Exxon Valdez “incident,” common disaster-response organizations, such as hospitals, the medical field in general, transportation organizations and the military have a viable need for a policy regarding the management of fatigue when responding to disasters.

Great strides have been made in the last century with regard to knowledge about sleep, sleep need, the effects of sleep loss on performance and related issues. More recently, major advances have occurred in human circadian rhythm research, leading to an improved understanding of sleep and fatigue physiology and the human circadian pacemaker in the brain. In light of this relatively new knowledge regarding sleep and human’s need for sleep, now would be an excellent opportunity for disaster-response organizations to develop a fatigue management policy for implementation during disaster relief events. Prior chapters have identified much of this information and the necessity of addressing fatigue, citing poor statistical outcomes from incidents involving the sleep-deprived. This final chapter will seek to provide a review of some key research outcomes, dispel the many myths that when adhered to and propagated become pitfalls to disaster workers and leaders alike, and finally to address and explore sound fatigue countermeasure practices.

LEADERSHIP AND FATIGUE

The recognition of fatigue is a leadership responsibility in all sectors of society, especially in the discipline of disaster management. Persons who anticipate duty assignments in which they bear some or all responsibility for alertness management need to be aware of the effective countermeasure that exist and to be equally aware of the myths and fruitless measures that people have utilized. Leaders and researchers from all the professions reviewed advise a unified interface to other government agencies, leverage research resources and lessons learned and developing new approaches toward regulation. Through education and understanding, recovery from disasters will progress positively and not fall prey to the insidious accidents and mishaps associated with fatigue. When scientifically-based data on fatigue, its causes and its consequences is considered in tandem with the disaster mission, economics, regulations, operations and other countless factors, safety in disaster-relief can be measurably improved. Ultimately, future areas of research may be influenced or discovered. The aim is for administrative policy to be first defined, and then implemented, to reduce this threat to disaster relief workers.

One of the paramount goals for any leader or business aiding in disaster relief should be safety. Ensuring safety during disasters is a prime issue to consider, and issues of fatigue management fall squarely under the umbrella of issues relating to safety. Fatigue effects staff endurance, efficiency and effectiveness, and persons working under the hardships of fatigue are statistically prone to be less attentive and alert while working, creating an environment rife with potential for accidents. It is clear now that humans need sleep and there are consequences to sleep loss. Fortunately there are causes and signs of fatigue that leaders can easily recognize.

Typically disaster relief efforts deal with an understaffed work force often enduring what seems to be over-whelming situations. If leaders do not implement adequate rest schedules, the relief force will rapidly become highly ineffective. Disaster work forces often include medical staff. As previously noted, reduced sleep time has long been commonplace for interns and residents, but is certainly not wise or advisable. Studies have identified that sleep loss and fatigue result in significant neurobehavioral impairments. A recent review of studies, addressing the effects of sleep loss on cognition, performance, and health in surgical and non-surgical residents, nicely described the effectiveness of countermeasures for sleepiness, highlighting again that work-hour restrictions are effective and reduce errors and neurobehavioral impairments (Veasey, Rosen, Barzansky, Rosen, & Owens, 2002).

Every leader and staff member should understand the importance of coming to work well rested. Efforts should be made to minimize chronic partial sleep loss. Recognizing the inevitable need for disaster rescue staff to work long hours necessitates that leadership take countermeasure steps. Devising optimal work schedules, increase efficiency in performing work duties, develop workstation and sleep environments that minimize distractions, implement systems for detecting high-risk adverse events such as driving while fatigued and scheduling naps during long work shifts are all proven approaches. Currently there are no studies or trials identified that study this issue of sleep schedules and nap-use as countermeasures during disasters or disaster exercises. More controlled trials are needed to evaluate the broader effects of sleep loss and fatigue on disaster staff.

Once a disaster is in effect, implementing a pre-briefed rest plan with naps is highly advised for all responders.

THE COST OF FATIGUE

The end result of operating under conditions of fatigue in the fields of transportation, medicine, aviation, the military and even space exploration have similar outcomes, all resulting in significant morbidity and mortality, not to mention the overall cost of mission failure. Whether the mission goal is safe health care, effective transportation of oil in Alaska or expedition class missions to the Moon and Mars, the costs of fatigue are severe. It has been estimated that fatigue costs between $18 billion (Coren, 1996) and $50 billion year (Coplen et al., 2003) in lost revenue and productivity. Furthermore, fatigue contributes to over 1,500 roadway fatalities and has been a major contributory factor in multiple aircraft accidents (both civilian and military) in the U.S. alone (Coren, 1996).

KEY ISSUES IN FATIGUE

Many consensus statements by various experts in specific transportation and economic fields as well as international groups who study human performance safety and prevention of accidents associated with work schedules, night activity, and inadequate sleep have identified several key issues that are the perfect review and starting point for this countermeasures chapter. These groups stated that these key issues include: 1) our "24-hour society", with around the clock operational demands challenges the powerful and vital need for sleep. Sleep, alertness and performance are fundamentally linked to the 24-hour biological clock. 2) The major causes of fatigue are: (a) the time of day of the operation (e.g. night/early morning), (b) a long duration of wakefulness, (c) inadequate sleep, (d) pathological sleepiness (sleep apnea, etc.), and (e) prolonged work hours (not necessarily while operating a vehicle). 3) Fatigue (sleepiness, tiredness) is the largest identifiable and preventable cause of accidents in transport operations (between 15 and 20% of all accidents), surpassing that of alcohol or drug related incidents in all modes of transportation (Akerstedt, 2000).

It should be pointed out that official statistics do not provide a realistic look at the contribution of fatigue to disasters and accidents. The aforementioned experts noted that 1) Underestimation of the impact of fatigue can lead to the under-utilization of important countermeasures, and 2) Public and environmental safety, health and productivity are compromised by fatigue and sleepiness, with substantial financial costs to individuals and society. These experts concluded that through educated intervention, carefully considered work hours, and a wise approach to the use of new technologies and various response strategies, the risks associated with persons operating under the duress of fatigue could be effectively mitigated (Akerstedt, 2000).

FATIGUE AND COGNITION

As a brief review, the signs of fatigue are general discomfort, sleepiness, irritability, and apathy or loss of interest. They also include decreased concentration, loss of appetite, impaired sensory perceptions, mood changes and impaired decision making. The outcomes of chronic sleep deprivation have been proven scientifically and are seen as alterations in neurobehavioral and cognitive effects. They include: slower response time; instability of attention (increased number of errors of omission and commission); rapid deterioration of performance ("fatigability" or vigilance decrement); cognitive slowing on subject-paced tasks; increased cognitive errors with increased time pressure (in work-paced tasks); decline in both short-term recall and working memory performance;

reduced learning (acquisition) of cognitive tasks; increased “response preservation” on ineffective solutions; neglect of nonessential activities increases (loss of situational awareness); onset of involuntary “microsleep” attacks and increased compensatory effort required to maintain behavioral effectiveness (Dinges, 2001).

Further impaired memory findings, such as difficulty remembering recent events, a tendency to forget secondary tasks and task performance all rely on "habits" acquired in the past (good or bad) (Dinges, 2001). Leaders may see other clinical signs of excessive sleepiness in disaster relief workers such as irritability, moodiness, and dis-inhibition. If the fatigue is extensive they may see frontal lobe signs such as apathy, impoverished speech, flattened affect (not caring or no personality), impaired memory, inflexible thinking and impaired planning skills (an inability to be novel or to multitask) (Dawson & Anderson, 1991).

Dr. Dinges, a nationally recognized expert on fatigue, has identified some straightforward preventive and operational countermeasures in regards to fatigue management. Among his suggestions are that one cannot replace or subvert the need for sleep, and as such, one should not operate a car or heavy machinery between the typically sleep-filled hours of 2 a.m. and 9 a.m., and most importantly, there is a deadly correlation between the effects of sleep loss and alcohol consumption. Also of note, a person who is dangerously fatigued will display behavioral changes and the redeeming properties of prophylactic naps should not be dismissed (Dinges, 2001). It should be evident that no single approach or "fix" has been successfully in eliminating fatigue as an issue thus far. Many measures must be taken to address fatigue and require operational flexibility, and even creativity, as the issue of fatigue is negotiated. Understandably, fatigue-related issues cannot be the only ones considered in establishing schedules for rest and work during disasters; however these considerations need to be included in the plan.

FATIGUE COUNTERMEASURE MYTHS

Before this chapter delves into more specific countermeasures, a review of some myths and unsuccessful countermeasures might prove useful, for knowing what does not work is as important as knowing what does work. Some have been noted previously but are included for review purposes. Here are some common and typical statements people make about operating while not fully rested:

"I know how tired I am."

"I have lost sleep before and I did just fine."

"I am motivated enough to push through it."

"The solution to the problem of fatigue is simple."

"8 hours of rest is the same as 8 hours of sleep."

"All I need is a cup of coffee and I will be fine."

These statements are all myths, and have been explained in previous chapters as to why they do not hold true. Along with these myths, ineffective countermeasures have often been tried in vain. These include: nicotine; ventilation and cold temperature; exercise; diet; loud sound; odor/fragrance and over-the-counter sleep aids (Neri et al., 1995; Landstrom, Knutsson & Lennernas, 2000; Reyner & Horne, 2000; Roehrs & roth, 2000;Hexheimer & Petrie, 2002). These countermeasures lack scientific data demonstrating their effectiveness or may cause accidents or health problems, such as the correlation between the use of tobacco and/or nicotine and cancer. Scientifically speaking, these approaches are not advised, (Bonnet & Arand, 1994).

PROVEN FATIGUE COUNTERMEASURES

Methods for preventing fatigue and management techniques for chronic fatigue exist and have proven through research data and operational experience to be effective. They encompass both the prevention of fatigue (by getting enough sleep) and the mitigation of fatigue (through countermeasures applied when one becomes tired). Individual countermeasures will need to be combined, based on specific operational circumstances. These countermeasures are: adequate sleep; napping; anchor sleep; trip planning; good sleeping environment, pharmacologic interventions and light therapy.

A brief but detailed description of each countermeasure will be provided. Generally a definition will be included along with advantages and limitations to be considered in the use of each countermeasure. The reader may find more scientific information about established countermeasures in the reference list.

ADEQUATE SLEEP

The primary culprit for feeling fatigued is sleep loss. The most effective countermeasure for fatigue is to do as much as possible to prevent it from occurring in the first place. So, whatever can be done to obtain regular sleep and to prevent sleep loss should be priority. The principal advantage of getting enough sleep (as it relates to disaster preparedness) is that it will reduce on-the-job fatigue, thereby reducing the need for other countermeasures (Roth, Roehrs, Carskadon, & Dement, 1994; Carskadon and Dement, 1994). The very first general strategy for minimizing sleep loss is to establish a routine approach to obtaining sleep that allows enough time to get sufficient sleep and ensures an appropriate sleep environment. Sleep environment and hygiene will be addressed later.

Relief workers often change shift schedules. This can lead to sleep loss because the body is not adapted to sleeping at a different time of day, so it is necessary to establish shifts and stick with them. The best approach for reducing sleep loss associated with a new shift schedule is to start the new shift with no sleep debt. A goal would be getting at least two nights of unrestricted sleep, prior to beginning a new schedule. Certainly this might be complicated before an un-scheduled disaster, but in the case of hurricanes, it is actually operationally a realistic goal of organized and educated leaders, due to the scientific ability to predict these events with fairly decent accuracy. If making a radical schedule shift, such as between days and nights, it will also be important to obtain some compensatory sleep prior to the start of new shift. For example, if the schedule starts at midnight Friday, it would be desirable to get two full nights of sleep on Wednesday and Thursday night. Then, sleep as long as possible on Friday morning, and try to nap for a couple hours before the start of the midnight shift that day. Napping prior to extended periods of wakefulness will reduce fatigue and improve alertness (Veasey et al., 2002; Bricknell, 1991.) This concept will be addressed again in the context of anchor sleep and jet lag.

A third approach to minimizing sleep loss is to match work schedules to individual physiology. In other words, matching people with shifts that mirror when they feel they are most productive. Designing a tentative schedule in advance of an emergency situation and discussing this with the staff will prepare any team for an accident or disaster. When new workers join a situation, identify if they feel more like a “night person” or more like a “morning person.” Morning people perform best on work schedules with early morning starts (e.g., 0700 hours or before). Night people perform best on work schedules that start in the afternoon or night hours (Bonnett, 2000).

SLEEP AGENTS

The use of prescription sleep aids is not advocated here. Programs that use such medications, as noted previously, have on staff physicians and further training for workers that use such aids. However since the topic is adequate sleep these agents are effective in the proper setting. Ambien and Sonota work well as sleep agents, useful in promoting the onset of sleep in less than ideal conditions. These drugs reduce the amount of time required to fall asleep, improve ability to stay asleep, and can maintain sleep for 7 to 8 hours (Roehrs and Roth, 2000). Although hypnotic drugs such as Halcion and Restoril are part of a class of drugs (benzodiazepines) that are useful for inducing sleep, they are used less and less due to their long half lives and undesirable side effect profile.

NAPPING

Napping is an excellent countermeasure. Many experts recommend the use of naps. A JAMA article summarized combinations of napping countermeasures, referencing 108 articles (Veasey et al., 2002). A 2- to 8-hour nap prior to 24 hours of sleep loss can improve vigilance and minimize sleepiness for 24 hours (Bensimon, Benoit & Lacomblez, 1989). Naps as short as 15 minutes can significantly ameliorate performance decrements if provided at 2- to 3-hour intervals during 24 hours of sleep deprivation (Bonnet & Arand, 1994). Two-hour naps every 12 hours ameliorate performance decrements across 88 hours of sleep deprivation (Reyner & Horne, 2000). Naps must be no longer than 2 hours to minimize sleep inertia. The time of the day most refractory to countermeasures is the circadian nadir, 2 AM to 9 AM, so napping during those hours is not as effective (Gillberg et al., 1994).

Based on biological rhythms, it is normal for humans to feel sleepy between 1 p.m. and 4 p.m. and between 2 a.m. and 6 a.m. That afternoon lull, during which many Americans reach for a caffeine product is siesta time in many countries. A person might be better off reaching for a cot than a cup of coffee. A fifteen minute to and hour long nap can significantly help those who are sleep-deprived (Coren, 1996). Napping as little as 30 minutes every 3 hours and occasional low-dose caffeine may provide safe countermeasures for prolonged shifts (Veasey et al., 2002). Caffeine use will be addressed later.

The nap concept has caught on; in 2006 in New York, a start-up company started offering sleep pods for naps in downtown New York City. The pods block light, are temperature controlled and offer earplugs or soothing quiet music with noise-canceling efforts. Many companies also offer naps to employees (Frenkel, 2004). So education, briefing, promoting and even enforcing sleep/nap schedules is something a sage leader will do. There is a reason that NASA tracks the sleep schedule of astronauts in space! In review of sleep physiology from Chapter One, naps during work periods should be limited to 45 minutes to minimize waking from deep sleep (stages 3 and 4) where it can take more than 30 minutes to become fully alert. Allow 15-30 minutes after a nap to become fully alert (Gillberg et al., 1994). The deeper the sleep, the longer the period needed to become fully alert. Napping should be part of a continuous, non-split shift duty period, and should not be used to extend the duty period.

ANCHOR SLEEP

Another countermeasure on dealing with sleep loss is implementing “anchor sleep” or four hours of sleep the same time each day. Anchor sleep should be used as a coping mechanism for situations where you cannot get a full eight hours of sleep, but not as a routine. Some work schedules do not allow you to get a full eight hours of sleep at the same time period every day. In order to effectively cope with schedules like these, you should arrange to get at least four hours of sleep at the same time every day; additional sleep can be obtained as your schedule permits. Anchor sleep periods have the advantage of stabilizing your circadian rhythm to a 24-hour period, so that you do not constantly feel "out of sync." One can time the anchor sleep period so that his or her circadian rhythm high and low points correspond to their work and sleep periods. Leaders should review sleep schedules and implement anchor sleep if able.

Anchor sleep is not a substitute for getting a full eight hours during any 24-hour period. Instead, it is a coping mechanism meant to keep your circadian rhythm synchronized to a person's daily schedule, by allowing them to sleep for a period of time. It is important to augment anchor sleep with supplemental naps that are sufficient to give the worker the complete sleep allotment that he/she will need on a daily basis. Establishing a "duty day" and maximum hours would allow leaders to decide when and how to implement anchor sleep, if it is needed. "Duty day," is a term used to describe the total hours in a workers day from wake-up, through the shift and including the rest period. In looking at medical training, under the new rules that took effect in 2003, residents will work no more than 80 hours per week, have shifts that are no longer than 24 hours and have 10 hours of rest between shifts. As has been discussed, pilots, truck drivers, boat operators and other fields have mandated policy on duty days to reduce fatigue but perhaps during disasters, rules and duty hours would be a reasonable fix.

TRIP PLANNING

The final sleep countermeasure is "trip planning". Trip planning can be considered both a preventive countermeasure, as well as an operational approach. Trip planning would involve ensuring that you are properly rested prior to starting a trip, or at least finish resting on the way to a disaster. Trip planning deals with jet lag, which of course involves flying. A disaster relief worker can travel across the country or they may cross the world for their job. The goal during such long travel entails getting enough sleep during your main sleep period, and taking a nap prior to a trip start time that occurs during your normal sleep period. Many mariners, for example, take a fairly long nap prior to docking in the middle of the night (Comperatore, Tothblum, Rivera, & Kingsly, 2006). Similarly, airplane pilots might nap prior to a red-eye flight (Comperatore, Rivera, & Kingsley, 2005). The limitations on trip planning involve factors that are often outside of the immediate control of the disaster member, such as when their work shift starts, the availability of rest areas, unplanned delays and the pace of the operations. In general, though, trip planning is an effective approach to starting work more refreshed and alleviating fatigue while on the job. To conclude the issue of trip planning and jet lag the mention of melatonin is appropriate. Melatonin, as the reader will recall, was noted in Chapter One, and is a hormone involved in the control of sleep in mammals. Melatonin in small doses (0.3 to 5 mg) has rapid sleep inducing effects, and lowers alertness and body temperature following administration. When combined with proper timing and light exposure, melatonin can help to adjust the circadian rhythm to a new schedule, and reduce the effects of fatigue and jet lag (Burgess, Sharkey, & Eastman, 2001). As noted, it is not FDA approved, so the over the counter dose is questionable.

SLEEP ENVIRONMENT

To ensure that sleep is restorative, sleeping environments should be quiet, dark and comfortable. “Sleep hygiene” falls in this category and encompass a variety of different practices that are necessary to have normal, quality nighttime sleep and full daytime alertness. Some of the most useful sleep hygiene practices are going to bed and getting up at the same time each day and establishing a regular bedtime routine. The sleep area should be away from traffic and construction noise, if possible. During hurricane Katrina the sleeping areas for many relief workers were unfortunately at the airfield. Individuals should remove any noise sources, especially those that are predictable (e.g., slamming doors, heavy equipment operation, generators). Tips such as the use of earplugs to reduce traffic noise or other external sounds or the use of a constant low-level “white noise” source (such as a fan) often help many people sleep in a less-than-desirable situation. If a noise source can’t be moved (such as in the case of a generator), placing a noise shield between it and the sleep area helps immensely.

Temperature tends to affect the overall comfort level during sleep, and therefore potentially affects quality of sleep. So, if an individual is inclined to feel sleepy anyway, a warm environment may increase those feelings. However, the opposite is not true – there is little benefit to opening a window or lowering the temperature if an individual is already fatigued. In fact, sleeping in a cold environment may decrease the quality of sleep (Mavjee, & Horne, 1994). Using blackout shades—heavy dark fabric for curtains, or “hurricane shutters” over windows can reduce the amount of light in a sleeping area. Some people also use eyeshades. Having a pre-made sleep kit is a common item found on the packing list of experienced disaster and heavily deployed persons or business travelers. Separating out sleeping tents or areas by shifts is wise. Finally, scheduling of maintenance activities for generators, toilets, etc., is best done right after a shift change before persons try to sleep.

The following are a few more final sleep hygiene “best practices.” First, reserve the bedroom only for sleep, not as a work area too. Use relaxation techniques (e.g., meditation) shortly before sleep; allow at least one hour unwinding time before bed. Regular, vigorous daily exercise, preferably in the morning or after waking is advised. Adequate exposure to natural daylight everyday has proven helpful. When sleeping, keep the bedroom as dark as possible and avoid stimulants of any kind within one hour of retiring (e.g., caffeine and alcohol). In fact a “cocktail” before sleep does not aid in rest. Recall from Chapter One that alcohol interrupts the sleep cycle. Do not let staff use alcohol to try to help them sleep. Alcohol cannot be used effectively as a sleep aid (Zarcone, 1994).

PHARMACOLOGIC COUNTERMEASURES-CAFFEINE

Previous chapters discussed various pharmacologic interventions in the mitigation of fatigue. In this chapter, the discussion will center on the well known and widely used agent caffeine. Caffeine is a well-established and available fatigue countermeasure and is widely used throughout the developed and under developed world for its proven fatigue mitigating properties (Bonnet, & Arand, 1994). Caffeine is a xanthine alkaloid compound that acts as a central nervous system stimulant in humans with the effect of temporarily warding off drowsiness and restoring alertness. It is arguably the world's most widely consumed psychoactive substance. In North America, 90 percent of adults consume caffeine daily (Lovett, 2005). The U.S. Food and Drug Administration lists caffeine as a "Multiple Purpose GRAS (Generally Recognized as Safe) Food Substance" (United States Code of Federal Regulations 2003).

Caffeine stimulates the central nervous system initially at lower dosage levels, the cortex and medulla at moderate dosages, and finally the spinal cord at higher doses (Bolton, & Null, 1981). Mild cortex stimulation appears to be beneficial resulting in clearer thinking and less fatigue. Caffeine has also been shown to improve attention in a study that simulated night driving (Lienart & Huber, 1966). Caffeine is considered a non-addictive stimulant (Bonnet, & Arand, 1994) with many of the same behaviorally activating properties as the amphetamines and ephedrine compounds.

Caffeine affects on the nervous system occur within 15 to 30 minutes. These include a more rapid heartbeat and increased alertness, and they last for about four to five hours, but may last up to ten hours in especially sensitive individuals (Bonnet & Arand, 1994). It is important to use caffeine only as a short-term way to boost alertness; regular use can lead to tolerance and various undesirable side effects, including elevated blood pressure, stomach problems, and insomnia and disrupted sleep if taken too close to bedtime (Carskadon, 1993). Caffeinated beverages can help overcome drowsiness for a short period of time and are often used for highway driving.

Obviously, the best prevention for drowsy driving is a good night's sleep the night before your trip (National Sleep Foundation, 2006). Development of simple "check and balance" endurance program that records sleep hours and scheduled naps by first line supervisors monitor it is an effective way to monitor disaster personnel's fatigue levels. A constant and deep "leadership interest" is always a valuable way to stress a point and to prevent accidents.

The training and use of medications to mitigate fatigue to ensure success of mission is seen in specialized programs in the military and the space environment. Military personnel sometimes use stimulants during sustained operations, although this practice has recently been questioned. The effects of prescription stimulants such as Dextroamphetamine and Modafinil are clear-cut: alertness is increased and performance is enhanced, relative to sleep-deprived individuals (Babkoff & Krueger, 1992). It should be noted that in practice, (especially in the U. S. military) these measures are rarely used, typically require extensive oversight by trained physicians and leadership, and approval for use often involves a pre-operational ground test (Bell, Ducharme, Drolet, & Boyne, 2005). Every available alternative means to mitigation of fatigue is used before the possible utilization of such pharmaceutical aids is considered.

One reason to be wary of such a countermeasure is the potential for drug misuse and/or abuse. Highly developed and controlled organizations have systems with better ability to monitor and enforce punishment for misuse than individuals, and the possibility of uncontrolled self-medication is typically the main reason stimulant use is not advised and/or recommended.. The military may well set the standard for use of such a countermeasure during the initial 48-72 hours of national and civilian all-cause disasters, while disaster relief organizations such as FEMA, Homeland Security, the CDC and the numerous other smaller agencies do not have these resources and the risks do not outweigh the benefits. Therefore, the use of controlled stimulants and sleep aids is not advised during disaster relief at this time.

LIGHT THERAPY

Light therapy is a countermeasure that has been extensively studied and will be discussed here briefly. Light therapy can be particularly useful for pilots and other transport workers who rapidly shift through multiple time zones, and for those who work on a forward rotating schedule that changes by one shift each rotation (e.g., day shift, afternoon, night). There are also approaches that can be used for permanent night shift workers. It may not be applicable currently during disaster efforts, but future advances in technology may prove to make this a valuable countermeasure. It certainly can be useful in combating jet lag enroute to a disaster globally.

In order to shift the circadian rhythm using bright light and controlled dark exposure, an individual needs to determine whether he/she wants to advance or delay his/her rhythm. Advancing the rhythm means shifting it so that the low point in the daily cycle (as measured by body temperature) occurs earlier, whereas delaying the rhythm means shifting it so the low point occurs later. Advancing the rhythm will make the day seem shorter; the individual will feel sleepy earlier, while delaying the rhythm will extend the day and the individual will be able to stay up later (Eastman et al., 1995).

Advancing the circadian rhythm allows an individual to adjust to eastbound travel, for example, or to an earlier schedule. Delaying the circadian rhythm allows adjustment to westbound travel, or a later schedule. In general, if an individual is exposed to light following the low point in his/her rhythm it will advance, making it easier to go to sleep earlier and wake up earlier (Eastman et al., 1995). In contrast, if an individual is exposed to light before his/her low temperature point, the rhythm will delay, making it easier to work and sleep later. In practice this means exposure to light during the first part of a night shift to delay the rhythm, or exposure to light prior to normal wake up time, if an individual is a day worker, to advance the rhythm (Eastman et al., 1995).

The light exposure discussed is in the range of 3000 to 10000 or more lux, obtained simply from indoor lights. Space Shuttle crews often utilize this countermeasure before missions to prepare for the massive time zone shifts they will experience as due course of their mission set (Jennings, 2006a). Special equipment is required to generate this level of illumination and some evidence suggests that the green wavelength is especially effective at countering circadian rhythm desynchronization (Wright & Lack, 2001). Using light exposure for several hours over a period of several days is usually most effective in shifting the circadian rhythm, although periods as short as 30 minutes have been shown to have an effect (Cajochen, Zeitzer, Czeisler, & Dijk, 2000).

In addition to light exposure, it is also important to control the timing of darkness. This is especially true for those workers who may be traveling between work and home in the bright morning sun. In these cases, it is important to minimize exposure to the sunlight by wearing dark glasses (special goggles are recommended), and to ensure that your sleeping quarters are blacked out. This can easily be implemented during disasters if the proper gear is brought for the mission.

Exposure to indoor-lighting levels for several hours during the early part of the night (e.g., prior to bedtime) can also promote alertness, and with greater alertness at higher light intensities. This countermeasure can be used in addition to light exposure, or by itself to shift circadian rhythm. This is a particularly good countermeasure to use if one has the flexibility in the work environment to control the lighting level (Cajochen et al., 2000). The use of light therapy may be limited in difficult or uncontrollable environments seen in disasters, but the future may bring more deployable devices that could function or serve disaster personnel in dealing with shift work and rapid time changes. A head visor currently exists that markets this technology. It has even been sent up to the international space station, not as a tested and approved NASA device, but as a personal item for an astronaut (Jones, 2007).

FATIGUE "FITNESS FOR DUTY" TEST

One thing currently lacking in fatigue management is a simple "fitness-for-duty test" a way for supervisors to say this person is too tired or fatigued to work. Generally such a test should employ short tasks to measure a worker's abilities that would be affected by fatigue. These include: reaction time; eye-hand coordination tasks; tracking; short-term memory; involuntary eye reflexes such as pupil diameter and/or speed and amplitude of pupil response and saccadic velocity. Other alertness measure tests include the Psychomotor Vigilance Test designed by Dr. Dinges. Currently no gold standard or single cost effective and simple to use fitness for duty test for fatigue exists. Having one or more fitness test stations set-up with such a "test" at transportation hubs or briefing stations for staff might permit periodic staff fitness testing before workers begin a work shift would be ideal for disaster supervisors. Sadly there is currently there is not an off the shelf solution to the need for a fitness-for-duty test.

OTHER FATIGUE TOOLS

In the transportation field there might be the first emergence of just such a tool. International conferences have looked at this very issue for several years now and are close to developing an answer (Hartley, Horberry, Mabbott, & Krueger, 2000). These groups are aiming to integrate combinations of several different monitoring technologies, employing both vehicle performance and operator physiological status indicators, and offers the best chance of keeping a transportation equipment operator informed of his/her alertness status and impending fatigue effects on safe vehicle control (Dinges & Mallis, 1998). A growing number of in-vehicle and operator status monitoring systems are being tested and evaluated commercially and through government sponsored field-testing in the U.S. and abroad. Measures of alertness as noted earlier are under investigation by the DOT. They include: the wrist worn *SleepWatch*®; the retinal monitoring based *CoPilot*®; SafeTRAC® a technology selected for providing feedback to drivers on their lane tracking; and finally a technology selected for reducing the physical work of controlling vehicle stability while driving called the *Howard Power Center Steering*®. Finally the effective use of scheduling tools by supervisors and administrators such as the

SAFTE model and the FAST scheduling system can play a huge roll in preventing fatigue related problems right up front.

When effectiveness in terms of reliability, sensitivity, and validity is attained through formal validation testing, it may prove worthwhile to incorporate that 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 alertness monitoring technologies (Hartley, et al., 2000). The technologies to come claim to be able to detect fatigue. Focused research is needed to ascertain the sensitivity, reliability, and validity of these devices.

DISASTER PLAN

Some effective countermeasures exist and are proven. Some, like integrated monitoring devices, light therapy and a fitness for duty tool will likely be readily available in the near future. One disaster countermeasure that does exist is having a disaster plan. Most disaster plans do not readily have built in fatigue countermeasures. Several prime examples exist. A tour and briefing given by the director of the CDC's operations center in January 2006 revealed to the author that no fatigue management plan existed (Noah, 2006).

During a CDC Katrina debriefing attended by the author that same month, repeatedly CDC staff voiced frustrations and complaints about the challenges of rest, sleep and fatigue in the deployed environment. Assistance by the author during the first week after Katrina in a Louisiana 911 center found the staff fatigued and admittedly working at a non-optimal performance by day two.

In fact, several post-Katrina conferences brought up this repeated theme from many persons, ranging from Coast Guard officers, law enforcement, FEMA, to NORTHCOM.

Personnel voiced the concern that no established protocol or rest plans existed. Most blamed this on the chaos of the situation and this exemplifies the common myths of sleep. They noted no organizational deployment plan or policy on fatigue from within their organizations and certainly no guidance from higher-ups on the issue.

Seemingly, there were far more important issues to address. The final example is of physicians and hospitals. Physicians are some of the key promoters of fatigue management, they run sleep centers, many do research and physicians often oversee disaster plans. However, implementing work schedules and nap schedules into hospital disaster plans is something that is very difficult to locate on the World Wide Web. In fact this author was unable to find any on multiple searches. Medicine mandates work schedules for regular resident workdays. Does it not seem odd that we neglect this during our disaster development plans? Do we really need a loss of 20-30% effectiveness by twenty-four hours into a disaster event?

As a recent example, Hurricane Rita in 2005 was expected to hit the coast of Texas on Galveston Island. The large medical center there was completely evacuated. It executed this task superbly. Staff hurriedly prepared their homes plus worked long hours to complete the hospital evacuation and prepare the structures for the expected category 5 storm. It was a busy time. Then the staff that remained on the island waited for the storm to hit. No sleep plan was implemented for the staff prior to the storm in these phases of preparation. Staff staying behind should be placed into a rest mode so that when the chaos starts they are at least rested not sleep deprived during the disaster.

An editorial in the British Medical Journal in 2002 commented on the U.S. medical training reforms. The article mirrors the situation seen in disaster response; it states that this is an amazing era for research on the changes occurring. The literature on sleep deprivation supports the medical training reforms. The literature shows that sleep deprivation in laboratory and field studies has a negative effect on the performance of residents. The editorial challenges the academic community that it must not ignore the opportunity to benefit from the natural experiment that will result from the implementation of the new standards for hours of duty that started in 2003 (Philibert & Barach, 2002). Each year, disaster response agencies have the same opportunities to improve the process and promote a safer work environment. Lack of a fatigue management plan is serious. Having another Exxon Valdez is hopefully not needed to stress this point.

A final hospital example can be seen in the Bioterrorism (BT) Hospital Preparedness Program began after 9/11. Since that time many states, in partnership with hospitals and supporting healthcare systems, have made significant strides in preparing to respond to bioterrorism, natural disasters and other public health emergencies. As a result, beginning in 2005, states have been required to give increased attention to documentation of efforts and, more importantly, demonstration of an ability to perform in the event of an incident. Performance measurements and documents need to demonstrate compliance with minimal levels of readiness. Amazingly this Hospital BT preparedness checklist does not track or monitor rest or sleep cycles (Leavitt, 2005).

FATIGUE RESEARCH DURING DISASTERS

The understanding of fatigue is plagued by misconceptions about its causes and characteristics. Fatigue research during disasters needs to be studied. There is no substitute for valid empirical data to guide leaders in decision-making and policy for approaches to fatigue. However that data does not exist. The NTSB may be the closest link; it makes determinations on fatigue in transportation accidents. However, this does not occur during disasters for small accidents, but large-scale events like the Exxon Valdez. In a CDC report entitled *Surveillance for Illness and Injury After Hurricane Katrina, New Orleans, Louisiana, September 8–25, 2005,* amazingly no mention of fatigue, fatigue related accidents or sleep monitoring is found. Nor did it track or associate injuries linked to sleep deprivation or fatigue. Although the goal of the article was to document the illness and injuries during Katrina relief, taking this a step further would allow prevention practices to be further accepted and re-enforced by response agency leadership. A similar CDC report from the tsunami in 2004 and also from Hurricane Andrew in 1992 did not mention fatigue either (CDC, 2005b; CDC 1993).

	Relief workers		Residents		Unknown		Total	
Selected injuries and exposures	No.	(%)	No.	(%)	No.	(%)	No.	(%)
Injuries								
Falls	46	(13.6)	196	(27.4)	222	(23.0)	**464**	**(23.0)**
Bites/Stings	67	(19.8)	92	(12.8)	152	(15.8)	**311**	**(15.4)**
Motor vehicle crash	16	(4.7)	65	(9.1)	64	(6.6)	**145**	**(7.2)**
Intentional injury	4	(1.2)	20	(2.8)	18	(1.9)	**42**	**(2.1)**
Other unintentional injuries*	117	(34.6)	237	(33.1)	362	(37.6)	**716**	**(35.5)**
Undetermined etiology	72	(21.3)	99	(13.8)	128	(13.3)	**299**	**(14.8)**
Toxic exposure/Poisoning								
Carbon monoxide poisoning	5	(1.5)	3	(0.4)	6	(0.6)	**14**	**(0.7)**
Other toxic exposure	11	(3.3)	4	(0.6)	12	(1.2)	**27**	**(1.3)**
Total	**338**	**(100.0)**	**716**	**(100.0)**	**964**	**(100.0)**	**2,018**	**(100.0)**

* Includes cuts, blunt trauma, burns, and environmental exposures.

Table 8. Hurricane Katrina Injuries and Illnesses. Modified from CDC, 2005b

Considering that the above data is already being tracked, extending that to a CDC protocol seems obvious. In reviewing Table 7 above an effective measure would be to start establish a national metric to measure fatigue as well as criteria for inclusion of fatigue related injuries during disasters.

CONCLUSION AND RECOMMENDATIONS

The emphasis of this paper has been to educate disaster leaders on fatigue and fatigue management. In summary of the various chapters, it would seem that further investigation and research of fatigue relationships during disasters is obvious. Recall that most examples of how various models of excellence in our society and economy have dealt with and currently deal with fatigue is by research and then consensus statements from experts. That approach is strongly advised here. The current lack of research from disaster relief events is striking. Leaders in organizations such as FEMA, Department of Health and Human Services, the National Disaster Medical System, CDC, Homeland Security, and NORTHCOM can provide an invaluable service to the staff that work for them, the population they are aiding, the nation and globally, by convening a panel of experts to make a consensus statement on rest and fatigue policy to be used during disasters. Further, they can establish a series of study programs for education modeled on what the FAA and the DOT have done. Similarly to the NASA Ames aviation study, a long term research program would be the most appropriate and does not require a Congressional request. History has proven that the catalyst for change often requires a fatigue related disaster such as the Exxon Valdes or a large commuter plane crash. The research program would be utilized during disasters and disaster exercises. The goal being, based on study data, to develop straight forward, easy to use disaster fatigue management protocol and policy.

More research is needed to fully understand the capabilities and limitations of the human sleep and circadian systems. An additional challenge is the appropriate application of this research to operational environments such as disaster relief. Research also needs to continue to address regulatory, scheduling, and countermeasure questions as well as the application of advancing fatigue technologies, meanwhile the search for “the fatigue fitness for duty test” continues.

The risks associated with fatigue in the aviation and transportation industries, space, medicine, the military and disaster relief organizations have associated outcomes all resulting in morbidity and mortality, not to mention failure in an execution of the mission. The recognition of fatigue is a leadership responsibility in all sectors of society. It is those leaders who can learn from each other to mitigate fatigue and to further validate and sanction the use of effective countermeasure practices.

The research has consistently produced a clear general consensus that cognitive psychomotor performance is impaired by sleep disruption and extended wakefulness. This performance is associated with increased risk of accidents. The clear disconnect between the evidence for fatigue related performance decrements, and the perception, understanding and awareness of the implications of sleep deprivation by the general public, policy makers and leaders can only be addressed through education and commitment to fatigue countermeasure programs. Such programs need to: assess and clarify needs; define and measure the fatigue problem; change the organizational culture toward fatigue; change individual behavior; develop tools and technologies; and finally improve implementation effectiveness and evaluation through effective reliable, sensitive, and valid ongoing research.

The final recommendation is that leaders have a disaster plan that includes fatigue management and implements known countermeasures. It also needs to ensure that human factors groups or committees are formed, plan and are part of the disaster response package. Those groups should monitor and provide feedback to leaders on successes and failures. They should also ensure that all persons in leadership and scheduling positions are trained and “certified” to actually be responsible for work shifts and rest periods. Effectively, such a fatigue program with leadership commitment, staff education, human factors committee oversight and trained schedulers would culminate in a highly effective program. Thus resulting in a fatigue handbook of “good practices for use during disasters. The area of fatigue is riddled by misconceptions about its causes and characteristics. There is no substitute for valid empirical data to guide decision making and policy.

Nothing is so fatiguing as the eternal hanging on of an uncompleted task.

William James (1842-1910)

American philosopher and psychologist

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VITA

Sean Andrew Hollonbeck was born in Martin Army Community Hospital at Fort Benning Georgia in November 1999 to CPT Gary-Hollonbeck, O.D. and Mrs. Susan Hollonbeck, both from Illinois. . He enlisted in the United States Army in October 1987 in the Illinois Army National Guard. After serving in the light infantry for five years there he was first commissioned into the medical corps at an Illinois National Guard forward support medical battalion and then was selected for the Health Promotions Scholarship Program as a Reserve officer.

During that time he completed his undergraduate degree in Biology at the University of Illinois in 1992. He was accepted to medical school at Southern Illinois University School of Medicine. Upon graduation in May 1997, he attended Family Practice residency training at Fort Benning, Georgia from June 1997 to July 2000. After a selection assessment and graduation from residency he commenced training to serve as the flight surgeon for 3rd Battalion Special Operations Aviation Regiment (Airborne) at Hunter Army Airfield (2001 to 2003). During that time he deployed extensively in support of Operations Enduring Freedom and Iraqi Freedom. He then became a team chief in charge of the internal medicine, aviation medicine, flight medicine and occupational health sections of Lawrence Joel Army Health Clinic at Fort McPherson Georgia (2003-2005).

In the spring of 2005, he was selected to attend the University of Texas Medical Branch Masters of Public Health degree program as part of a second residency. He is finishing Aerospace Medicine residency training at the Naval Aviation Medical Institute at Naval Air Station-Pensacola, Florida.

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SUMMARY OF CAPSTONE

The emphasis of this paper has been to educate disaster leaders on fatigue and fatigue management. The need for sleep is real, inescapable and often misunderstood. The impact of fatigue on performance is greatly magnified when individuals have to operate under conditions of high emotional, psychological or physiological stress – all inherent conditions for disaster response teams. Fatigue can clearly increase the risk of fatalities and injuries. Fatigue in disaster relief workers is an unstudied and critical safety issue in the complex process of disaster management and relief. This paper is designed for leaders in disaster agencies and management as guide to understanding the problem of fatigue in the austere uncontrolled chaos of a disaster event and to be able to implement effective scientific countermeasures to ensure mission success.

The National Transportation Safety Board (NTSB) has found that the incidence of fatigue is underestimated in virtually every transportation mode, because it is so hard to quantify and measure. Many accident investigations do not obtain the information necessary to determine the contribution of fatigue; namely, the condition of the workers, the extent to which they have been deprived of sleep, and their state of alertness.

This report will show through studied “best practices” in areas of industry (the military, medicine, the transportation industry and aviation) that the un-researched hazard of fatigue during disasters exists and more importantly by comparing and review these other areas the reader will be prepared address the challenge of severe decrements in cognitive and physical performance caused by fatigue. The outcome is to educate disaster relief leaders about fatigue, human fatigue physiology, the risks and hazards of fatigue as well as countermeasures to fatigue. Then armed with this new knowledge disaster leaders will be empowered to make effective decisions and establish policy and doctrine with a resulting positive impact on disaster relief safety.

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This dissertation was typed by Sean E. Hollonbeck.

You can't solve a problem unless (a) you recognize you've got a problem and (b) you understand the nature of the problem.

Judith Orasanu, Ph.D., NASA AMES Research Center