Chapter 15

JET LAG AND SLEEP DEPRIVATION

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INTRODUCTION

Current and projected US military strategies call for rapid deployment of forces based in the continental United States to any part of the globe. These rapidly deployed forces will travel by air across multiple time zones and will need to be operationally effective immediately on arrival. These forces will conduct operations 24 hours a day, with the bulk of fighting occurring at night. Such rapid transmeridian travel will lead to desynchrony between external time cues at the new time zone and the service member's internal timing (circadian) system. Desynchronosis refers generally to situations in which external time cues are out of synchrony with the body's internal rhythms, the body's internal rhythms are out of synchrony with each other, or both. Jet lag is a specific instance of desynchronosis caused by crossing time zones. The symptoms of jet lag include cognitive performance impairment, sleep difficulties, gastrointestinal problems, fatigue, and mild depression.[1] Many of the body's physiological processes (eg, body temperature, hormonal rhythms) are cyclic; peaks and troughs recur at predictable times relative to external time (eg, body temperature reaches a nadir between 4 and 6 AM and begins rising again toward the end of the sleep period) and to each other. These cyclic processes readjust slowly to changes in external cues. In the case of deployment across multiple time zones, it takes 5 to 8 days for these cyclic processes to synchronize with the new local time. During this 5-to-8-day readjustment period, the individual suffers from jet lag. Shift work causes many of the same symptoms as jet lag because individuals are attempting to remain awake at times when bodily rhythms are synchronized for sleep.

During deployment, military personnel who rapidly cross time zones and work in shifts will suffer desynchronosis from both. Deployments increase the risk of jet lag, and they also increase demands on the service member's alertness and cognitive performance because of the advanced technology used by today's US military services and increases in operational tempo. For purposes of managing sleep to sustain alertness and performance before and during deployments, the researchers at the Walter Reed Army Institute of Research (WRAIR) are developing a Sleep Management System (SMS). The SMS will consist of six elements:

1. means to measure sleep under operational conditions,
2. a computer-based algorithm to predict performance on the basis of prior sleep,
3. recommendations for safe, effective stimulant drug use when no sleep is possible,
4. recommendations for safe, effective sleep-inducing drugs to promote good sleep under non–sleep-conducive conditions,
5. systems for on-line, real-time monitoring of alertness and performance, and
6. guidelines and doctrine for managing sleep to sustain alertness and performance during deployments.

Efforts toward managing sleep and alertness are also under way by other branches of the military and at the National Aeronautics and Space Administration. Each of these efforts focuses on one or more individual components of the WRAIR SMS. A comprehensive listing of fatigue-related resources is maintained by the Department of Transportation and can be found at the website http://olias.arc.nasa.gov/zteam.

This chapter is divided into two sections. The first section describes jet lag and factors influencing its duration and severity, effects of jet lag on sleep and of consequent sleep deprivation on performance, and a review of general approaches aimed at alleviating jet lag effects. The second section describes the Army Aviation Fighter Management System (AAFMS). The AAFMS is a practical guide for maximizing crew endurance by minimizing fatigue and performance degradation throughout a mission. The AAFMS describes practical applications of certain components of the WRAIR SMS but, in addition, provides specific guidance for coordinating scheduled unit activities such as aircraft maintenance cycles, refueling, briefing, and meals. The AAFMS can be used as a guide for scheduling activities to reverse desynchronosis occurring after transmeridian flights or during shift work. In a more general sense, however, the AAFMS is a guide that can be applied to any military scenario in which the goal is to improve crew endurance through sleep management.

JET LAG

Flight Factors

Several factors have been identified that affect the severity and duration of jet lag. These include the direction of travel, number of time zones crossed, and flight duration. In the case of the first factor, direction of travel, an eastbound flight crossing six time zones is perceived as more stressful than a westbound flight crossing the same or even a greater number of time zones.[2,3] Fragmented sleep (sleep with frequent awakenings) is a common problem following eastbound travel particularly, because sleep is being initiated during the individual's physiological day. On the other hand, after westbound travel, sleep is generally initiated at some point within the individual's physiological night.

The second factor affecting jet lag is the number of time zones crossed; jet lag duration is a direct function of number of time zones crossed.[2,3] As a general rule, one day of recovery is required for each time zone crossed. Whether a flight is homebound or outbound appears to have no effect on either severity or duration of jet lag. A homebound flight in an easterly direction will be perceived to be as stressful as an outbound flight in the same direction.

Flight duration, the third factor, affects jet lag severity but has no effect on its duration. Longer flights across the same number of time zones cause more severe jet lag. Flight duration probably causes general fatigue; some malaise is reported[4] after long north-south flights in which no time zones are crossed. In addition, long flights often involve some degree of sleep deprivation. It is likely that longer flights increase jet lag by increasing sleep loss.

Individual Differences

Individual differences are thought to affect severity and duration of jet lag, and they include chronotype (whether an individual is a morning person or an evening person), age, and personality (whether an individual is an introvert or an extrovert).[5] Only age, however, has a demonstrated objective effect on jet lag. When crossing the same number of time zones, individuals as young as 37 to 52 years of age suffer more severe and longer-lasting jet lag as measured by objective criteria (eg, performance, sleep quality) than younger (18–25 years old) individuals.[6] It is unclear whether this discrepancy is due to age-related declines in circadian system flexibility, in overall health, or in sleep pattern consistency in general (regardless of time zone transition). Individuals reaching early middle age, therefore, may require jet lag interventions for a longer period than young adults.

Rate of Adaptation to Time Zone Change

Over time, individuals become adapted to the new local time. One factor affecting rate of adaptation is exposure to social cues. Individuals allowed social contacts adapt up to two times more quickly to new time zones than individuals who remain isolated from social contact by, for example, remaining inside hotel rooms or barracks.[7] Similarly, regular exercise and regularly scheduled meal times may hasten subjective adaptation to new time zones.[5] The success of those two activities may reflect a more general effect of engagement in regular activity, no matter what the source. Factors such as social cues, exercise, and meals may act as general "zeitgebers" (time cue providers). Any activity occurring regularly may act as a zeitgeber and thus hasten adaptation to new time zones.

JET LAG AND SLEEP

Although jet lag is a consequence of desynchronosis, a growing consensus suggests that the most important component of jet lag is desynchronosis-induced sleep deprivation.[8] Indeed, many of the symptoms of jet lag (eg, degradation in performance, alertness, and mood) mimic those of sleep deprivation, suggesting that sleep loss is one of the main factors contributing to jet lag symptomology, such as sleep difficulties and fatigue.

The effects of transmeridian travel on sleep are well described.[9] Following eastbound travel, both the ability to fall asleep (sleep initiation) and to stay asleep (sleep maintenance) are adversely affected. These effects can last up to 8 days following a 7-hour time zone shift. Following westbound travel, the ability to fall asleep is unaffected, but the ability to stay asleep in the second half of the sleep period is impaired[10] because this portion of the sleep period occurs during the individual's physiological morning. Both eastbound and westbound flights also affect the balance of the various sleep stages.[9] The consequences for performance and well-being are probably marginal, however, because there is no evidence that any one sleep stage is more important than any other, as long as duration of sleep is preserved. Because the recuperative value of sleep, in terms of next-day performance and ability to maintain alertness, is dependent on duration,[11] eastbound travel in particular diminishes sleep's recuperative value by decreasing sleep duration through increased time spent either awake or in very light, nonrecuperative sleep. A repeating pattern of a night of poor sleep followed by a night of good sleep is often experienced by jet-lagged individuals, particularly after eastbound flights. This zigzag pattern of alternating good and poor sleep reflects the combined effects of desynchronosis, which leads to a poor night's sleep, and subsequent sleep deprivation, which drives "good" sleep on the following night.

Flight scheduling also affects the amount of sleep deprivation incurred with transmeridian travel. Eastbound flights are generally scheduled as night flights, with passengers arriving in the morning of the new local day; this requires them to miss more than 24 hours of sleep if they did not sleep during the flight. Westbound flights are usually day flights arriving in the afternoon of the new local day, therefore resulting in only several hours of sleep deprivation (equal to the number of time zones crossed) before nocturnal sleep.

The most important consequences of transmeridian travel on sleep are the inability to fall asleep and, once asleep, frequent awakenings throughout the night. Both these effects lead to decreased quantity and impaired quality of sleep and result in diminished performance and alertness.

SLEEP DEPRIVATION AND PERFORMANCE

Partial sleep deprivation, total sleep deprivation, and fragmented sleep (even if the normal total hours of sleep are accumulated) have deleterious effects on alertness, cognitive performance, and mood. A variety of studies suggest that higher-order mental operations (ie, those involving the prefrontal cortex) are particularly sensitive to sleep deprivation. Complex cognitive performance, including the ability to understand, adapt, and plan in rapidly changing circumstances, is affected.[12] In a detailed and realistic simulation of artillery fire operations,[13] five-person teams were evaluated for their ability to conduct simulated continuous combat operations lasting 36 hours. Each team's task was to plot target locations; derive range, bearing, and angle of gun elevation; and charge immediately on receipt of the target and update situation maps. Across 36 hours of sleep deprivation, each team's ability to derive range, bearing, and elevation accurately and to charge was unimpaired. After approximately 24 hours without sleep (about the same amount of sleep deprivation incurred following nighttime eastbound flights of more than 6 hours), however, team members stopped updating their situation maps and stopped computing preplanned targets immediately on receipt of new information. As a consequence, the teams disrupted their smooth, accurate flow of work, fired on prohibited targets, and generally lost control of the operation. This is exemplary of the types of performance deficits seen in real-world situations involving partially or totally sleep-deprived individuals.

In laboratory simulations, sleep fragmentation and sleep deprivation result in a decline in overall performance (primarily because of reduction in speed), but accuracy is relatively preserved. Performance degradation in the laboratory across time, when no sleep is allowed, is characterized by a gradual, systematic decline (Figure 15-1). In actual operations, this systematic decline in performance may be of no great consequence if the task is simple and familiar and if accurate (albeit slower) performance is sufficient. However, if the task is complex, unfamiliar, intrinsically time-limited, or any combination of these, sudden failure may occur when the time needed to reach an accurate decision exceeds the time available. When time runs out, the individual is forced to guess, and performance drops to chance levels. In actual operations, a gradual decline in performance may still maintain the appearance of adequacy until performance drops below some critical threshold, at which point sudden failure occurs. If the individual is a critical element in a complex system, the sudden performance failure may result in catastrophic consequences.

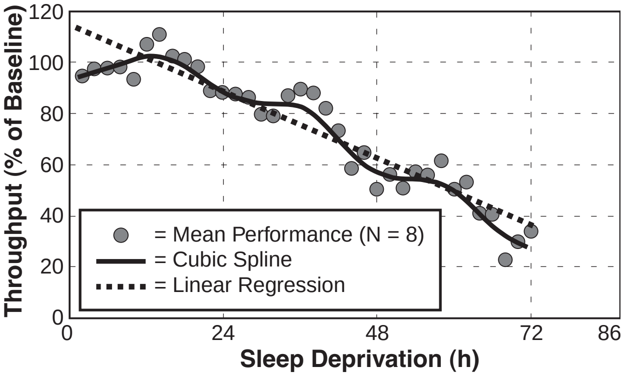

Fig. 15-1. This graph illustrates performance on a computerized, serial, addition-subtraction task across 72 hours of total sleep deprivation within the laboratory. Data are from eight healthy young males undergoing 72 hours of total sleep deprivation in the laboratory. In this task, subjects mentally added or subtracted two numbers appearing sequentially on the screen (followed by an arithmetic operation sign), and entered the answer on a numeric keypad. The spheres represent mean performance on the serial addition or subtraction task. Data points represent the product of speed and accuracy, and as a percent of baseline (presleep deprivation) performance. The speed * accuracy product is noted as "throughput." Throughput is the same as productivity, the amount of useful work performed per unit of time. Superimposed on this linear decline is the normal circadian rhythm shown here as the cubic spline fit to the data.

JET LAG INTERVENTIONS

The most important consequence of transmeridian travel is impaired sleep. Impaired sleep leads to performance degradation, so most interventions are aimed at either improving sleep or, when sleep is not possible, improving alertness. Approaches aimed at overcoming poor sleep, as well as boosting performance under sleep-deprived conditions, have been successful and are well documented.[14–16] Interventions aimed at speeding the rate of reentrainment (ie, overcoming the desynchronosis component of jet lag) have had less success,[5] with the exception of carefully timed bright light.[17]

Speeding Reentrainment

Chronobiotics

The search for a chronobiotic agent, an agent that speeds reentrainment of the body's clock to new local time, has met with only limited success. Dietary interventions receiving some attention include combination carbohydrate-protein diets and tryptophan. None of these approaches has been shown to speed reentrainment or to prevent or alleviate jet lag as measured objectively by performance, body temperature, or sleep-wake cycles. Positive effects on subjective ratings of performance and mood, however, have been noted. Pharmacological approaches to speeding reentrainment have included using caffeine, benzodiazepines, and melatonin.[5] Although these compounds have not yet been shown definitively to speed adaptation to time zone changes, they have demonstrated objective effectiveness for improving either alertness or sleep.

Bright Light

There is substantial evidence[17] that properly timed exposure to bright light can speed rates of reentrainment (as measured by body temperature) to new time zones. Timed bright light, however, requires scheduled, controlled exposures and therefore is impractical for most military operational settings. Conversely, improperly timed light exposure can slow reentrainment. Ambient daylight is bright light. Appropriate timing of exposure to ambient daylight is important for adjustment to new time zones and to shift work. Thus, management of ambient light exposure is an important element in adaptation to new time zones and is being incorporated into the WRAIR SMS.

Prophylaxis

Prophylactic measures attempt to minimize desynchronosis on arrival at the new time zone. The most straightforward approach consists of gradually shifting bedtime to match the destination's local time before embarking. This proactive approach is impractical, however, because it requires the individual to overcome powerful environmental cues and social demands, such as going to bed several hours before the norm. It is unreasonable to expect an individual planning to take a trip crossing eight time zones to go to bed at 4 PM for 1 week before he or she leaves.

Interventions for Improving Sleep and Alertness

Interventions aimed at improving sleep quality and alertness have been used successfully to combat sleep loss caused by transmeridian travel and sleep loss during continuous or sustained operations. These interventions are being incorporated into the WRAIR SMS.

Naps

Naps aimed particularly at alleviating sleep deprivation may be a useful strategy because in continuous operations naps can significantly improve performance.[18] As with the main sleep period, naps must be of sufficient duration and continuity to be effective. For example, a 1-hour nap that is fragmented with awakenings and shifts to light, nonrecuperative sleep may not be as effective as a 30-minute nap that is unfragmented. Prophylactic naps taken during transmeridian flights offer some benefit, particularly on eastbound flights when individuals arrive in the morning of new local time and must begin work immediately. Even though there may be opportunity to sleep on transmeridian flights, conditions are rarely conducive: sleep is interrupted by meals and other in-flight services, the cabin is well-lit and noisy, and the seats are uncomfortable for sleep. Nap quality can be improved by the use of nonpharmacological sleep aids (eg, ear plugs, sleep masks) and pharmacological ones.

Caffeine

Stimulants may be useful in the short-term management of alertness following a night of reduced sleep. Caffeine in doses from 300 to 600 mg (a cup of coffee contains approximately 100 mg of caffeine) is effective in reversing the cognitive performance deficits of 48 hours of sleep deprivation, with effects lasting up to 12 hours.[19] In situations where an opportunity to sleep becomes available after caffeine administration, however, the ability to fall asleep, even in the face of sleep deprivation, may be impaired.[14] In addition, caffeine cannot replace sleep itself. Thus, caffeine may be used as a short-term solution to sleep deprivation, but it has no effect on speed of reentrainment and may adversely affect subsequent sleep.

Pharmacological Sleep Aids

Orally administered benzodiazepines represent the most widely prescribed class of sleep-inducing agents. Their effects on improving duration and continuity, and hence recuperative value, of sleep are well documented.[20–22] Drugs such as triazolam (Halcion), temazepam (Restoril), and zolpidem (Ambien—a nonbenzodiazepine that has effects similar to benzodiazepines) improve sleep by reducing the time taken to fall asleep and the number of awakenings, thus improving sleep duration by reducing fragmentation.

To be useful in a military setting, sleep-inducing agents should act quickly and should not impair postsleep performance. In laboratory studies[23] of sleep during and following a simulated eastbound flight, the short-acting agents triazolam and zolpidem substantially improved sleep by putting people to sleep quickly and keeping them asleep in spite of a bright, noisy environment in which the subjects were sitting upright. However, at sleep-inducing doses (0.5 mg of triazolam, 20 mg of zolpidem—twice the currently recommended dose of both drugs), triazolam and zolpidem produce cognitive performance impairments (primarily impairing the ability to learn new material) if individuals are forced to awaken and perform mental work when the drug is having its peak effect. Thus, the benefits of drug-induced sleep under operational conditions may be offset by potentially hazardous performance impairments if personnel are required to awaken and perform before the drug effects have dissipated. Performance impairments due to sleep-inducing drugs may not be immediately apparent because individuals are able to perform tasks and recall information that was learned before taking the drug. However, if military personnel are given a new task or instructions while still under the effects of the drug, their subsequent memory for this new information is likely to be impaired. In a field study[24] involving long-range deployment by air, 0.5 mg of triazolam (the only dose found to be sleep-inducing under non–sleep-conducive conditions) had equivocal effects on sleep during the 8-hour eastbound flight. More important, triazolam produced operationally significant impairments in new learning on arrival in Germany, 8 hours after drug administration. In fact, other studies[16,23] have shown that the more effective triazolam and zolpidem are for inducing sleep, the greater the performance decrement at estimated peak drug plasma concentrations, approximately 1.5 hours after oral ingestion for both drugs. Because high doses of triazolam and zolpidem (as well as other sleep-inducing agents) appear to be necessary to substantially improve sleep in healthy, young adults in non–sleep-conducive conditions, up to 8 hours of downtime is required following administration of 20 mg of zolpidem and up to 12 hours may be necessary following administration of 0.5 mg of triazolam.[15,16] Lowering the dosage (eg, 0.25 mg of triazolam or 10 mg of zolpidem, the maximum doses currently recommended) would reduce the risk of postsleep performance impairments. It might also reduce the amount of recuperative sleep obtained, particularly in non–sleep-conducive environments or in relatively well-rested individuals. Pharmacological sleep aids can improve the recuperative value of sleep, but they carry the risk of impaired postsleep performance if the duration of downtime following drug administration is inadequate. Given with adequate downtime in the schedule, both drugs are considered safe and effective for improving sleep.

An alternative to extended downtime following administration of pharmacological sleep aids is the administration of an "antidote" drug that reverses within minutes the effects of the sleep-inducing agent. The combination of triazolam followed by caffeine has been investigated, but caffeine has little effect on reversing triazolam-induced performance deficits.[25] Flumazenil (Romazicon), a nonstimulant drug used to reverse benzodiazepine anesthesia and overdose, has been tested in simulated deployment situations.[15] Flumazenil fully reversed the performance-impairing effects of sleep-inducing doses of triazolam and zolpidem. A two-drug system, consisting of a combination sleep-inducing agent (triazolam or zolpidem) followed by a rapid-reawakening agent (flumazenil), is currently under development for the WRAIR SMS.

Melatonin

Melatonin may be useful for improving sleep, speeding adaptation after transmeridian travel, and speeding adaptation to shift work. The potential benefits of a low pharmacological dose of melatonin (10 mg or less) are its lack of toxicity,[26] short duration of action,[27] minimal side effects, and putative resynchronization[28] and sleep-inducing properties.[29] Melatonin (5 mg) decreases sleep latency, improves sleep quality, and increases next-day alertness,[30] although to a lesser degree than triazolam or zolpidem. Similarly, melatonin increases subjective sleepiness following administration of 2 mg and 5 mg.[2,31] A study[32] of efficacy in the prevention of sleep loss and cognitive degradation in volunteers traveling eastward across eight time zones and working nighttime duty hours showed that a 7-day melatonin regimen (10 mg administered twice, once at 7 PM and again at 8 PM) resulted in longer sleep duration and improved postsleep performance.

Following eastbound flights, melatonin administration during the late afternoon and early evening of the new local time may hasten sleep onset. Following westbound travel, administration during the second half of the night may reduce sleep maintenance problems. For the latter, a time-release formula taken before bedtime would avoid disrupting sleep to take medication. It is unclear what dosage of melatonin is optimal for chronobiotic effects, because recent findings indicate that larger doses (eg, 5 mg) are more effective than smaller doses for inducing phase shifts.[28] As with the benzodiazepines, however, melatonin doses of greater than 1 mg may impair postsleep performance. In particular, the time required for the return of full alertness following a given dose of melatonin has yet to be determined, and currently there is no available “antidote.” Research is under way to determine melatonin’s effectiveness during multiple rapid deployments, its effects on flight performance, grounding time for aviators, possible interactions with the menstrual cycle, and appropriateness for incorporation into the WRAIR SMS.

The most deleterious consequence of desynchronosis due to jet lag or shift work is its effects on sleep quality. Impaired sleep quality, in turn, adversely affects performance and mood. Interventions aimed at either improving sleep or bolstering alertness when sleep is not possible have been successful. Conversely, with the exception of bright light and possibly melatonin, attempts to speed reentrainment have been unsuccessful. Impaired sleep and sleep deprivation have thus been identified as causing impaired performance and mood following transmeridan travel or shiftwork. The above interventions aimed at improving sleep and alertness, however, are general in nature. Guidelines for identifying specific activities that could potentially interfere with crew sleep and improving coordination of these activities are also required. The US Army Aviation Fighter Management System was developed in response to these needs.

THE US ARMY AVIATION FIGHTER MANAGEMENT SYSTEM: A SYSTEMS APPROACH TO CREW ENDURANCE

Because the most deleterious, and avoidable, consequence of desynchronosis is sleep deprivation, the Army Aviation Fighter Management System (AAFMS) focuses on controlling sleep and factors that affect it. The implementation of a desynchronosis prevention plan requires an integrated system that encompasses a crew endurance plan and a sleep and daylight exposure plan. To be successful, this effort must include everyone from the individual service member through the upper management strata. The AAFMS is a guide to creating this integrated system. Although the AAFMS describes activities relevant to Army aviation missions, activities specific to any branch of the military could be substituted.

The crew endurance plan is a set of activities that must be coordinated for any mission. These activities, or elements, are best arranged by order of flexibility (Figure 15-2). Mission objectives are the least flexible of these elements so cannot be changed by the crew, while materiel activities (eg, maintaining and operating aircraft) are the most flexible and usually can be scheduled by the crew. The most flexible elements or activities are scheduled around the least flexible.

Mission Requirements

At the center of the crew endurance management system are mission requirements, the activities over which the unit has no control. Mission requirements determine how the crew rest plan evolves and determine the unit’s work-rest cycles, mission flight schedules, operational tempo, and flight environment. Elements of a crew rest plan for a particular mission are determined by the unique requirements of that mission.

Individual-Level Activities

The individual level is composed of strategies that, although developed by unit planners based on the mission requirements, must be adjusted by the

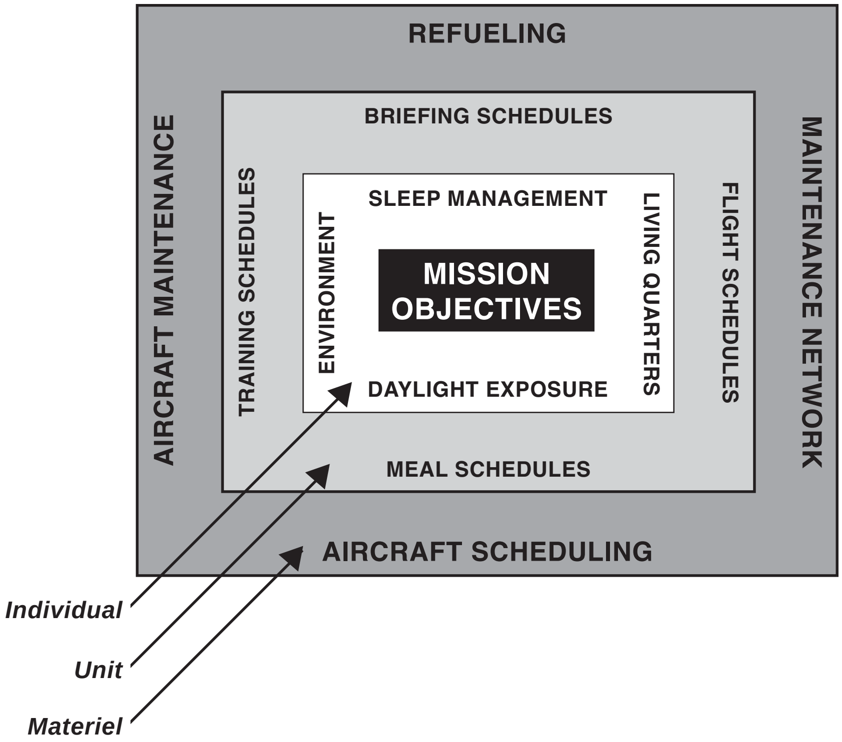

Fig. 15-2. Schematic of the Crew Endurance Management System. At the core of the system-and driving the other elements-are mission objectives. Individual-, unit, and materiel-level elements for improving crew sleep and alertness are coordinated around mission objectives.

individual service member to meet his or her needs. These controls are nonpharmacological. The use of pharmacological means of improving sleep and alertness should be restricted to special instances in which the outlined controls are inadequate or impractical. The potential risks of using pharmacological sleep inducers or alertness enhancers or both must be weighed against the potential benefits to accomplishing mission objectives. These individual-level critical strategies help prevent sleep deprivation following transmeridian deployment or shift work. They include a sleep management plan, a daylight exposure management plan, and an environmental management plan (Table 15-1).

Sleep Management Plan

Sleep management requires the identification of bedtimes and awakening times that are likely to provide sufficient rest and return military personnel to duty at their maximum alertness. A knowledge of mission requirements, such as deployment timing and tactics, must precede the design of the sleep management plan. Bedtimes and awakening times are scheduled around the deployment schedule or flight mission. Other schedule elements at the unit and materiel levels (eg, meals, briefings, aircraft maintenance) are then adapted to the sleep management plan.

After the sleep management plan is approved, it should be reviewed by the chain of command. Each person in the chain should be trained regarding the plan's implementation. This ensures that each service member understands his or her individual strategies. Although the sleep management plan is tailored to the individual, its controls generally are applied to small groups. For example, sound masking (a technique to help individuals sleep in a noisy environment) benefits all personnel trying to sleep in the immediate area. Both individual and small-unit responsibilities are involved in implementing a sleep management plan.

Light Management Plan

The daylight exposure management plan provides a schedule of daylight exposure or avoidance that will synchronize the body clock to the mission-driven work-rest cycle. The plan is based on how the body's circadian rhythm responds to light, depending on time of day. In general, most people's circadian rhythms respond to light exposure at a given time of day by shifting in the same direction.[33] The light exposure

TABLE 15-1

PRACTICAL CONTROLS FOR SLEEP, AMBIENT LIGHT, AND ENVIRONMENTAL MANAGEMENT AT THE INDIVIDUAL LEVEL

Goal	Practical Control
Ensure adequate duration and continuity of sleep	Schedule one continuous sleep period lasting 6–8 h
Ensure that sleep takes place in darkness	Black out windows if sleep is taken during the day Use sleep masks if sleep is taken during the day
Improve sleep-conducive quality of noisy environments	Provide ear plugs to dampen noises Mask sounds using rushing sounds but a constant rate and volume
Improve sleep-conducive quality of hot environments	Improve evaporative cooling by providing fans
Improve sleep-conducive quality of cold environments	Warm tents before the sleeping period to avoid disruptive effects of fire inspections required when heaters are used during sleep
Hasten adaptation from day work to night work	Avoid varying initial daylight exposure after awakening Avoid daylight immediately before or during sleep period Wear dark sunglasses at other times to reduce the amount of light reaching the eyes Retire as soon as possible after night operations
Hasten adaptation from night work to day work	Seek as much daylight exposure as possible within the hours dictated by the light management plan

Source: Comperatore CA. The crew rest system. In: Comperatore CA, Caldwell J, Caldwell L, eds. *Leader's Guide for Crew Endurance*. Fort Rucker, Ala: US Army Safety Center; 1996.

plan is designed to enhance speedy adaptation to a new work schedule or time zone or both, without the need for timed exposure to artificial bright light. Individuals traveling eastward who have daytime duty hours should avoid daylight from sunrise to approximately 10:30 AM, particularly when they have crossed more than five time zones. They should seek daylight exposure after 10:30 AM because the exposure will stimulate the advance of the sleep-wake cycle and promote adaptation to the new time zone. This approach should be implemented during the first 2 days after arrival. Thereafter, daylight exposure may begin at sunrise.

When nighttime operations are combined with travel across more than five time zones, military personnel need only advance sleep onset by 2 to 3 hours relative to their bedtime at the home time zone. In this case, if night operations extend into the early morning hours (eg, 4:00 or 5:00 AM), service members should retire before sunrise; if the duty period extends past sunrise, they should avoid exposure to daylight by, for example, wearing dark sunglasses that prevent light intrusion into the eyes. Individuals should seek daylight exposure after 10:30 AM. This process will eventually result in the advance of the sleep-wake cycle by approximately 2 to 3 hours in the first week after arrival.

Environmental Management Plan

Noise and daylight intrusions into sleeping quarters degrade sleep and hence its recuperative value for sustaining subsequent alertness and performance. This is particularly problematic when personnel are sleeping in the field. Similarly, extreme temperatures in sleeping quarters will degrade sleep.

Unit-Level Activities

The unit level includes coordination of scheduled activities within groups of service members. These elements must be scheduled after considering the individual-level schedule of activities. For example, unit and aircrew mission briefings should be scheduled to occur before or after the designated sleep

TABLE 15-2

PRACTICAL CONTROLS FOR SLEEP, AMBIENT LIGHT, AND ENVIRONMENTAL MANAGEMENT AT THE UNIT LEVEL

Unit-Level Activity	Practical Control
Briefings	Schedule briefings to occur outside the designated sleep period
Training for night operations personnel	Modify training schedule to accommodate designated sleep periods
	Segregate day crews from night crews to reduce ambient noise levels during scheduled sleep periods
Meals	Schedule breakfast as first meal after awakening for both night and day workers
	Schedule all meals outside of designated sleep period

Source: Comperatore CA. The crew rest system. In: Comperatore CA, Caldwell J, Caldwell L, eds. *Leader's Guide for Crew Endurance*. Fort Rucker, Ala: US Army Safety Center; 1996.

period. Most elements at this level can be customized by the unit. Common unit activities that must be considered within the crew rest plan are summarized in Table 15-2.

Materiel-Level Activities

The materiel level involves work schedules and activities associated with equipment used to accomplish mission objectives. For example, in an aviation unit, elements in the materiel level are primarily concerned with maintaining and operating aircraft. This level is the most flexible and can often be tailored to schedules at the individual level. The unit's management of aircraft involves scheduling maintenance, refueling, air crews, and aircraft flight times. Each of these activities may potentially disrupt the crew rest plan if coordination is neglected. Materiel-level elements and practical controls for their coordination within the crew rest plan are found in Table 15-3.

TABLE 15-3

PRACTICAL CONTROLS FOR SLEEP, AMBIENT LIGHT, AND ENVIRONMENTAL MANAGEMENT AT THE MATERIEL LEVEL

Materiel-level Activity	Practical Control
Aircraft maintenance	Submit maintenance requests immediately after arrival from night missions to prevent disruption of crew rest
Refueling	If near designated sleep areas, schedule refueling to occur before or after sleep period
Aircraft scheduling and operations	Keep aircraft keys and log books in a tent separate from where crew are sleeping to prevent disrupting crew rest to get access to keys and log books
	Plan approach routes into field landing zones and bivouac areas so that aircraft do not fly over designated sleep areas
	Direct visiting aircraft to landing areas that are not adjacent to sleeping personnel

Source: Comperatore CA. The crew rest system. In: Comperatore CA, Caldwell J, Caldwell L, eds. *Leader's Guide for Crew Endurance*. Fort Rucker, Ala: US Army Safety Center; 1996.

Further Information

Detailed descriptions of crew endurance management plans for specific missions, such as night operations and rapid deployment, are contained in the Army's *Crew Endurance Leader's Guide*[34] published by the Army Safety Center, Fort Rucker, Ala. For more information on crew endurance and light management plans, contact Dr. Lynn Caldwell, US Army Aeromedical Research Laboratory, Aeromedical Factors Branch, ATTN: MCMR-UAS-AF, PO Box 620577, Fort Rucker, AL 36362-0577, DSN: 558-6858, (334) 255-6858. For more information on sleep and performance in general, and the WRAIR SMS, see the WRAIR Division of Neuropsychiatry's home page on the World Wide Web at *http://wrair-www.army.mil* or contact COL Gregory Belenky, Director, Division of Neuropsychiatry, Walter Reed Army Institute of Research, 503 Robert Grant, Silver Spring, MD 20910-7500; e-mail: gregory.belenky@na.amedd.army.mil.

SUMMARY

Optimum mental performance is critical to successful combat operations at all levels of command and control today, and all visions of future combat demand even-more-sophisticated cognitive operations of military personnel at all levels. Adequate sleep is central to sustaining cognitive performance. The disruptive effects of rapid deployment across time zones on sleep and subsequent performance imperil the military's capability to perform its mission, but there are techniques and pharmacological agents that can ameliorate these effects. The evolving US Army SMS and AAFMS will provide software, hardware, and doctrine that will unobtrusively measure and effectively manage sleep to sustain performance in combat situations.

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