Proposed Draft Advisory Circular
Fatigue Countermeasures

Purpose/Overview

This Advisory Circular (AC) provides individuals with an introduction to managing fatigue in aviation operations. The AC is divided into three sections. The first section provides basic information on the physiological factors that underlie fatigue. The second section presents information on personal alertness strategies, including both preventive and operational fatigue countermeasures. The third section examines practical considerations of managing fatigue in four specific flight environments.

It is important to acknowledge that managing fatigue in aviation operations is a complex task, and any industry-wide attempt to address these issues requires participation from all areas, including federal agencies, industry organizations, companies, and individuals. The information contained in this document merely introduces the topic, focusing on personal strategies for individuals. Many sources are available that provide more in-depth discussion of these issues, outline in detail the challenges to aviation operations, and describe comprehensive, scientifically-based approaches to fatigue management (see representative references).

The Issue

Maintaining aviation safety is a complex endeavor. Despite sophisticated technological equipment, human operators (pilots, controllers, maintenance personnel, and others) are central to safe, efficient flight operations. Human-related error accounts for approximately 70% of all transportation accidents, including aviation. Fatigue has been identified as a significant factor that contributes to human error in the industry. Over 20% of incident reports to NASA's Aviation Safety Reporting System (ASRS) refer to fatigue. The National Transportation Safety Board has cited fatigue as a probable cause in the aircraft accident involving a DC-8 in Guantanamo Bay, Cuba, and as a contributing factor in several other aircraft accidents.

Flight operations can lead to fatigue, disruption of sleep and circadian rhythms, and degradation of alertness and performance. Clearly, these factors affect operational safety. Acknowledging and managing these physiological challenges promotes safety and performance in flight operations, while ignoring them can increase the potential for errors, incidents, and accidents. Fortunately, a wide range of strategies is currently available to effectively manage fatigue in flight operations.

The first step in any effort to manage fatigue must be education, because even the most effective strategies cannot be used optimally without a basic informational foundation. Since the task of

managing fatigue is a shared responsibility among individuals, companies, industry organizations, and federal agencies, education should occur in each of these groups. The ultimate goal is to maintain—and wherever possible—enhance safety and performance in aviation operations. By developing effective, personalized approaches to managing fatigue, individuals in the aviation industry benefit themselves and contribute to that overall goal. This AC is only one element of any comprehensive effort to successfully address fatigue in aviation operations.

Basic Human Physiology: Sleep and the Circadian Clock

Sleep Basics

1. Sleep is a vital physical need. Like food, water, and air, sleep is required by the body for survival. Further, sleep is a critical requirement for alertness and performance. Data collected during actual flight operations demonstrate that, with sleep loss, alertness and performance degrade significantly; conversely, with sleep, alertness and performance can be optimized.

2. Sleep is a complex physiological process. Sleep comprises two distinct components. NREM (non-REM) sleep generally involves restoring the body, while REM (rapid eye movement) sleep generally involves restoring the mind. NREM sleep is divided into four stages, with stages 3 and 4 being the deepest sleep.

3. Average sleep requirement is 8 hours. An individual requires the amount of sleep necessary to achieve full alertness and an effortless level of functioning during waking hours. Most adults require about 8 hours of sleep, though there is a range of individual sleep-needs (e.g., about 6 to 10 hours).

4. Sleep debt: lost sleep accumulates. An individual who requires 8 hours of sleep and obtains only 6 hours is sleep-deprived by 2 hours. If that individual sleeps only 6 hours each night over 4 nights, then the sleep loss accumulates into an 8-hour sleep debt. Estimates suggest that in the U.S. today, most adults obtain 1–1.5 hours less sleep per night than they actually need. Generally, recovery from a sleep debt involves obtaining deeper sleep and sufficient amounts over 1 to 2 nights.

5. Sleep changes with age, alcohol, and disorders. Some of the most significant changes to sleep occur as a natural function of age. While younger people sleep more and deeper, as people age, they get less sleep during the night (although they still need the same amount), get less deep sleep, and have more awakenings. Sleep also changes with alcohol consumption. Although many people use alcohol to "wind down" and foster sleep, it can actually reduce sleep quality and quantity overall. Alcohol can reduce REM sleep in the first half of night, then disturb sleep in the second half of night.

A range of physiological sleep disorders also can disturb the quantity and quality of sleep, and subsequently can degrade waking performance and alertness. In any given year, about one third of American adults report a sleep disturbance. This figure is conservative, considering that sleepers often are unaware of these disturbances. One example of a common disorder is sleep apnea, characterized by a cessation of breathing during sleep that causes the sleeper to awaken repeatedly to resume breathing. A cardinal symptom of sleep apnea is snoring (although there are other causes for snoring besides sleep apnea). Sleep apnea is an example of a sleep disorder that is a well-documented health risk and can significantly reduce waking alertness and performance. Evaluation and treatment for sleep disorders are available at accredited Sleep Disorders Clinics.

6. Physiological vs. Subjective Sleepiness. Two aspects of sleepiness can be considered: physiological and subjective. Physiological sleepiness is the result of sleep loss: lose sleep, get sleepy. Sleep loss will be accompanied by increased physiological sleepiness that will drive an individual to sleep in order to meet the physiological need for sleep. Subjective sleepiness is an individual's introspective self-report of how sleepy they feel. Subjective reports of sleepiness can be affected by many factors, such as physical activity or a particularly stimulating environment (e.g., an interesting conversation), which tend to mask or conceal physiological sleepiness and lead people to overestimate their own level of alertness. Subjective reports of sleepiness often differ significantly from physiological measurements; individuals will generally report greater alertness than indicated by physiological state. Applying this fact to operations means that a flight crewmember who reports being alert, in fact, may be close to falling asleep.

7. Daily Maximum Sleepiness. Humans are hard-wired to experience two periods of physiological sleepiness each day. These are at about 3–5 AM and 3–5 PM, and are dictated by the circadian system controlled by the brain.

Circadian Basics

1. The Circadian Clock. Humans, like other mammals, have an internal circadian (*circa* =around; *dies* = day) clock that regulates physiological and behavioral functions on a 24-hour basis. Located in the brain, this "body clock" is set by external time cues, especially bright light.

2. Control of 24-Hour Rhythms. The clock coordinates daily cycles of sleep/wake, performance, physiology, mood, and other functions. It programs us to sleep at night, to be awake during the day, and to have daily peaks and troughs in different functions at specific times. Between 3 and 5 AM, physiological sleepiness peaks, and virtually all aspects of alertness and performance slow and degrade. Less dramatically, an afternoon dip between 3 and 5 PM also affects sleepiness, alertness, and performance.

3. Circadian Disruption. The circadian clock cannot adjust immediately when a person suddenly changes schedule (e.g., by flying to a new time zone or changing to a new work/rest schedule). This is the basis for the circadian disruption associated with jet lag and shiftwork patterns.

To shift schedules (e.g., from day to night shift), the body must override the circadian signals to sleep at night and be awake during the day. Also, the clock will receive conflicting time cues from the environment.

"Jet lag," resulting from flying to a new time zone, produces a different challenge to the circadian clock. The time cues in the new time zone provide consistent information to the clock, but it can take several days to weeks for the clock to get into step with the new local time. In addition, circadian rhythms in different body functions do not all adjust at the same rate and therefore may be out of step with each other for an extended period of time.

Fatigue Countermeasures: Personal Strategies

For the individual facing the challenges of managing fatigue in flight operations, a variety of well-tested countermeasure strategies can help maintain alertness and on-the-job performance. However, there is no simple, universal solution to fatigue in the workplace. Both operational requirements and human physiology are complex, and each individual is different. It is important to use multiple strategies, and tailor the strategies to individual needs. As new strategies become available, individuals should test them and evolve their approach to managing fatigue.

Fatigue countermeasures can be divided into two categories: 1) Preventive strategies are those used before work and during rest periods, and 2) Operational strategies are those used on-the-job (in flight, at a computer terminal, etc.). Preventive strategies are designed to minimize the sleep loss and circadian disruption caused by work demands. They are aimed at the physiological causes of fatigue. Operational countermeasures are designed to minimize the impact of sleep loss and circadian disruption on alertness and on-the-job performance. They can temporarily relieve the symptoms of fatigue, to help get the job done as safely and efficiently as possible.

1. Preventive Strategies

a. Minimizing Sleep Loss. A number of preventive strategies can be used to minimize sleep loss. The effective use of days off and rest periods to catch up on sleep is critical. Field studies in flight operations indicate that sleep loss is common. Since the effects of sleep loss are cumulative, it is important not to begin a new work schedule or trip pattern with an existing sleep debt. Therefore, try to get at least two nights of unrestricted sleep before a trip.

On nights before or between duty days, try to get at least as much sleep as you get on normal off-duty nights. If your duty schedule prevents you from getting that much sleep in a single sleep period, try to sleep more than once (e.g., morning and evening) or to take naps. Take advantage of times in the circadian cycle when it is easy to fall asleep. Conversely, because it is impossible to force sleep, don't depend on getting sleep during peaks in the circadian cycle when you would usually be awake.

b. Naps. Naps can acutely improve alertness and performance, and even very short naps can provide benefits. However, the duration of a nap is important because if you enter deep NREM sleep you may experience sleep inertia, a feeling of grogginess, sleepiness and disorientation that can last for 10 to 15 minutes. Therefore, if you have a short nap opportunity just before work, or if you are likely to be interrupted by a duty call, then limit the nap to about 45 minutes or less. At other times, longer naps can be beneficial, and 2 hours will normally allow for a complete cycle through the different states and stages of sleep. Generally, performance improves, even when people do not report feeling refreshed on awakening.

A nap reduces the duration of continuous wakefulness before a work period, and can be particularly beneficial before a period of night work, when the challenge of working through the circadian low point is also a factor. Getting some sleep is always better than none.

c. Good Sleep Habits. Good sleep habits can help improve sleep quality on a regular basis, at home and while on trips. By practicing a regular pre-sleep routine, you can teach your body and mind that certain activities mean that it is time to sleep. It separates the psychological stressors of the day from the sleep period. Once this pattern of cues is established, it can be used anywhere and anytime. It may include such things as checking door locks and turning off lights, or reading something relaxing and entertaining (not work-related). Also, various physical and mental relaxation techniques can be learned and used in this way, such as meditation, autogenic training, yoga, and progressive muscle relaxation. These skills must be developed and practiced before they can be expected to provide benefit. It is also important that the bedroom remain an environment conducive to relaxation and sleep, and does not become associated with stressful activities, such as work or worry. Sleep time needs to be given priority and kept as free as possible from other commitments and activities.

d. Sleep Environment. Physical aspects of the environment can also affect sleep. A dark, quiet room is preferable. Eye shades are a simple and portable solution to the problem of intrusive light. Earplugs can help by reducing noise, but they must be used such that they do not interfere with a required wake-up signal (such as an alarm clock or call for duty). Sudden sounds can disturb sleep, and continuous background "white" noise can help mask such noises. One

suggestion is to set the radio between two stations for this purpose. In general, sleep quality is better if the environment is cooler rather than warmer. A comfortable sleep surface also can be important.

e. Effects of Food, Alcohol, and Exercise. Food, alcohol, and exercise shortly before sleep can affect the quantity and quality of the sleep you obtain.

The discomfort associated with being hungry or, conversely, with having eaten too much, may interfere with falling asleep. If you are hungry or thirsty at bedtime, have a light snack or a small drink. In general, evidence that common foods significantly affect sleep is not yet conclusive. However, both caffeine and alcohol have well-documented disruptive effects on sleep.

Caffeine stimulates the nervous system, generally taking effect 15–45 minutes after ingestion and remaining active for 3–4 hours (up to 10 hours in some individuals). The effects of caffeine depend on a number of factors, including habitual usage, body mass, and previous food intake. However, regardless of how much caffeine someone habitually takes, caffeine before sleep can lead to lighter sleep with more awakenings and reduced total sleep time. Consider eliminating or minimizing caffeine intake at least 3 hours before bedtime. Individuals sensitive to caffeine effects should consider avoiding caffeine as much as 6 hours before bedtime. Nicotine has much the same effects as caffeine on nocturnal sleep and subsequent daytime sleepiness and performance. As with caffeine, avoid nicotine (tobacco or patch) for several hours before the time you want to fall asleep.

Alcohol is reported as the most commonly used sleep aid in the U.S. It can promote relaxation and thereby help a person to fall asleep. However, with moderate to excessive alcohol intake, sleep is easily disrupted. Alcohol suppresses REM sleep in the first half of the night, leading to REM rebound and withdrawal effects in the second half. Therefore, avoid drinking even moderate amounts of alcohol 2–3 hours before sleeping. Also, individuals with breathing disorders during sleep, for example apnea, should keep in mind that alcohol worsens these conditions and reduces oxygen levels during sleep. FAA regulations govern alcohol consumption in proximity to duty periods.

There is evidence that regular exercise may enhance deep sleep, which has been shown to be physically restorative. However, strenuous exercise results in physiological activation, which may interfere with sleep. Therefore, avoid strenuous exercise within several hours of going to bed.

f. Circadian Strategies. Currently, there are more practical, well-tested preventive strategies for minimizing sleep loss than there are for speeding circadian adaptation to different schedules. Resetting the circadian clock in an operational setting is complex for several reasons. First, unless a technique is applied correctly, interventions that reset the circadian clock can shift the clock in the

wrong direction, depending on when in the circadian cycle they are administered. At this time, there is no simple, practical way of measuring precisely where a person is in the circadian cycle, particularly in an operational setting. Without this information, an intervention intended to move the circadian clock "eastward" may end up sending it "westward." Further, for such a treatment to be successful, it is necessary to control exposure to the natural time cues in the environment, such as sunlight and darkness. In practice, this can be very difficult to achieve, especially on a trip.

In some situations, it may not be possible or even desirable to adapt the clock fully to rapidly changing schedules. For example, during long-haul flight operations, crewmembers usually spend each consecutive rest period (layover) in a different time zone, so it may not be preferable to adapt to the destination time zone. The known clock-shifting interventions (e.g., melatonin and bright light) need much more testing to determine their feasibility and effectiveness in improving alertness and performance in operational settings, including aviation environments.

2. Operational Countermeasures

Once on the job, the range of available strategies to combat fatigue is more restricted. In most commercial aviation operations, there is an additional constraint that crewmembers must remain in their cockpit seats from take-off through landing, except for "biological need," which currently does not include sleep. In general, operational countermeasures do not address the underlying physiological causes of fatigue. Instead, they are meant to temporarily enhance alertness and performance by masking fatigue, so that operational safety and efficiency are maintained.

a. Social Interaction and Conversation. Interacting with others can be a useful operational strategy. To maintain alertness, it is necessary to be actively involved in the conversation, not just listening and nodding. In fact, a lack of conversation can be associated with declining physiological alertness.

b. Physical Activity. Physical activity is one of the most effective ways of combating sleepiness. Some stretching and isometric exercises can be done in the cockpit seat. Even writing or chewing gum may help. Almost any physical activity is preferable to passivity.

c. Caffeine. Use the alerting effects of caffeine to help you stay awake during circadian low points or other times during operations when you struggle to maintain wakefulness (remember: on average, about 15–30 minutes to take effect, lasting 3 to 4 hours). To optimize caffeine as an operational strategy, avoid or minimize its use when you are already alert, such as at the beginning of a daytime work period or just after a nap. Start consuming caffeine about an hour before expected times of decreased alertness (e.g., 3–5 AM). However, consider your planned bedtime, and try to stop caffeine consumption at least three hours before that to avoid its disruptive effects

on sleep. In some situations, these requirements may be conflicting. For example, using caffeine to help work through the circadian low point at the end of a night flight could result in problems trying to fall asleep after coming off duty in the morning. In that case, consider the benefits and drawbacks in light of overall operational demands.

Caffeine is a diuretic, which can cause further dehydration for flight crews, who are already vulnerable due to low humidity in the cockpit. Another consideration when using caffeine is that, in high doses, caffeine can lead to anxiety, irritability, tremulousness, and insomnia.

d. Diet. Currently, there is no compelling evidence that specific types of food directly affect alertness and performance. Candy or other "energy boosters" can produce a transient increase in alertness (e.g., "sugar highs"), but this is frequently followed by a decrease in alertness (sometimes suddenly) as blood glucose levels fall. Stomach (gastrointestinal) upsets can be disruptive to sleep, and maintaining a balanced diet is important. Duty schedules can make it difficult to maintain a regular pattern of well-balanced meals, so plan ahead and bring nutritious snack foods with you on long flights or shifts.

e. Naps. The goal of all operational countermeasures is to improve on-the-job performance and alertness when compared to the no-countermeasure condition. Napping is one of the only countermeasures that has been rigorously tested in this way in a real-world operational setting. A NASA/FAA study examined the effectiveness of a planned cockpit rest period to improve subsequent performance and alertness in commercial long-haul flight operations. Crewmembers who were allowed to take planned naps showed better performance and higher physiological alertness during the last 90 minutes of flight than the control group crewmembers who had not napped. Planned cockpit rest is not currently sanctioned by the Federal Aviation Regulations. However, based on the results of this study, a proposal to allow planned cockpit rest is currently under review.

The significant results of this NASA/FAA study and other scientific research have demonstrated that naps can be extremely beneficial. Strategic naps should be used as a high priority countermeasure in appropriate circumstances. For example, there are many opportunities outside the cockpit environment when a short strategic nap can be an effective countermeasure, such as between flight legs when other duties are completed. Napping is the only operational countermeasure that addresses one of the major physiological causes of fatigue—the need for sleep—and reverses it. While other operational countermeasures primarily mask fatigue, naps actually reduce it.

3. Future Countermeasure Considerations

There are a number of countermeasures currently under investigation that require further evaluation to demonstrate their practicality and effectiveness in operational settings, but that have the potential to reduce the sleep loss and circadian disruption produced by multiple time-zone changes and shifting work schedules.

a. Bright Light. Bright light has received particular attention because of its importance as a cue for setting the circadian clock. Independent of this capacity, light appears to have an alerting effect. Some of the difficulties associated with attempting to shift the circadian clock were described in the section "Preventive Strategies."

b. Melatonin. The naturally occurring hormone melatonin is also under active investigation, for both its sleep-inducing properties and its capacity to reset the circadian clock. Currently, it is classified as a food supplement in the U.S., and is available in health food stores. Therefore, it is not controlled by any quality assurance mechanism, and the percent of active melatonin in health food store products may vary widely, as can any additional ingredients in the products.

An unknown number of shiftworkers and transportation operators already use melatonin. However, the scientific community is still investigating its effectiveness and safety. Melatonin affects a variety of physiological systems in addition to its sleep and circadian effects. It has been reported to have a range of other effects, including restricting the coronary arteries and exacerbating the symptoms of some psychological disorders (e.g., depression). In high doses, it may produce hangover effects on waking function.

While many claims are made about the benefits of melatonin, more information is needed before its effects, both short and long term, are understood. Given the current state of scientific knowledge, it would be prudent to take a conservative approach to melatonin use, particularly on a regular basis, either as a sleeping medication or as a circadian manipulator.

c. Physical Exercise. The role of exercise in resetting the circadian clock is also under investigation. Research has demonstrated that exercise at different times in the day can reset the circadian clocks of animals. Other, preliminary data suggest that exercise can have effects on the human clock as well. However, more research is needed to clarify the effects of different amounts and types of exercise in different parts of the human circadian cycle.

d. Diet. There is also considerable interest in possible dietary components that might promote sleep or alertness, or reset the circadian clock. It has been suggested that foods rich in carbohydrates (e.g., legumes, pasta, potatoes) may induce sleep, or that foods high in protein

(e.g., meats, dairy products, eggs) and certain amino acids may promote wakefulness. For example, one diet published some years ago tried to accelerate adaptation to a new time zone by exploiting multiple circadian time cues, including meal timing, fasting and feasting periods, high protein versus high carbohydrate meals, and timed caffeine consumption. However, two controlled studies have shown that the diet has equivocal effects at best, and can actually slow adaptation in some instances. Other dietary effects, such as the effect of the amino acid tyrosine on stress levels, are under investigation. There may well be other dietary factors that could be useful as fatigue countermeasures. Careful research is needed to demonstrate their effectiveness and to define how they might be used.

e. Anchor Sleep. Another concept that has been considered in the context of shiftwork and aviation operations is called "anchor sleep." This is based on the idea of having individuals obtain at least part of their off-duty or layover sleep during the normal home sleep time. Its usefulness over long sequences of transmeridian flights is limited by the fact that the circadian clock drifts away from a 24-hour period, which makes it difficult to relate sleep to physiological home time.

Addressing fatigue in specific flight environments

Different flight environments have different operational requirements, operate under various sets of regulations, and employ diverse populations of crewmembers. Therefore, each flight environment poses distinct physiological challenges to the individuals involved. This section describes specific fatigue issues facing four types of flight operations. Clearly, other flight environments exist, with their own unique demands.

Short-haul flight operations: While short-haul operations do not present the classic fatigue-inducing demands of "jet lag," (e.g., crossing time zones, flying through the night) these operations pose other challenges to human physiology, alertness, and performance.

Short-haul operations are generally domestic operations characterized by multiple flight legs of short duration. Operational requirements include long duty days, multiple take-offs and landings, and a large percentage of time spent in high-density terminal areas. Because each flight segment requires little flying time, many segments can be flown in a duty day within FAR flight time limitations, and long duty days can result. Not surprisingly, long duty days can result in fatigue and consequent decreases in alertness and performance. Additionally, these long duty days often require early report times. Because physiologically factors make it difficult to fall asleep earlier than normal, early wake-ups can result in sleep loss. Finally, short-haul operations require very high levels of alertness, performance, and vigilance because a larger percentage of time is spent in

busy terminal areas and critical flight phases. Fatigue-induced decrements can be magnified by these performance demands.

Long-haul flight operations: Long-haul operations are characterized by extended flights that often cross multiple time zones. These flights are operated by commercial airlines in jumbo jets as well as by corporate flight departments in business jets. Specific operational requirements include rapid multiple time-zone changes, extended flight and duty times, irregular work schedules, and long periods of time spent in cruise. Additionally, many long international commercial flights are made during nighttime hours. These demands frequently lead to sleep disturbances and circadian disruption which, in turn, result in fatigue, cumulative sleep loss, decreased alertness, and degraded performance.

Multiple time-zone changes have long been acknowledged to result in "jet lag." The primary physiological feature of jet lag is circadian disruption: the body clock is out of sync with the new time zone or schedule, which results in sleep loss and a variety of other physical symptoms. Irregular work schedules, which are common in long-haul flying, also can contribute to circadian disruption by requiring the body to adjust from day "shift" to night "shift" and back. Further, flying through circadian low points, especially in the 3–5 AM window, challenges the body and mind to function at a time when they are programmed to sleep.

In long-haul airline operations, flight hours are limited by FARs, but duty times are not addressed, and long duty days are possible. Long duty days can contribute to fatigue and sleep loss by decreasing the time available for sleep and by creating periods of extended wakefulness. Finally, long-haul flight crewmembers spend extended periods of time in cruise, which generally provides low levels of stimulation and activity.

Regional Flight Operations: Regional flight operations are characterized by multiple short flights within a certain geographical area. These operations present a number of unique challenges. In addition to the issues facing other short-haul operations, many operate under different regulations than the major airlines, regional airlines may in some cases operate older, less technologically advanced equipment (e.g., aircraft, navigation, etc.), and scheduling practices vary widely.

As in other short-haul operations, regional operators face long duty days, multiple take-offs and landings, more time in high-density areas, and the physiological results of these factors. Different FARs mean that many regional crewmembers can fly longer hours and receive shorter off-duty periods, which can restrict sleep opportunities. Additionally, regional crewmembers report that older equipment and less automation can lead to increased fatigue by demanding more vigilance, increasing workload, and creating physical stresses associated with high noise and vibration levels.

Finally, in response to operational and other demands, many regional operators use certain scheduling practices that may contribute to fatigue (e.g., "stand-up" overnights, during which the crewmember remains on duty through the night between flights).

Overnight Operations: Overnight operations include most cargo flights as well as some commercial passenger flights. These operations require that crewmembers (among others) fly when their bodies and minds are programmed to sleep. This can lead to decrements in alertness and performance, as well as circadian disruption.

Maintaining wakefulness during the circadian low 2–6 AM poses a significant challenge to crewmembers. Even if individuals can remain awake, virtually all aspects of alertness and performance are degraded during this time, including reaction time, problem-solving, decision-making, and communication. Monitoring skills, in particular, suffer decrements during the window of circadian low. This is important because especially in highly automated aircraft, monitoring is the primary task during cruise.

Approaching Various Flight Environments. Each flight environment has different operational requirements. However, the physiological needs of the human operator remain the same. Therefore, an understanding of both physiological and operational requirements must be applied to the development and evaluation of countermeasure strategies to create operationally feasible approaches to managing fatigue.

Conclusion

Clearly, there is no single approach or countermeasure that will eliminate fatigue from flight operations. Operational demands, human physiology, and individual differences are too complex for a simple mechanistic approach. Since there is no simple answer, the challenge is to manage fatigue. Education is a crucial first step in any effort to manage fatigue. The information in this AC is provided as one element in this educational process. By learning about the issues involved, by maintaining and spreading awareness of these issues, by developing and using personal strategies to maximize alertness and performance during operations, everyone in the aviation industry can support efforts to reduce fatigue-related risks and can contribute to safer flight operations.

Representative References

Caldwell, J.A. (1997). Fatigue in the Aviation Environment: An Overview of the Causes and Effects As Well As Recommended Countermeasures. *Journal of Behavioral Medicine,* 68:932–938.

Graeber, R.C. (1994). Jet Lag and Sleep Disruption. In M.H. Kryger, T. Roth, & W.C. Dement (Eds.), *Principles and Practice of Sleep Medicine.* Philadelphia, PA: Saunders.

Fatigue Countermeasures Program, National Aeronautics and Space Administration Ames Research Center. (1998.) *Crew Factors in Flight Operations: The Initial NASA-Ames Field Studies on Fatigue.* Aviation, Space, and Environmental Medicine, 69 (9, Suppl.).

Rosekind, M.R., Gander, P.H., Connell, L.J., & Co, E.L. (in press). *Crew Factors in Flight Operations X: Alertness Management in Flight Operations.* NASA Technical Memorandum. Moffett Field, CA: NASA Ames Research Center.

Rosekind, M.R., Gander, P.H., Gregory, K.B., Smith, R.M., Miller, D.L., Oyung, R.L., Webbon, L.L., and Johnson, J.M. (1996.) Managing Fatigue in Operational Settings 1: Physiological Considerations and Countermeasures. *Journal of Behavioral Medicine,* 21:157–165.

Rosekind, M.R., Gander, P.H., Gregory, K.B., Smith, R.M., Miller, D.L., Oyung, R.L., Webbon, L.L., and Johnson, J.M. (1996). Managing Fatigue in Operational Settings 2: An Integrated Approach. *Journal of Behavioral Medicine,* 21:166–170.

Rosekind, M.R., Graeber, R.C., Dinges, D.F., Connell, L.J., Rountree, M.S., Spinweber, C.L., & Gillen, K.A. (1994). *Crew Factors in Flight Operations IX: Effects of Planned Cockpit Rest on Crew Performance and Alertness in Long-Haul Operations.* NASA Technical Memorandum 108839. Moffett Field, CA: NASA Ames Research Center.