**Aeromedical experts expect fatigue-related problems to worsen with the advent of more ULR flights, unless reliable countermeasures are implemented.**

# Easing Fatigue

BY LINDA WERFELMAN

The aviation industry generally has failed to incorporate new knowledge of fatigue-fighting techniques into flight crew scheduling provisions and flight and duty time limitations, according to sleep experts who recommend ending prohibitions on cockpit naps and authorizing the use of certain sleep-inducing medications.

In a position paper adopted by the Aerospace Medical Association (AsMA),[1] the organization's fatigue countermeasures subcommittee wrote that few changes have been made in flight time limitations and flight crew scheduling since the first limits were adopted in the 1930s, despite numerous recommendations, including the 1997 publication by Flight Safety Foundation of duty and rest scheduling guidelines for corporate and business operators.[2]

"Although the scientific understanding of fatigue, sleep, shift work and circadian[3] physiology has advanced significantly over the past several decades, current regulations and industry practices have in large part failed to adequately incorporate the new knowledge," the fatigue panel said. "Thus the problem

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of pilot fatigue has steadily increased along with fatigue-related concerns over air safety."

A separate fatigue study conducted for the European Aviation Safety Agency (EASA) concluded with a call for new limits on duty time (See "Study: EASA Needs Stricter Limits on Fatigue," p. 24).

The AsMA position paper said that accident statistics, pilot reports and operational flight studies all indicate that aviation operators are increasingly concerned about fatigue.

"Long-haul pilots frequently attribute their fatigue to sleep deprivation and circadian disturbances associated with time zone transitions," the fatigue panel wrote. "Short-haul (domestic) pilots most frequently blame their fatigue on sleep deprivation and high workload. Both long- and short-haul pilots commonly associate their fatigue with night flights, jet lag, early wakeups, time pressure, multiple flight legs and consecutive duty periods without sufficient recovery breaks. Corporate/executive pilots experience fatigue-related problems similar to those reported by their commercial counterparts."

Concerns about fatigue are likely to increase as ultra-long-range (ULR) flights — those of 16 hours or more — increase, the panel said.

"An important question for ULR operations is whether the strains imposed by the extension of flight duty hours beyond the limits commonly flown will effectively be mitigated by the standard fatigue countermeasures, which in part have been responsible for the acceptable safety record of existing flight operations," the panel said. "Without proper management, ULR operations may exacerbate the fatigue levels that have already been shown to impair safety, alertness and performance in existing flight operations."

## Causes and Effects

Research has found that the causes of fatigue are similar in all types of aviation operations, as are the effects.

Studies conducted during flight and in simulators have found that fatigue interferes with the functions of the central nervous system, that pilots may experience "vigilance lapses" during periods of flight marked by low workloads, and that pilots are especially susceptible to microsleeps — periods of sleep that last only several seconds and often go unrecognized — in the middle-to-late segments of cruise flight during long-haul operations.

The fatigue panel cited a survey by the U.S. National Aeronautics and Space Administration in which 80 percent of 1,424 flight crewmembers from regional airlines said they had "nodded off" during a flight. A survey of 1,488 corporate/executive flight crewmembers found that 71 percent had fallen asleep during flight.

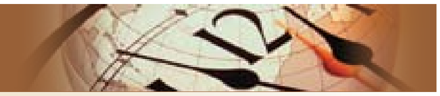
"Fatigue in aviation is a risk factor for occupational safety, performance effectiveness and personal well being," the panel said. "Humans simply were not equipped (or did not evolve) to operate effectively on the pressured 24-7 schedules that often define today's flight operations, whether these consist of short-haul commercial flights, long-range transoceanic operations or around-the-clock military missions. Because of this, well-planned, science-based fatigue management strategies are crucial for managing sleep loss/sleep debt, sustained periods of wakefulness and circadian factors that are primary contributors to fatigue-related flight mishaps."

## Current Practices

The AsMA fatigue panel rejected the rule-making approach typically used by the U.S. Federal Aviation Administration (FAA) and other regulatory agencies to prescribe the limits on flight, duty and rest times (Table 1, p. 24). Such limits should be developed from scientific research on the effects of sleep and circadian rhythms on job performance, the panel said.

"The risks associated with non-science-based regulatory approaches may have been unknown in the 1930s, when flight and duty time limits were first addressed," the panel said. "At the time, research documenting the performance and alertness decrements associated with sleep loss and circadian disruption was limited, and it seemed sufficient to ensure safety via agreements between flight crew and management. However, with the demands of 24-7 aviation operations, it has become increasingly apparent that such prescriptive

## Study: EASA Needs Stricter Stand on Fatigue



European Aviation Safety Agency (EASA) rules do too little to mitigate the effects of fatigue on pilots, according to a report by human factors researchers that was applauded by pilot organizations and faulted by airlines as "seriously lacking."

The report, made public in January after it was submitted to EASA by Moebus Aviation and the European Committee for Aircrew Scheduling and Safety (ECASS), said that a number of existing EASA rules and proposed rules changes conflict with scientifically developed principles of fatigue prevention.

"Our responses are based on the available scientific knowledge which, briefly, finds that fatigue is increased by extended time awake, reduced prior sleep, the window of circadian low and task load, and that these effects are modified by changes of time zones and rest provisions," the report said.

The researchers said they were especially concerned with provisions that allow "a large number of duty hours in a short time. … The permissible maximum of 180 duty hours in three consecutive weeks allows for a high density of work hours in a short period of time and should be limited through an additional provision for a maximum of 100 duty hours in 14 consecutive days."

Their report also said that the maximum daily flight duty time of 13 to 14 hours "exceeds reasonable limits, especially under exacerbating circumstances (e.g., high workload, night flying … ) and should be reduced."

The Association of European Airlines denounced the report as "seriously lacking in substantive scientific and medical content" and said it "arrives at conclusions which are oblivious to the evidence of decades of safe operation."

The European Cockpit Association welcomed the researchers' findings, noting that fatigue has been cited as a contributing factor in 15 to 20 percent of fatal aviation accidents associated with pilot error.

The results of the study were not included in a proposed revision of regulations governing air operations that were published in late January, EASA said. Instead, the study will be the subject of a regulatory impact assessment to consider the potential safety benefits of its recommendations, as well as their social, economic and environmental aspects, EASA said.

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**Note**

1. Moebus Aviation and ECASS. "Consensus Report Prepared by ECASS: Scientific and Medical Evaluation of Flight Time Limitations," TS.EASA.207.OP.08. 2008. <www.easa.europa.eu/ws_prod/r/doc/research/FTL%20Study%20Final%20Report.pdf>.

**FAA Rest, Flight and Duty Time Limits**

| Type of Limit | Non-Augmented Crew[1] | Augmented Crew[2] |
|---|---|---|
| Minimum pre-duty rest period | 10 hours | 10 hours |
| Minimum post-duty rest period | 10 hours | 12 hours<br>18 hours for multiple time zones |
| Maximum flight time | 10 hours | 12 hours |
| Maximum duty time | 14 hours | 16 hours |
| Maximum duty time per week | 30 hours | 30 hours |
| Maximum duty time per month | 100 hours | 100 hours |
| Maximum duty time per year | 1,400 hours | 1,400 hours |

FAA = U.S. Federal Aviation Administration

1. A non-augmented crew includes the minimum flight crew required to conduct a flight.
2. An augmented crew includes more than the minimum number of crewmembers to conduct a flight.

Source: *Aviation, Space and Environmental Medicine*

**Table 1**

approaches do not address inherent sleep and circadian challenges, nor do they provide operational flexibility."

For example, the panel said, current FAA regulations do not recognize any difference between eight hours of duty time during the day and eight hours at night. A "scientifically informed" regulation would acknowledge a difference, based on time of day and circadian rhythms, the panel said.

### In-Flight Strategies

The fatigue panel reviewed several in-flight fatigue countermeasures: napping on the flight deck, activity breaks, bunk sleep on long-haul and ULR flights, in-flight rostering — scheduling some flight crewmembers to assigned positions on the flight deck while freeing others for in-flight rest — on long-haul and ULR flights, and increased exposure to flight-deck lighting.

"All of [these] in-flight countermeasures … clearly have a place in sustaining the alertness and performance of aviation personnel," the panel said. "However, the manner in which these strategies are employed should be based on the currently available scientific knowledge and should be implemented only after thoughtful consideration."

Members of the panel said they "take exception to the current prohibition on in-seat cockpit napping in civil aviation," and described in-seat napping of up to 40 or 45 minutes as a "safe and effective" risk-management tool that could "significantly improve alertness … and help sustain aircrew performance during situations in which unexpected delays require the postponement of the next consolidated sleep opportunity."

In-seat naps should not, however, be used to replace in-flight bunk sleep during long-haul and ULR flights, the panel said, adding that bunk sleep — used along with in-flight rostering — should be considered a primary method of fatigue mitigation. Additional research is needed to determine the best timing for sleep to help crewmembers maintain maximum performance, AsMA said.

Research also has found that alertness is improved with breaks for mild physical activity and increased social interaction "or even just temporary disengagement from monotonous tasks," the panel said, recommending breaks of about 10 minutes each hour.

In addition, laboratory studies have shown that increasing the light level on the flight deck, especially at night, can temporarily improve alertness and performance, the panel said. This technique should be used only with an understanding of how light can affect circadian rhythms, however.

Off-duty naps that are intended to promote on-duty alertness should be "as long as possible, and whenever feasible, they should occur at the circadian time most conducive to natural sleep (i.e., early afternoon or early predawn hours, according to the body clock)," the panel said. "The principles outlined for good sleep hygiene should be followed to promote optimal nap quality and duration (Table 2).

"Upon awakening from a nap, there should be a wake-up period of at least 30 minutes prior to the performance of any safety-sensitive tasks."

## Sleep-Inducing Medications

Because sleep often is difficult to obtain — if the environment is noisy, hot, uncomfortable,

### Strategies for Better Sleep

**Recommendations to optimize sleep opportunities**

- Wake up and go to bed about the same time every day.
- Use the sleep area only for sleep — not for chores.
- Establish a consistent bedtime routine — for example, read and take a hot shower, then go to bed.
- Perform aerobic exercises every day but not within two hours of bedtime.
- Keep the sleep area dark, quiet, comfortable and relatively cool.
- Move the alarm clock out of sight.
- Avoid caffeine in the afternoon and evening.
- Avoid using alcohol to promote sleep.
- Avoid cigarettes, especially before bedtime.
- If you can't sleep, leave the sleep area and do something relaxing. When you become sleepy, go back to bed.

**Recommendations for rotating shift schedules**

- When rotating onto night duty, avoid morning sunlight.
- To promote daytime sleep, keep the sleep area dark and cool; use eye masks and either earplugs or a "masking noise" to limit interference from light and noise.
- Comply with the "Recommendations to optimize sleep opportunities," above, with adjustments for daytime sleep.
- Before night duty, take a short nap.
- After waking from daytime sleep, expose yourself to at least two hours of sunlight or artificial bright light in the late afternoon or early evening.

**Recommendations for time zone adjustments**

- Quickly switch to the new time zone schedule for sleep, meals and activities.
- Maximize sunlight exposure during mornings.
- Minimize sunlight exposure during afternoons.
- Avoid heavy meals at night.
- Comply with the "Recommendations to optimize sleep opportunities," above.
- Use relaxation techniques to promote sleep at night.
- If possible, take a hot bath before bed. Cooling off after the bath "may mimic the circadian-related temperature reduction that normally occurs during sleep."
- During the first few days of adjustment, use sleep medications, if authorized, to promote nighttime sleep and caffeine to promote daytime alertness.

Source: *Aviation, Space and Environmental Medicine*

**Table 2**

or otherwise not conducive to sleep; if the individual is excited or anxious; or if the sleep opportunity occurs at a time not biologically conducive to sleep — the fatigue panel recommended allowing the off-duty use of one specific type of sleep medication.

The panel said that zolpidem — sold under the brand names of Ambien, Myslee and Stilnox — should be authorized for use by civilian pilots up to four times a week, "in situations where natural sleep is difficult or impossible due to circadian or other reasons." The FAA currently allows its use no more than twice a week, and requires 24-hour grounding for any pilot who takes it (Table 2, page 25).

The panel outlined three conditions for use of zolpidem: The pilot must first determine, while off duty, that he or she has no unusual reactions to the medication; the dose must not exceed 10 mg in a 24-hour period; and at least 12 hours must pass between the time the pilot takes the medication and the time he or she returns to duty.

"Zolpidem should not be taken to promote any type of in-flight sleep," the panel said. "It should be noted that facilitating quality sleep with the use of a well-tested, safe pharmacological compound is far better than having pilots return to duty when sleep-deprived or having then return to duty following a sleep episode that has been induced with alcohol."

The panel's recommendation did not extend to other types of sleep-inducing medications.

Other sleep medications not yet on the market are likely to be more effective — and may improve sleep efficiency so much that fewer than eight hours of sleep a day will be required for "effective wakefulness," the panel said.

Like the FAA, AsMA's fatigue panel discourages the use of herbal substances such as valerian and kava and the synthetic hormone melatonin that sometimes are used to promote sleep.

Because the U.S. Food and Drug Administration does not regulate these substances, the quality of compounds that contain them is left up to individual manufacturers and cannot be assured, the panel said. Melatonin probably is the most frequently used of these substances, and studies indicate that it may be useful in some aspects of sleep-promotion, especially when it is taken outside the usual sleep period. In some countries other than the United States, melatonin is regulated, and laboratory tests have found pharmaceutical-grade melatonin effective.

## 'Tactical Caffeine Use'

Crewmembers also should understand how their intake of caffeine — in coffee, tea, soft drinks and some pain relievers — will affect their alertness, the panel said (Table 3).

"Numerous studies have shown that caffeine increases vigilance and improves performance in sleep-deprived individuals, especially those who do not consume high doses," the panel said. "Caffeine … is already used as an alertness-enhancing substance in a variety of civilian and military flight operations, and it has proven safe and effective."

Most people feel the effects of caffeine — including increased alertness, decreased sleepiness and a more rapid heartbeat — within 15 to 20 minutes, and these effects typically last four or five hours, longer in people who are especially sensitive.

Crewmembers who use caffeine for alertness should consume it in small quantities, "and save the arousal effect until they really need it," the panel said. "This is called 'tactical caffeine use.'"

**Caffeine Content of Common Drinks and Over-The-Counter Medicines**

| Substance | Average Caffeine Content |
|---|---|
| 1 cup Maxwell House coffee | 100 mg |
| 1 Starbucks short coffee | 250 mg |
| 1 Starbucks tall coffee | 375 mg |
| 1 Starbucks grande coffee | 550 mg |
| 1 Coke | 50 mg |
| 1 Mountain Dew | 55 mg |
| 1 cup tea | 50 mg |
| 2 Anacin | 65 mg |
| 2 Extra Strength Excedrin | 130 mg |
| 1 No Doz Maximum Strength | 200 mg |

Source: *Aviation, Space and Environmental Medicine*

**Table 3**

The panel endorsed the continued use of caffeine as a fatigue countermeasure and recommended that crewmembers avoid taking more then 1,000 mg of caffeine in any 24-hour period, take it only "when it is truly needed to reduce the impact of fatigue" and avoid it within four hours of bedtime.

"Here are some situations where using caffeine makes sense: leading into the predawn hours, mid-afternoon when the alertness dip is greater because of inadequate nocturnal sleep and prior to driving after night duty, but not within four hours of going to sleep," the panel said.

## New Technologies

The panel cautioned against any over-reliance on fatigue-detection technologies and scheduling tools that rely on biomathematical models of alertness — such as monitoring an individual's brain waves, eye gaze, muscle tone or other characteristics.

Nevertheless, some of these tools can be incorporated into overall safety management, and some have great potential but have not yet been shown to meet practical, scientific and ethical standards, the panel said.

"None of the real-time fatigue-detection technologies have been sufficiently proven in an aviation environment (with the possible exception of the wrist-worn alertness device that triggers an alarm sound when wrist inactivity occurs for a preset amount of time) to warrant widespread implementation," the panel said.

The panel said that some crew scheduling tools based on fatigue-prediction models have proved "to a limited extent" worthwhile, especially those that are used to evaluate the fatigue associated with different schedules and design alternatives.

"Refinement of both the new fatigue monitoring technologies and scientifically based scheduling software must continue, and once they are validated for specific types of operations, they should be incorporated as part of an overall safety management approach supplementing regulatory duty limitations," the panel said.

## No 'One-Size-Fits-All' Cure

To discourage overreliance on sleep medications, the panel said, "crewmembers should be educated about proper sleep hygiene, the benefits of aerobic exercise for promoting quality sleep and natural strategies designed to promote circadian readjustment."

Education must lead to an understanding of the dangers of fatigue, the causes of sleepiness and proper sleep habits, which can help ensure that crewmembers obtain about eight hours of sleep every night, the fatigue panel said.

"Ultimately, the individual pilot, schedulers and management must be convinced that sleep and circadian rhythms are important and that quality day-to-day sleep is the best possible protection against on-the-job fatigue," the panel said. "Recent studies have made it clear that as little as one to two hours of sleep restriction almost immediately degrades vigilance and performance in subsequent duty periods."

Educational efforts should emphasize five points, the panel said:

- "Fatigue is a physiological problem that cannot be overcome by motivation, training or willpower;
- "People cannot reliably self-judge their own level of fatigue-related impairment;
- "There are wide individual differences in fatigue susceptibility that must be taken into account but which presently cannot be reliably predicted;
- "There is no one-size-fits-all 'magic bullet' (other than adequate sleep) that can counter fatigue for every person in every situation; but,
- "There are valid counter-fatigue strategies that will enhance safety and productivity, but only when they are correctly applied."

Along with educational efforts, operators should implement a fatigue risk management system (FRMS) to develop flight and duty schedules based on physiological and operational needs rather than prescriptive hours-of-service limitations that do not take into consideration the effects of circadian rhythms, the panel said.

The panel characterized an FRMS as an "evidence-based system for the measurement, mitigation and management of fatigue risk" that often exists within an operator's safety management system.

"A multi-component FRMS program, with a scientific foundation, helps ensure that performance and safety levels are not compromised by offering an interactive way to safely schedule and conduct flight operations on a case-by-case basis," the panel said.

The development of fatigue countermeasures requires increased attention to individual differences in responding to sleep loss, sleep disruption and time zone transitions, the panel said.

"Many issues associated with flight operations remain unanswered and can only be answered by collecting data during carefully scientifically designed research," the panel said. "While fatigue represents a significant risk in aviation when left unaddressed, there are currently numerous countermeasures and strategies that can be employed to increase safety. Furthermore, new technologies and countermeasures are being developed that hold great promise for the future."

### Notes


1. Caldwell, John A.; Mallis, Melissa M.; Caldwell, J. Lynn; Paul, Michel A.; Miller, James C.; Neri, David F.; AsMA Aerospace Fatigue Countermeasures Subcommittee of the Human Factors Committee. "Fatigue Countermeasures in Aviation." *Aviation, Space, and Environmental Medicine* Volume 80 (January 2009): 29–39.
2. Flight Safety Foundation Fatigue Countermeasures Task Force. "Principles and Guidelines for Duty and Rest Scheduling in Corporate and Business Aviation." *Flight Safety Digest* Volume 16 (February 1997).

3. A circadian rhythm is the human body's natural internal cycle — approximately 24 hours long — of periods of sleep and wakefulness.

### Further Reading From FSF Publications


FSF Editorial Staff. "Lessons From the Dawn of Ultra-Long-Range Flight." *Flight Safety Digest* Volume 24 (August–September 2005).