



# THE ALERT CREW

FATIGUE AWARENESS  
IN FLIGHT OPERATIONS

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# THE ALERT CREW: FATIGUE AWARENESS IN FLIGHT OPERATIONS

## INTRODUCTION

The Alert Crew: Fatigue Awareness in Flight Operations is a distillation of recommendations that the scientists of Alertness Solutions have been providing for years to members of the aviation industry, particularly flight crews.

While managing jet lag is important for the individual traveler, crew fatigue is a significant safety issue for aviation professionals. Today's global business environment requires round-the-clock operations, which for the flight crew can result in fatigue and safety risks. For example, fatigue may result in slowed reaction time, reduced attention span, decreased communications, and diminished judgment.

Today's business aviation flight departments are characterized by flexibility rather than limitations. The safest and most efficient flight departments incorporate science-based fatigue training and operational policies into a Fatigue Management Program with duty time limitations that ensure crew fatigue does not reduce the safety of any flight.

Although the nature of their operations is different from corporate flight departments, single-pilot and light business aircraft (LBA) operators face the same fatigue challenges and will also benefit from developing and adhering to personalized professional practices that minimize fatigue risks.

## Fatigue 101

### Costs

In short, fatigue affects all aspects of human functioning. Operational factors that can affect crew fatigue include:

- Timing of flight and duty periods

- Length of flight and duty periods
- Number of flight segments
- Time zone changes
- Delays and time waiting on ground
- Other non-flight duties

Lost sleep and disruption to the circadian (body) clock due to these factors are known to lead to degraded alertness and performance. Judgment and decision-making become impaired, reaction time slows, and mood and communication can be affected.

### It's a Safety Issue

Some major societal disasters are known to have had fatigue-related causes, such as the space shuttle Challenger disaster. Most major industries (transportation, energy, health care, public safety) recognize fatigue as a significant safety issue that can lead to increased errors, incidents, and accidents. Since 1990 the NTSB has made about 200 fatigue-related recommendations while investigating many crashes in all modes of transportation.

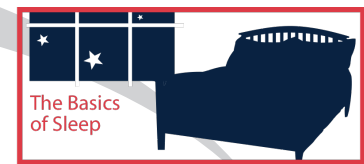
Fatigue affects the safety of flight operations of all types, from commercial airlines to LBA. This article provides an overview of sleep basics, the physiological effects of fatigue, and practical countermeasures that are proven to increase safety during flight operations. Individuals and organizations are encouraged to obtain comprehensive science-based training on these complex issues to gain more complete understanding of the issues and optimal solutions.

### Sleep Basics

Sleep is a vital human physiological need; it restores us mentally and physically. Scientific studies have

determined that most of us need about 8 hours of sleep on a daily basis. Unfortunately, there are a variety of factors that can conspire against good, regular sleep. Age, alcohol, and sleep disorders are three such factors that can significantly affect sleep. There are about 90 known sleep disorders that affect millions of people—many of whom are unaware of the problem. Insomnia, sleep apnea and restless leg syndrome are some commonly occurring disorders.

When we don't get the sleep we need over a period of time, the lost sleep builds up into a cumulative sleep debt. Think of accumulated sleep loss as an overdrawn bank account; you are plunged ever deeper into the red until you are bankrupt from exhaustion.



### Two Types of Sleep

Our sleep periods contain two distinct types of sleep: rapid eye movement (REM) and non-REM sleep. REM sleep is mentally restorative and it is during REM sleep that we dream. There are four stages of non-REM sleep, including lighter and deeper periods of sleep. Non-REM sleep is when the body is physically restored.

Across our sleep periods, we alternate through regular cycles of REM and non-REM sleep, with most of the non-REM sleep in the first third and most of the REM sleep during the second half of the sleep period.

When awakened from the deeper stages of non-REM sleep, one will often feel groggy and disoriented for several minutes or longer. This phenomenon is known as sleep inertia.

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## Impact of Lost Sleep

Studies have shown that with 2 hours of lost sleep, performance can be significantly affected. Scientists determined that 2 hours less sleep than needed affects performance in the same manner as having .05% blood alcohol concentration (BAC); if you have lost 4 hours of sleep, then performance can be impaired equivalent to a .10% BAC—or being legally impaired as defined in the US. Such studies provide powerful metrics with which to assess the effects of different levels of lost sleep.

## Hours Awake

Scientific research has documented how our alertness and performance degrade after long hours of being awake. Since we are biologically programmed for a 16-hour day, once our consecutive hours of wakefulness approaches 17 hours, performance begins to decline more quickly.

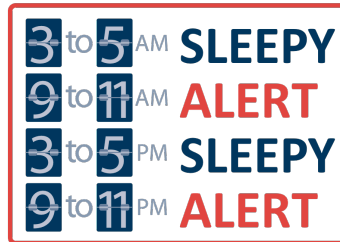
Studies have shown that after 17 hours of being awake, vigilance and reaction times are significantly impaired. At about 17 hours awake, it was found that performance was impaired equivalent to .05% BAC. When awake for around 24 hours, performance was measured as equivalent to .10% BAC.

## Circadian Clock

### Clock Basics

Sleep is regulated by the body's internal clock, known by scientists as the "circadian clock." The tiny mass of brain cells that makes up the circadian clock exerts a lot of control over much of your body's functioning, not only the sleep/wake cycle, but also digestion, body temperature, and hormones. The circadian clock programs us for regular periods of increased alertness and maximum sleepiness.

Light is the most powerful cue for setting the circadian clock. The circadian clock's natural programming runs slightly longer than our 24-hour day, so daily exposure to light, especially the morning sun, provides a daily "reset" to keep us in sync with the Earth's 24-hour cycle.



## Circadian Disruption

Circadian disruption occurs when the timing of sleep and wake periods become misaligned or out of sync with the timing of your internal clock. The two most common causes for circadian disruption are shift work and traveling across time zones. This creates circadian desynchronization, more commonly known as jet lag, when traveling.

Air travel allows us to be transported long distances in a matter of hours. However, our internal circadian clock doesn't move as fast as the aircraft on which we travel. It can take your circadian clock a few days or more to adjust to a new time zone. Whenever the phase of your internal circadian clock is out of sync or misaligned with the local or environmental external time, you're going to experience fatigue associated with the classic negative consequences of sleep loss and circadian disruption. While people attribute jet lag to a variety of different travel factors, the biological disruption associated with sleep loss and circadian disruption are the primary causes of fatigue symptoms that you experience in these situations.

## FATIGUE AWARENESS FOR THE FLIGHT DECK (AND BEYOND)

### Trip Planning

#### Be Fit for Duty

Looking to your next trip, it's important to be rested and "fit for duty" when reporting. Studies have found that sleep is often shortened the last night at home before a trip, which can intensify fatigue challenges once a trip begins. Make a point of getting adequate sleep the two nights before leaving home or starting work, making sure to plan for your commute time. Most important, make sleep a priority and don't leave home "in the red" with a sleep debt; you may accumulate more sleep debt across your trip which will decrease your alertness while on duty.

### Personalized Planning

Now that you are familiar with the basic principles underlying the science of sleep, you can develop a personalized plan that will address the particular circumstances of your next trip. That planning should begin before your departure. When scheduling your pre-trip sleep, have in mind the time you need to first report for duty and how long you anticipate being awake on that first day.

When you have an early departure, such as at 0600 "home time", your report time will be during a circadian low point, so plan ahead for sleep and other strategies to manage your alertness. Note that due to the timing of our circadian clock it can be difficult to simply go to sleep early the night before when you need to wake earlier than usual.

If you have flexibility with a later report time and a long duty day ahead of you, try to awaken later to minimize your hours awake prior to duty.

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## Pre-Trip

### Commuting

For pilots, it's possible to live far from their base. This allows for operational and personal flexibility but can introduce fatigue issues related to commute times.

When considering the effects of commuting on fatigue, the mode of the commute is not the critical issue. A 2011 report from the National Research Council included commute information from about 25,000 mainline and regional pilots: about half had a commute less than 150 miles, while nearly a quarter had commute distances of more than 750 miles. Of course, not all commutes are equal just based on miles, as busy urban areas can lead to extra time on the road due to highway traffic and congestion. The critical factors when considering commute issues and fatigue are the hours of wakefulness, how commute time contributes to your total waking hours either prior to or following duty, and the timing of your body clock.



## Flight Duty Periods

### Circadian Misalignment

The severity of sleep loss due to circadian disruption that you experience can be affected by a variety of different factors, including the direction that you travel across time zones.

Physiologically, adjusting to eastward travel is more difficult than adjusting to westward travel.

Recall that your internal circadian clock actually has a rhythm that runs slightly longer than 24 hours. When traveling eastward, you lose hours, your day is shortened which works against the programming of your natural internal circadian clock. When you travel west, you are extending your day, adding hours and literally flying with the natural rhythm of your internal clock.

When you travel to a new time zone, your internal sleep/wake cycle and circadian clock are out of sync or misaligned with the local external time. The severity of disruption to your sleep and circadian cycle will be affected by both the direction you fly and the number of time zones that you cross. Without any intervention, it could take a few days or more to have your circadian clock line up with external local time. Your rate of adjustment is not only related to your sleep/wake schedule but is influenced by your other internal rhythms that are programmed by the circadian clock. There are effective strategies like planned light exposure, that when used properly can lead to rapid adjustment of your sleep and circadian rhythms to a new local time zone. Strategic use of light, the most powerful cue for the timing of your clock, is a complicated issue and an important element of a science-based training program and trip planning.

## Strategies

### Are You Able to Nap?

Brief sleep periods are a great strategy for promoting alertness, but, believe it or not, there is an art to effective napping.

- For a short nap, try up to 45 minutes.
  - You want to avoid awakening from deep sleep, which could cause sleep inertia and therefore be counter-productive. With a nap of no longer than 45 minutes, you're less likely to enter a deep sleep phase.
  - For a long nap, try about two hours, if you have the opportunity, which will take you through a full cycle of non-REM and REM sleep. You will wake up refreshed and get both physical and mental recovery benefits.
- Allow 15 minutes "wake-up" time after a nap.
- Depending on the situation or the environment, you may find that an eye mask or earplugs could be helpful. Be sure that you have some mechanism to wake you up on time, like an alarm clock.
- Avoid a long nap too close to your next sleep period, which can interfere with your normal sleep period.
- When planning sleep periods, take advantage of sleep-friendly windows in your circadian clock between 0300-0500 and 1500-1700.

Keep in mind, some sleep will always be better than none. Even a few minutes of sleep can help to improve your performance and alertness compared to staying sleepy.

## The Benefits of Napping

NASA research in long-haul crews showed that a short, 26-minute cockpit nap taken in-flight by pilots improved their performance 34% and alertness 54%.

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## Caffeine

A valuable tool for achieving alertness, caffeine can work to your benefit throughout your travels if used knowledgeably and strategically.

- Try to use caffeine in anticipation of when you'll be tired, not as a pick-me-up after the fact.
- To determine an optimum time for caffeine, keep the following facts in mind:
  - Caffeine can become effective within 15-30 minutes.
  - Its effects can last 3-4 hours.
- Effectiveness of caffeine varies by individuals based on sensitivity and tolerance levels.
- Don't use caffeine too close to a planned sleep time.
- Be aware that some food products, such as chocolate, contain caffeine.
- The concentration of caffeine in various foods and beverages varies widely.

Caffeine can be found in varying amounts in many drinks and other foods. Here are a few examples:

Know Your Caffeine Content	
8-OZ. COFFEE BEVERAGE	MILLIGRAMS
INSTANT .....	25-102
DRIP .....	115-250
BREWED .....	80-135
ESPRESSO (4 oz.) .....	120-200
DECAF. ....	2-10
8-OZ. TEA BEVERAGE	
INSTANT .....	15-30
BREWED .....	25-83
ICED .....	10-50
DECAF. ....	1-5
12-OZ. SOFT DRINKS	
COLA .....	35-47
ORANGE SODA .....	40
BARQ'S ROOT BEER .....	23
MOUNTAIN DEW .....	55
JOLT .....	71
OVER-THE-COUNTER MEDICATIONS	
STIMULANTS .....	100-200
PAIN RELIEVERS .....	32-65
COLD MEDICATIONS .....	30-65
FOOD	
FROZEN DESSERTS .....	8-85
CHOCOLATE .....	5-31
YOGURT .....	1-45

Remember, strategic use of caffeine is a great way to temporarily counteract the effects of fatigue,

especially if you anticipate a sleepy period when you need to be awake and productive. Also, be careful of both drinks and food that may contain caffeine and try to avoid them close to bedtime.

## Crew Resource Management

Effective coordination and communication with other flight crew (when applicable) are integral parts of crew resource management. Interacting with others socially can also help to keep you alert. When trying this tactic, make an effort to talk with someone else; become actively engaged in a dialogue. Though its effects do not last as long as caffeine or naps, social interaction is a practical alertness strategy that can be used anywhere, at any time.

## Activity Breaks

Brief, frequent breaks during a long duty period are another way to mitigate fatigue. Such breaks allow for physical activity, a change in social interaction, and an opportunity for a snack.

A NASA study of pilots flying simulated 6-hour night flights found that taking periodic breaks over time were better than a single, longer break mid-flight. When the pilots were given the opportunity to take 5-minute breaks every hour during the cruise portion of the flight, they were more alert and performed better for 15 minutes after each break. Also, they reported feeling more alert for up to 25 minutes after the breaks, especially during their circadian low points.

When appropriate, take a few minutes every hour or so for a short break. If possible, stretch or take a quick walk to energize your body. Eat a healthy snack or drink water (or a caffeinated beverage, depending on the timing of your

break). These activities can be effective at keeping you alert.

## Layover

### Plan for Sleep

While on layover, after crossing time zones, remember that your circadian rhythms will be out of sync with the light and other time cues around you, which will affect when you feel sleepy. Depending on the length of your layover and the schedule of your next flight, you may need to decide whether to stay on your home time or adjust to the local time, then plan your sleep and nap periods accordingly.

Make a plan for getting optimum sleep in order to be fit for your next duty. If possible, allow for a full 8-hour sleep period to decrease any sleep debt you may have accumulated. Create a restful sleep environment: close heavy curtains, wear an eye mask, avoid consuming caffeine and/or alcohol, use ear plugs or leave a fan on in the room to mask external noise.

A NASA study of long-haul pilots found that about 2/3 of them used naps or split sleep periods during layovers. If you can't manage an 8-hour sleep period during your layover, try napping or splitting your sleep to get close to that 8-hour goal (per day). Use your knowledge of circadian rhythms to determine when sleep-friendly windows of time will be for naps or short sleeps. In general, even if you only have time for a short nap, some rest is better than none.

While awake on layover, recognize that your alertness may be off a bit, so plan accordingly if you need to work, drive, plan to go sightseeing, or otherwise be active. Also, recall that performance declines more quickly when you've been awake for 17 hours.

See the Resources section for the Trip Planner tool located at the end of this article.

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## Other Factors: Alcohol

While drinking alcohol can lead to a relaxed state and feelings of sleepiness, be aware that too much alcohol can disrupt the quantity and quality of your sleep. Alcohol can also worsen snoring and other breathing-related issues. As a general rule, limit alcohol use within a couple of hours of bedtime.

Also keep in mind that alcohol use in conjunction with lost sleep or a sleep debt can worsen the effects of fatigue.

## 30-Minute Rule

Can't fall asleep? Use the 30-minute toss and turn rule.

Basically, when you have not been able to fall asleep for 30 minutes, get out of bed. Do something that is going to help make you sleepy, such as reading something boring or using an exercise designed to relax the mind and body.

Some relaxation techniques include:

- meditation
- positive imagery
- yoga
- progressive muscle relaxation

Avoid turning on bright lights, watching TV, using the Internet, or other stimulation. Also, don't be a clock watcher; turn the clock around so it is not interfering with your ability to get to sleep.

As soon as you are sleepy, get back into bed again and try to fall asleep. The 30-minute toss and turn rule is a critical strategy to help you avoid associating the bed and the bedroom with problems getting to sleep.

## Other Factors: Meals

The circadian clock regulates digestion, sending timed signals that can be thrown off by changing time zones. Stomach problems are

often associated with travel and the following common sense tips may help:

- Consider your home time when eating so that the size and content of your meals reflect the type of meal your body is expecting at that time.
- Pay particular attention to good nutritional practices when traveling.
- Drink sufficient fluids to promote health and comfort; stay hydrated.

People often wonder about how meal contents affect sleep. Know that generally due to the digestive process, most everyone will feel some sleepiness about 90 minutes after eating, no matter what was eaten. There isn't strong evidence on whether different types of food such as carbohydrates or proteins help with sleep. On the other hand, meals that are heavy in proteins and spicy foods can be difficult to digest and/or may create discomfort and disturbances during sleep, so keep that in mind when making dinner or bedtime snack choices.

There have been a variety of claims that manipulating food content can help minimize the effects of jet lag. However, studies conducted at the Cornell Medical Center evaluating the "jet lag diet" showed the diet had the same effects on sleep as a placebo, non-"jet lag diet", and that for some people it actually made sleep worse.

## Other Factors: Exercise

Regular exercise has a critical role in promoting good health. Exercise increases your metabolism for an extended period of time and improves your overall mood and health in general. In addition, people who get regular exercise get more deep non-REM sleep, leading to better-quality sleep. Recall that

these are the stages of sleep in which physical restoration occurs.

There is also some evidence that when traveling and crossing time zones, exercise periods may help shift your circadian clock, specifically the sleep-wake cycle. If you're used to a morning run when at home, doing so when away from home may provide your body with a timing cue that may help you adjust to the new time zone. When combined with outdoor light, this combination may help you adapt more easily to your new time zone.

Remember to avoid exercise within at least a couple of hours of bedtime, as too much physical activity close to bedtime can make it difficult to relax and fall asleep.

## Post-Trip

### Drowsy Driving

As discussed earlier, studies have documented reduced levels of alertness and performance and increased sleepiness when approaching 17 hours of wakefulness. Acute sleep loss and any accompanying sleep debt may accelerate and increase the risks related to hours awake. With that in mind and based on your expected duty periods, plan accordingly for activities, like your post-trip drive home:

- Total amount of time that you anticipate being awake by the time you complete your drive home
- Your sleep quantity and quality and total time awake during the past 48 hours

Don't ignore the risks of drowsy driving. If necessary, take action to manage your fatigue before driving home.

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## Make Recovery Sleep a Priority

Sleep debt can accumulate quickly, especially if you lose sleep over several nights in a row. How do you recover from a sleep debt? The good news is you don't have to pay sleep debt back hour-for-hour. For those of us in sleep bankruptcy, that's great news. We do seem to recover from sleep debt by extending our usual sleep period and by getting more deep, non-REM sleep. Now the bad news: you can't put credit in your sleep bank. So, if you have a really tough week coming up and decide "I'll sleep all weekend trying to build up as much sleep credit as I can, then next week I'll just go to my sleep bank to take it out," unfortunately, that doesn't work. You can't sleep more than you need in advance.

How long will it take to recover from a sleep debt? On average, it will probably take about two consecutive nights of good sleep. If you have a very high sleep debt, it may take you more than two nights. When back home, be sure to allow enough time for getting the amount of sleep you need to make up for what you may have lost while on your trip.

## OTHER CONSIDERATIONS

### Policies

Many factors should be addressed and balanced to minimize flight crew fatigue. While this article is focused on individual considerations, a shared responsibility should exist between crew members and organizations.

Flight departments should provide support and structure for its personnel in managing potential fatigue issues. Written policies should be established on crew duty time limitations and minimum rest requirements that provide adequate opportunities for sleep. The flight

operations manual should clearly state these policies.

When developing duty and rest policies, a business aviation department should take into consideration the characteristics of its normal operational demands and build in provisions that allow for the necessary flexibility. Early morning starts, late night arrivals, and multiple flight segments in high-density airspace can create fatigue issues similar to long transcontinental and international duty periods.

Policies for daily duty and rest are a minimum layer of protection, but there is added benefit to defining maximum allowable total duty time over multiple-day periods, such as 5 or 7 days. These take into account potential accumulated fatigue due to workload and lost sleep over a period of time.

The Flight Safety Foundation has published Principles and Guidelines for Duty and Rest Scheduling in Corporate and Business Aviation. Though the duty and rest periods presented in this report are not regulatory, they are recommended practices and guidelines based on scientific research. Please see the Resources section for the reference to this document.

Additional policies can provide further protections, such as reporting processes that recognize and provide for corrective actions and fatigue mitigation both before and during operations. A just culture empowers flight crew with responsibility for their own safety and health, as well as for their passengers', by encouraging communications with management when they are fatigued and providing a framework for taking actions to promote alertness and optimal performance.

LBA and single pilot operators should develop their own plans that are communicated to family members, business associates, and other stakeholders so there is proper understanding and recognition of potential fatigue risks. This will reinforce why certain practices, and possible limitations, are necessary for the single pilot to fly safely. Establishing personal rules and routines regarding your ability to be alert and perform is as important as any other safety practice that you follow in a single pilot aircraft.



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## RESOURCES

### Trip Planner: Where is Your Body Clock?

How much fatigue will you experience on your next trip? This varies from person to person, due to one's health, age, and other factors. You can get some idea of your expected fatigue from the number of hours your body clock will be displaced going from "home time" to "local time." Use the blanks in "local time" below to figure out your body's sleepy and alert periods for your next trip across time zones.

Be sure to consider optimal local times for sleep and nap periods and timing for caffeine, both when it will most help and when it may interfere with rest opportunities.

Example: Imagine that you are based in New York and travel to London, a change of five time zones east. Your body is programmed to be alert, for instance, from about 0900 until 1100 New York time (see chart, below). When you travel to London, the time change will cause your body to be alert from about 1400 to 1600 local time. On the other hand, your body, which is sleepy from about 1500 until 1700, New York time, will be sleepy from about 2000 until 2200, London time. You should take this into account when taking a nap in London. It can take up to several days for your body to adapt to the local time (i.e., for your body to be alert from about 0900 until 1100 London time).

	SLEEPY A.M.					ALERT A.M.					SLEEPY P.M.					ALERT P.M.								
NYC Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
LON Time	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5

	SLEEPY A.M.					ALERT A.M.					SLEEPY P.M.					ALERT P.M.								
Home Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Local Time																								

### References

Flight Safety Foundation. (1997). Principles and Guidelines for Duty and Rest Scheduling in Corporate and Business Aviation. Flight Safety Foundation, 16(2), 1-11.

Visit our website for more information and links to related sites on sleep, alertness, sleep disorders, naps, caffeine, and other topics: <http://www.alertness-solutions.com>

### About Alertness Solutions

Alertness Solutions is a scientific consulting firm that translates knowledge on sleep, circadian factors, alertness, and performance into practical strategies and tools that improve productivity and safety in our 24-hour society. We offer a wide range of products and services, including **Z-Coach**, our online fatigue management program, and the **SAFE** program, that address these issues for aviation professionals. To access these resources, schedule a live presentation, or engage our services, please contact us:

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