WHAT RESEARCH IS SAYING ABOUT

SLEEP & FATIGUE

As society moves further into 24-hour, 7-days-a-week operation, researchers and policy makers are focusing on the hazards of fatigue.

Tom Keating

It's known to some passengers as the "red-eye special" – a direct flight from Perth to the east coast of Australia, departing around midnight. Seasoned travellers generally avoid it because they know that they will wind up at their destination tired and sometimes more than a little aggravated.

This red-eye special departed Perth at 2.11 am (eastern standard time) on July 24 last year. Just before it arrived at its Canberra destination at 5.44 am (EST) the flight crew got an unexpected terrain caution . On board the Boeing 737 were two flight crew, 80 passengers and five cabin crew.

As the aircraft approached Canberra, the crew elected to track to the Church Creek (CCK) instrument approach fix to enter the holding pattern and descend to 5000 ft to intercept the instrument landing system approach for runway 35. But the co-pilot – under instructions from the pilot in command – entered the wrong data, sending the 737 about 11 nm beyond the established holding pattern limit.

What happened next ranks as one of the worst fears for an airline pilot: a computer-generated male voice with a north American accent sounded an abrupt warning: "CAUTION TERRAIN".

The flight crew did not wait for the next announcement from the enhanced ground proximity warning system (EGPWS). They immediately climbed to 6500 ft and out of danger, joining the runway 35 localiser for an uneventful landing. No-one was hurt.

Analysis by Australian Transport Safety Bureau (ATSB) investigators showed that the aircraft passed 810 ft above terrain, some 5 km north, abeam Tinderry ridge.

The ATSB report, released May 2005, says that the crew's operational performance "was affected at a critical stage of the flight by fatigue, the late advice of the status of air traffic services and the crew's misinterpretation of the CCK locator holding pattern data on the runway 35 ILS approach chart".

According to the report, "the crew's ineffective contingency planning … and the erroneous data entry … suggest that they crew was not functioning at an appropriate level of alertness".

"It is likely that both the pilot in command and the copilot were experiencing fatigue due to the cumulative effects of ineffective sleep in the period preceding the Perth to Canberra night sector and the ongoing period of wakefulness during the flight."

Compounding the risk of fatigue was the fact that the pilot and copilot were working at a low point in their circadian rhythms, the internal biological clocks that govern a 24-hour cycle in body functions – including sleep/wakefulness, motor activity, hormonal processes, temperature and performance.

Investigators believe that flight crew's fatigue may have been exacerbated by a malfunctioning air conditioning system, which caused temperatures in the flight deck to rise about 10 C above normal.

Since the occurrence, the aircraft operator has moved to fix flight deck temperature control problems and has increased the minimum holding pattern altitude at Church Creek.

Fatigue in long-haul operations – like the Perth to east coast red-eye specials – has attracted a great deal of attention from researchers, including NASA's Ames Research Centre. Their findings indicate that fatigue in long-haul operations can be attributed to a number of factors: transmeridian travel causing a mismatch between patterns of sleep and the cycle of day and night; extended overnight flights; consecutive night work; and the length of time worked.

Studies show that fatigue can occur in short-haul operations as a result of insufficient or poor quality sleep. Fatigue ratings of US short-haul airline pilots showed a significant variation as flight crew progressed across a 3 or 4 day short-haul schedule.

The fatigue ratings were highest during the schedule and decreased to baseline levels during the post-schedule recovery period. The studies, led by New Zealand researcher, Philippa Gander, also showed significant time-of-day variation, with fatigue lowest immediately after waking, and generally increasing across the flight duty period.

UK research has also shown that fatigue increases over consecutive days during a 6-day schedule and across a 4-sector flight duty period.

Shift work: Shift workers are vulnerable to sleep problems that can lead to fatigue. They are working against their body clocks, and trying to sleep at times when others are active.

A review of the shift work literature, by ATSB researcher Sylvia Loh, shows that work-related fatigue is also modified by environmental, social and domestic factors. These occur in the operating environment and the home.

In the operating environment, high temperatures and loud environmental noise are associated with perceptions of fatigue. Turbulence and dehydration can also play a part.

Domestic factors can be important contributors to fatigue, as shift workers attempt to balance work with social demands and family obligations by reducing the time they allocate to sleep.

According to Transport Canada, fatigue is one of the conditions most frequently cited as a contributing factor in aviation accidents. However, no systematic study of the contribution that fatigue makes to aviation accident has yet been undertaken in Australia, partly because of difficulties in collecting information.

Nevertheless, the association between fatigue and human-error related accidents is well established, particularly for road transport. US army research and a host of international studies have shown that performance degrades and crash risk increases markedly after the 12th hour of any duty time during a work shift.

At a symposium of sleep researchers held late last year at the Woolcock Institute of Medical Research at the University of Sydney, some of the world's leading sleep researchers gathered to present their results.

The key message came from Professor David Dinges, a world-renowned sleep researcher from the Department of Psychiatry and Centre for Sleep and Respiratory Neurobiology at the University of Pennsylvania's School of Medicine.

His message was blunt. Pausing for dramatic effect, he glared at the researchers, policy makers, shift work managers and union leaders assembled before him. He prefaced his statement with the plea that if anything was to be remembered from his opening address, then it should be one, short statement. Then he called it, twice for effect: "You can't beat biology".

It doesn't matter how competent, fit or professional you are, if you do not get sufficient sleep your performance will be degraded. The problem is that researchers have shown that when you are chronically fatigued, it is difficult for you to recognise the condition. There is, however, a simple test: if you are not waking up refreshed, you have a problem.

The biological basis for sleep is not fully understood. However, it is clear that sleep is an essential function for mammals. Rats die after 3-4 weeks of sleeplessness, and humans die after between 7 months and one-and-a-half years without sleep. Neurobiologist have also located a cluster of cells, consistent across mammalian species, that account for the mechanisms of sleep.

Many studies have found that men and women need between 7 and 9 hours of sleep on a regular basis to prevent fatigue, and a condition researchers call sleep debt. You build up a sleep debt whenever you cheat nature. And you have to pay back the debt to function normally. Some US research indicates that you can pay back your sleep debt at a favourable rate, as long as it is good quality sleep (if you owe 9 hours, you may be able to pay the sleep debt back with as little as 3 hours).

There are two types of fatigue that affect pilots: acute or short-term fatigue and chronic fatigue. Acute fatigue is caused by recent sleep loss or disturbance. It can also result from intense mental or physical activity over a relatively short period of time, such as working under the pressure of a deadline or flying in difficult instrument conditions for a long period. This kind of fatigue is easily remedied by a good night's sleep.

Chronic fatigue results from many episodes of insufficient or disrupted sleep (cumulative sleep debt).

Acute and chronic fatigue can interact in the flight environment. The greatest workload usually occurs at the end of a flight, during the approach and landing phase, when the pilot is also the most tired and consequently has reduced concentration.

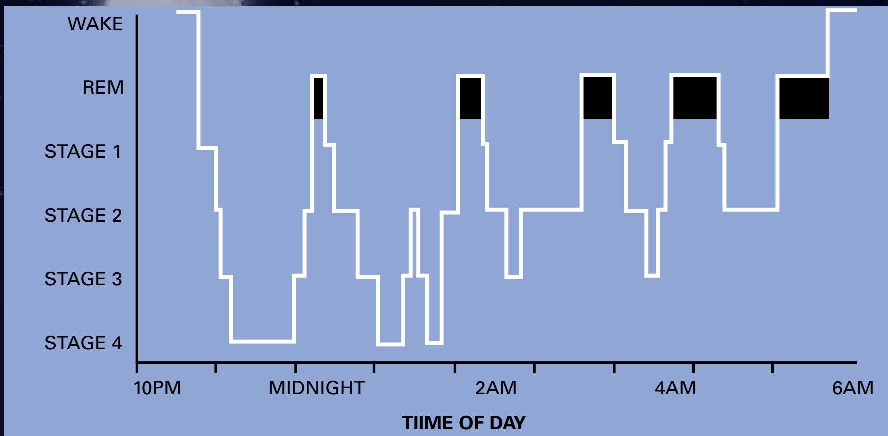

Diagram of the non-REM/REM cycle across the night

THE SLEEP CYCLE

The normal human adult generally enters sleep without dreaming (non rapid eye movement). Rapid eye movement (REM) sleep – associated with dreaming – generally does not occur until 80 minutes or longer after falling asleep. After the first period of dreaming, REM sleep and NREM sleep alternate through the night in an approximate 90-minute cycle.

The progression of sleep stages across a single night in a normal adult young adult, shows four stages of sleep.

The result can be acute fatigue which can contribute to error. If the pilot is also suffering from chronic fatigue due to cumulative sleep debt, judgement and decision making can be impaired, resulting in inadequate responses to threat and error.

We all experience sleep, so most people have some entrenched views about the subject. The problem is that many of our ideas about sleep are wrong. After several decades of research, it is possible to lay out some practical facts. Following are 11 commonly-held myths about sleep:

① **Snoring isn't harmful. Although snoring may be harmless for for many, it can be a symptom of a life-threatening sleep disorder called sleep apnea.** Sleep apnea involves pauses in breathing that prevent air from flowing into or out of a sleeping person's airways. People with sleep apnea awaken frequently during the night gasping for breath, but may not be are that they are doing so. The breathing pauses reduce blood oxygen levels, can strain the heart and cardiovascular system, and increase the risk of cardiovascular disease. Snoring on a frequent or regular basis has been directly associated with hypertension. Obesity and a large neck can contribute to sleep apnea. Sleep apnea typically affects middle-age, overweight men, and may affect women in later years. It can be aggravated by alcohol, sleeping pills and tranquilisers taken at bedtime. The condition can be treated; men and women who snore loudly, especially if pauses in the snoring are noted, should consult a physician.

② **You can adapt to getting less sleep. You cannot – you actually become chronically fatigued, but may not be able to recognise it.** Sleep experts say most adults need between 7 and 9 hours of sleep each night for optimum performance, health and safety. When we don't get adequate sleep, we accumulate a sleep debt that can be difficult to "pay back" if it becomes too big. The resulting sleep deprivation has been linked to health problems such as obesity and high blood pressure, negative mood and behavior, decreased productivity, and safety issues. University of Minnesota studies show that humans only need to make up one-third of what they have lost. The exception is people with insomnia, who are advised to keep their sleep-wake schedule as consistent as possible.

③ **You don't need a regular bed and wake time schedule.** Our sleep-wake cycle is regulated by a "circadian clock" in our brain and the body's need to balance both sleep time and wake time. A regular waking time in the morning strengthens the circadian function and can help with sleep onset at night.

④ **Insomnia is characterised by difficulty falling asleep.** Difficulty falling asleep is but one of four symptoms generally associated with insomnia. The others include waking up too early and not being able to fall back asleep, frequent awakenings, and waking up feeling unrefreshed. Insomnia can be a symptom of a sleep disorder or other medical or psychological/psychiatric problem, and can often be treated. When insomnia symptoms occur more than a few times a week and impact a person's daytime functions, the symptoms should be discussed with a doctor or other health care provider.

⑤ **Health problems such as obesity, diabetes, hypertension, and depression are unrelated to the amount and quality of a person's sleep.** Studies have found a relationship between the quantity and quality of one's sleep and many health problems. For example, insufficient sleep affects growth hormone secretion that is linked to obesity; as the amount of hormone secretion decreases, the chance for weight gain increases. Blood pressure usually falls during the sleep cycle, however, interrupted sleep can adversely affect this normal decline, leading to hypertension and cardiovascular problems. Research has also shown that insufficient sleep impairs the body's ability to use insulin, which can lead to the onset of diabetes. More and more scientific studies are showing correlations between poor and insufficient sleep and disease.

⑥ **Exercise before bedtime to get a good night's sleep.** In general, exercising regularly makes it easier to fall asleep and contributes to sounder sleep. However, exercising sporadically or right before going to bed will make falling asleep more difficult. In addition to making us more alert, our body temperature rises during exercise, and takes as much as 6 hours to begin to drop. A cooler body temperature is associated with sleep onset. Finish your exercise at least 3 hours before bedtime. Late afternoon exercise is the perfect way to help you fall asleep at night.

⑦ **Coffee overcomes the effects of drowsiness.** Stimulants are no substitute for sleep. Drinks containing caffeine, such as coffee or cola can help you feel more alert, but the effects last only for a short time. If you drink coffee and are seriously sleep-deprived, you are still likely to have "micro-sleeps" — brief naps that last around four or five seconds.

⑧ **You can tell when you are going to go to sleep.** If you're like most people, you believe you can control your sleep. In a test, nearly four-fifths of people said they could predict when they were about to fall asleep.

Stage 1 – The first cycle of sleep persists for 1-7 minutes at the onset of sleep. Stage 1 sleep appears to be a transitional stage between wakefulness and sleep. It has a low arousal threshold, in which even soft sounds can wake the subject. In severely disrupted sleep there is generally an increase in the amount and percentage of stage 1 sleep. Brain waves become smaller and slower. Stage 1 sleep makes up between 2 and 3 per cent of sleep.

Stage 2 – In stage 2 sleep a more intense stimulus is needed to produce arousal. It is a deeper, intermediate stage of sleep that occupies about 50 per cent of an adult's sleep pattern. In this stage, blood pressure, metabolism and cardiac activity decrease. Brain waves are larger, with occasional bursts of activity. A person will not see anything even if the eyes are opened. Stage 2 sleep accounts for around 45-55 per cent of sleep.

Stage 3 – This is the beginning of deep sleep and is characterized by slow brain waves which are about 5 times the size of brain waves during stage 2 sleep. A person is very difficult to awaken during this stage. From 3-8 per cent of sleep is made up of stage 3 sleep.

Stage 4 – Stage 4 sleep is when the deepest sleep occurs. This stage is characterised by large brain waves. If a person is a sleepwalker, this will occur in this phase. Between 10 and 15 per cent of sleep is stage 4 sleep.

Rapid eye movement (REM) sleep, which makes up about 20-25 per cent of sleep, dominates in the last third of the sleep cycle and is linked to the circadian rhythm of body temperature. It occurs in four to six discrete episodes.

They were wrong.

The truth is, sleep is not voluntary. If you're drowsy, you can fall asleep and never even know it. You also cannot tell how long you've been asleep. Researchers have measured a phenomenon called microsleep, in which fatigued people fall asleep for just seconds, before waking again, often without knowing they have done so.

⑨ **You're an expert and have done this many times before so it doesn't matter if you are sleepy.** The only safe pilot is an alert pilot. Even the safest pilots and LAMEs miss things, become confused or cranky and use poor judgement when they are sleepy. A drowsy pilot doesn't process information as fast or as accurately as an alert one and has slower reaction times.

⑩ **Most people get plenty of sleep.** Chances are good that you really aren't getting all the sleep you need. Ask yourself: "Do I wake up rested?" The average person needs 7 to 9 hours of sleep a night. If you go to bed late and wake up early to an alarm clock, you probably are building up a sleep deficit during the week. If you spend eight hours in bed but still feel tired, you may have a disorder preventing you from getting enough sleep. Whatever the cause, avoid safety-critical work when you feel drowsy. Rearrange your schedule so you get enough sleep.

As Phillipa Gander writes in her recent book, Sleep in the 24-hour society, the usual motivation for moving to 24-hour operations is to increase productivity and profitability. But the safety and health consequences of fatigue also have an economic impact, and they cannot be ignored.

Sources: *Proceedings of the 2nd annual sleep loss symposium, Woolcock Institute of Medical Research, University of Sydney;* Principles and Practice of Sleep Medicine*, 3rd edition, Kryger, Roth and Dement;* Sleep in the 24-hour society*, Phillipa Gander;* Flight crew fatigue in Australian short-haul operations – methodologies for assessing fatigue in flight*, PhD thesis, Sylvia Loh; American Academy of Sleep Medicine.*

SLEEP INERTIA & THE NASA NAP

Waking someone from stages 3 or 4 sleep is quite difficult. Anyone awakened from these sleep stages will most likely be groggy, disoriented and confused. You might experience a performance deficit called sleep inertia if awakened in these stages.

Recent research into sleep inertia has revealed a range of effects, including:

- Impairment of performance and reaction times.
- Reduction in memory ability.
- Impairment of the ability to make sound decisions.

Within the first 3 minutes of waking, decision making performance can be as low as 50 per cent of the person's best performance before sleep. Decision making performance can still be 20 per cent below the optimum up to 30 minutes after waking.

The degree of impairment that sleep inertia has on performance is influenced by:

- The abruptness of waking. If you wake from sleep normally, the effects of sleep inertia last for less than five minutes; however if you awoken suddenly, these effects can last up to 30 minutes, and sometimes more.
- The stage of sleep that has been interrupted. If you are awoken during deep or slow wave sleep, the effects of sleep inertia are more pronounced.
- The time between awakening and the time of the task – sleep inertia will cause less impairment as the time between awakening and task performance increases.

If you are fatigued, the effects of sleep inertia are worsened.

These findings have important implications for emergency workers, who are sometimes awoken suddenly to attend an emergency. They are also of interest to pilots taking short naps.

A NASA study of pilots on trans-Pacific routes found a consistent decline in performance measures such as vigilance and reaction time. However, when the researchers repeated the experiment over the same route, this time allowing a 40-minute nap, the results showed a marked improvement. However, the research on sleep inertia suggests that taking naps should be taken for no longer than around 40 minutes to ensure that you are not suddenly awoken from a deeper stage of sleep.

Napping can significantly improve alertness, communication and performance. However, it is important that the potential effects of sleep inertia following a nap be acknowledged and actions taken to mitigate effects. It would be unwise to nap just before a high workload or before a period when concentration is required.

THE FIGHT AGAINST FATIGUE

Strategies to help organisations and individuals manage fatigue.

Fatigue affects a person's health, reduces performance and productivity within the workplace, and increases the chance of an accident occurring.

One of the best ways to manage fatigue is to use a risk management approach, as used for workplace hazards generally.

There are five basic steps in the risk management process. They include:

1. **Identifying hazards**
2. **Assessing risks that may result because of these hazards**
3. **Deciding on control measures to prevent or minimise the level of risks**
4. **Implementing control measures**
5. **Monitoring and reviewing the effectiveness of control measures.**

1. Identify factors that contribute to fatigue

The first step when managing fatigue is to identify factors within the workplace that may contribute to fatigue. One workplace factor that should be carefully considered is roster design. Shift length and roster design can put workers at risk of sleep deprivation and fatigue. When looking at rosters, you should assess whether the roster provides workers with a sufficient opportunity for rest and recovery between shifts. You should consider:

- Length of shifts worked – the length of shifts worked can contribute to fatigue.
- Previous hours and days worked – the effects of fatigue are cumulative, workers may have sleep debt due to the previous hours and days worked, which can contribute to fatigue.
- Type of work being performed – pay particular attention to the level of physical and/or mental effort that is required.
- Time of the day when the work is being performed – remember that disrupting the body's circadian rhythms can cause fatigue and also impact on task performance.

There are many ways to identify workplace factors that contribute to fatigue. They include:

- Inspecting workplace rosters.
- Consulting with workers – ask them if they regularly feel fatigued. Also ask about any problems they have encountered, or any near misses or unreported injuries (note, however, that research shows that people find it difficult to assess their own performance when they are fatigued).
- Consult with workplace health and safety representatives and workplace health and safety committees.
- Conduct a safety audit.
- Analyse injury and incident reports – pay particular attention to injuries and incidents that occur in periods of high fatigue risk (the latter half of shifts and night work – particularly 2 am to 6 am).
- Conduct worker surveys.

2. Assess risk

The second step involves assessing the risks associated with the workplace factors that contribute to fatigue. Risk is the likelihood that death, injury or illness may result because of the factors that contribute to fatigue. To assess risk, you should consider both likelihood and consequences. For each of the risks:

- Determine the likelihood (that is, very likely, likely, unlikely, very unlikely) of an incident occurring at the workplace, bearing in mind the existing control measures.
- Determine the consequences (extreme, major, moderate, minor) of an incident occurring at your workplace, bearing in mind the existing control measures.
- Combine the likelihood and consequences estimates to rate the risk.

Once the above process has been completed, the ratings of each risk should be prioritised for further action.

The following should be considered when assessing the factors that contribute to fatigue:

- Time of day – incidents are more likely to happen in circadian low points (such as night time, especially between the hours of 2 am and 6 am).
- Length of shifts worked – the effects of fatigue are cumulative, workers are more likely to feel fatigued in the final hours of a shift, than in the first few hours of a shift.
- Lack of opportunity to recover from fatigue – incidents are more likely to occur if workers are not given a sufficient opportunity to recover from fatigue.
- How often the situation occurs – generally, the more often a worker is fatigued, the greater the likelihood is that an incident will occur.
- How many people are fatigued – generally, the more people who are fatigued, the more likely an incident is to occur.
- The skills and experience of persons fatigued – consider training and competence both to perform work-related tasks and manage fatigue.
- Any special characteristics of the people involved – for example is a worker is on medication for a condition that is affected by circadian rhythms and night shift work (such as asthma, depression or diabetes).
- The duration of exposure to fatigue – generally, the longer a person is fatigued, the more likely an incident will occur.
- The level of risk inherent in the work – incidents are more likely to occur in work that is generally hazardous.

3. Decide on control measures

The third step when managing fatigue involves deciding on control measures to manage exposure to fatigue.

The ideal solution when managing fatigue is to completely eliminate factors that contribute to it, such as elimination of night shifts and extended working hours. If this is not possible, there are a number of control options that may be used alone, or in combination, to minimise and control exposure to fatigue. Examples include:

- Limiting shift work to essential jobs and tasks that must be completed at night.

- Redesigning work practices so that routine administrative tasks are minimised for night shift workers, allowing them to focus on core duties during night work.
- Scheduling later start times so that maximum night sleep can be obtained before starting work (however this can affect those on night shift).
- Scheduling low risk work during periods of high fatigue, such as night time (especially during the hours of 12am and 6am) and in the latter half of shifts.
- Scheduling highly complex tasks to be performed only during the day.

Administrative controls should not be relied on until other options have been exhausted. In general, administrative controls should only be used:

- When there are no other practical control measures available.
- As temporary measures until a permanent solution is found.
- To supplement other controls

Examples of administrative controls that may be used to manage fatigue include:

- Sufficient supervision, particularly during periods of high fatigue (such as night time, or in the latter half of shifts) and especially for hazardous work.
- Contingency plans if workers become fatigued – this could involve removing fatigued workers from work activities where there is a considerable risk to health or safety.
- Effective emergency responses.
- Strict controls and procedures if performing hazardous work during high fatigue periods (especially during 2 am to 6 am).
- Job rotation for repetitive or monotonous work, or work that involves heavy physical demands.

4. Implement control measures

The fourth step is to put the selected control measures in place. This involves:

- Developing work procedures.
- Communicating control measures.
- Providing training and instruction.
- Supervision.

Work procedures need to be developed to ensure that fatigue control measures are effective. For example, you should design a shift system that provides staff with sufficient opportunity for rest and recovery. You should also define and communicate responsibilities.

You should tell workers about the control measures to be put in place (under State-based Occupation Health and Safety legislation, workers are likely to be entitled to be consulted about any changes in the workplace that could affect their safety).

You should provide training for workers and supervisors on fatigue covering:

- Common causes of fatigue, including shift work, extended working hours and roster patterns.
- Potential health and safety impacts.
- How workers must make appropriate use of their rest days, and they should ensure they are fit for duty on rostered shifts.

You should also provide adequate supervision to ensure that new control measures are being used correctly.

5. Monitor and review

The final step is to monitor and review the effectiveness of fatigue control measures. Consider whether:

- The chosen control measures have been implemented as planned.
- The chosen control measures are working.
- There are any new problems.

When answering these questions, you could:

- Consult with workers, supervisors, health and safety representatives, workplace health and safety officers and committees.
- Measure exposure to fatigue.
- Monitor incident reports and assess the likelihood that fatigue is contributing to incidents – pay attention to injuries and incidents that occur in periods of high fatigue.

Make sure you have built a process for monitoring and evaluation of workplace fatigue. This process should be regularly reviewed.

Adapted from Fatigue management guide *by Workplace Health and Safety Queensland, (c) 2005 Department of Industrial Relations, Queensland Government. Reproduced with permission.*

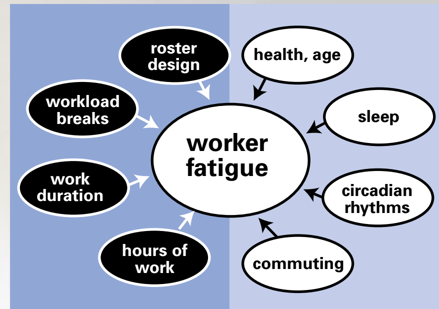

Figure 1: Factors that contribute to fatigue

What the rules say

Fatigue risk management systems are being adopted by a range of organisations to control the risks of fatigue-related accidents and incidents.

Operational demands sometimes can complicate application of fatigue risk management systems.

The Civil Aviation Safety Authority regulates flight and duty times under Civil Aviation Order 48 (CAO 48).

However, the limitations imposed by CAO 48 were developed well before the science of sleep was established – research has demonstrated that fatigue can cause significant impairment in performance.

Some emerging research is indicating that fatigue may not be adequately managed by rostering 10-hour breaks between shifts, limiting “stick hours” over certain periods, or other prescriptive measures.

Since late 2001 CASA has been testing and refining a risk management approach to the control of fatigue, with over 30 general aviation operators adopting fatigue risk management systems to protect their operations.

This effort is a response to the emerging science of sleep and fatigue and to the recommendations of a House of Representatives Standing Committee report, *Beyond the Midnight Oil*, on fatigue in transport industries, published in October 2000.

As experience with the use of fatigue risk management systems grows, it is likely that the safety regulator will seek to mandate this approach. Under the current rules, the adoption of a fatigue risk management system is approved by CASA as an exemption from CAO 48.