Understanding Fatigue Science and its Impact on Aviation Safety

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Disclosure Information

I have no financial relationships to disclose

Learning Objectives

- Learn about the **importance of fatigue in aviation** and its **impact on aviation safety**
- Understand and apply the **basic science principles of fatigue** in relation to the aviation environment
- Gain **basic knowledge on fatigue management approaches** supported by ICAO SARPS

ASIA

Indonesian airline pilots fell asleep mid-flight: Safety agency

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India updates pilot fatigue management system

Long flying hours, roster instability among top causes of pilot fatigue, says study

Virgin Australia is rostering pilots 'closer to the limit' of fatigue, watchdog tells Senate estimates

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Industry

FLIGHT ATTENDANTS CALL FOR BINDING CABIN CREW FATIGUE RULES

written by Jake Nelson | May 31, 2024

A Jetstar flight attendant. (Image: Jetstar)

Flight attendants have called for stronger fatigue regulations as part of a new "Fatigue Doesn't Fly" campaign for International Cabin Crew Day, 31 May.

Controller Fatigue Report Findings Prompt Immediate Change

Sean Broderick April 19, 2024

Credit: DFW Airport

A new FAA policy mandates longer minimum off-duty periods between air traffic controller shifts as soon as possible, addressing one of the near-term opportunities flagged in a new report on controller fatigue, Administrator Mike Whitaker announced April 19. The change, unveiled via an agency

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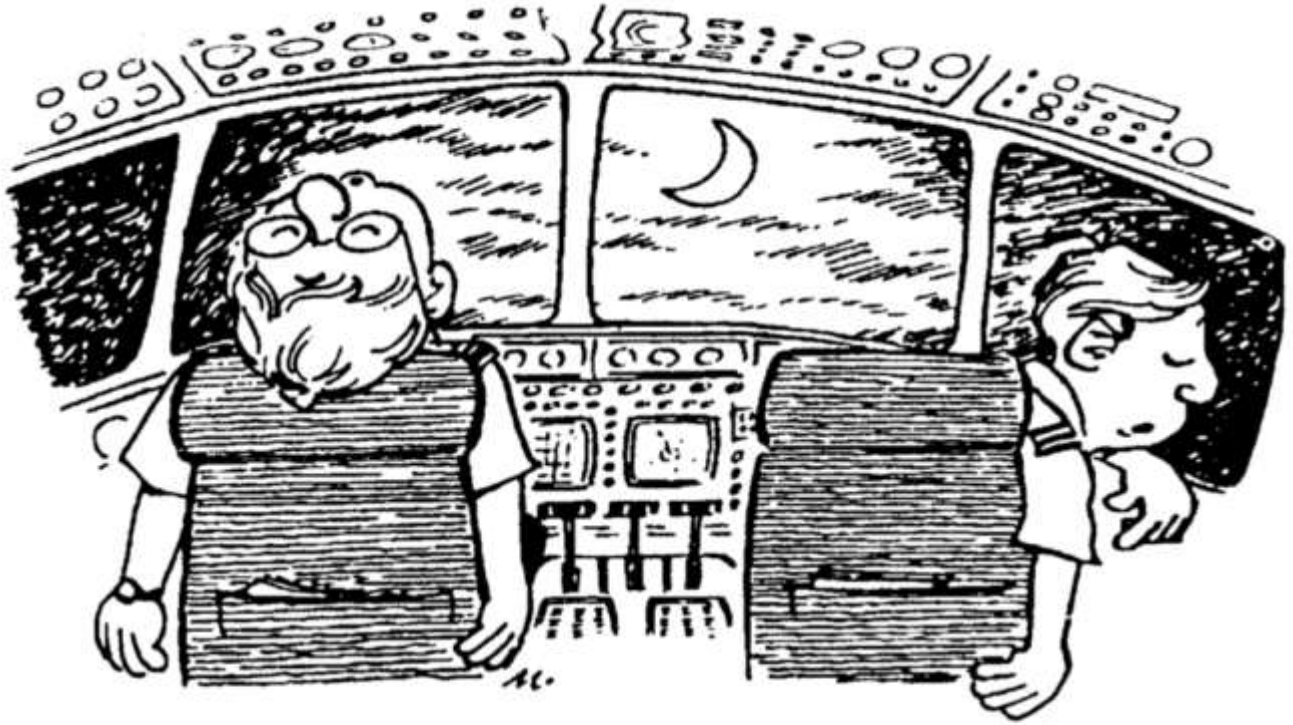


Constantly vigilant for any system malfunction the Captain scans the overhead panel as the co-pilot checks the window heat system with his forehead — at 03:00 pilots can't be too careful.....

Asiana Airlines 214
6 Jul 2013
3 fatalities, 181 injured, 12 critical

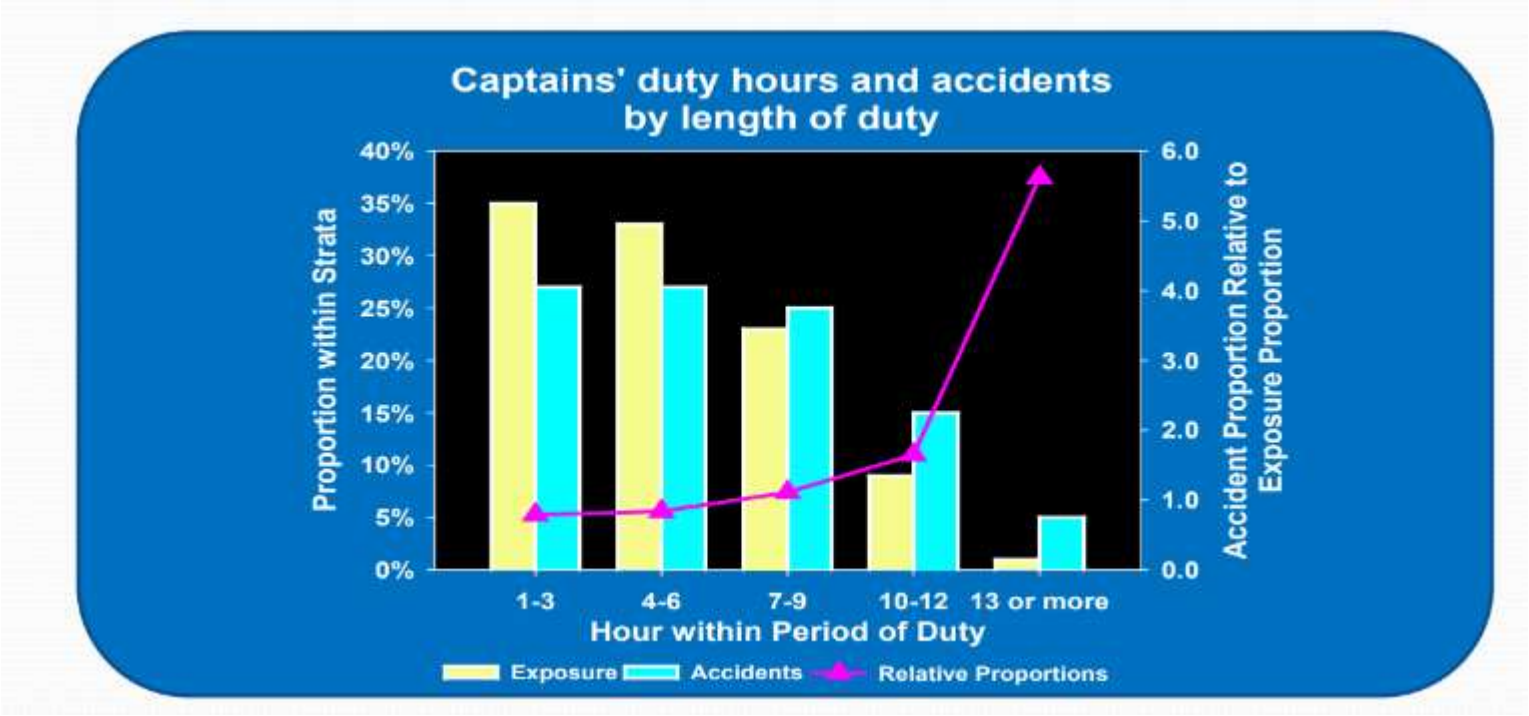
UPS Airlines 1354
14 Aug 2013
2 fatalities

It has been estimated that 4-7% of civil aviation incidents and accidents can be attributed to fatigued pilots

Flydubai 981
19 Mar 2016
62 fatalities

Convair 440
11 Sep 2019
2 fatalities

Fatigue and Aviation Risks



Goode JH. (2003). Are pilots at risk of accidents due to fatigue? J Safety Res, 34:309-313.

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Fatigue and Health

- Over the past decade, a substantial amount of research has shown that short or disturbed sleep not only degrades performance, but increases health risks

- Increased health risks translate to higher aviation risks

- The greater the amount of sleep restriction, the greater the extent of adverse effects on health

Fatigue and Health

- Sleep loss or deprivation (fatigue) is associated with increased risk of
  - Diabetes and disordered glucose metabolism
  - Obesity
  - Heart attacks
  - Poorer mental health
  - Premature deaths
  - Poorer relationships
  - Sexual dysfunction

All these translate into increased aeromedical risks that the system bears, adversely impacting aviation safety



Introduction to Fatigue

Introduction

A **physiological state of reduced mental or physical performance capability** resulting from sleep loss or extended wakefulness, circadian phase, or workload (mental and/or physical activity) that can **impair** a crew member's alertness and **ability to safely operate an aircraft** or perform safety-related duties.

Introduction

Fatigue increases the chances of **Pilot Error**

- Microsleeps / Decreased wakefulness
- Reduced cognitive abilities
  - Slower reaction time
  - Lapses in attention
  - Difficulty concentrating
  - Lapses in memory
  - Reduced ability to anticipate
  - Impaired decision-making
- Mood swings
- Increased irritability
- Increased risk-taking behaviour
- Impact on health (increased stress hormones, increased blood pressure)

Basic Principles of Fatigue in Aviation

The Fatigue Balance

Physical and mental demands of **all waking activities** (not only duty demands)

Recovery from those demands, which (except for recovery from muscle fatigue) requires **sleep**

Basic Physiology

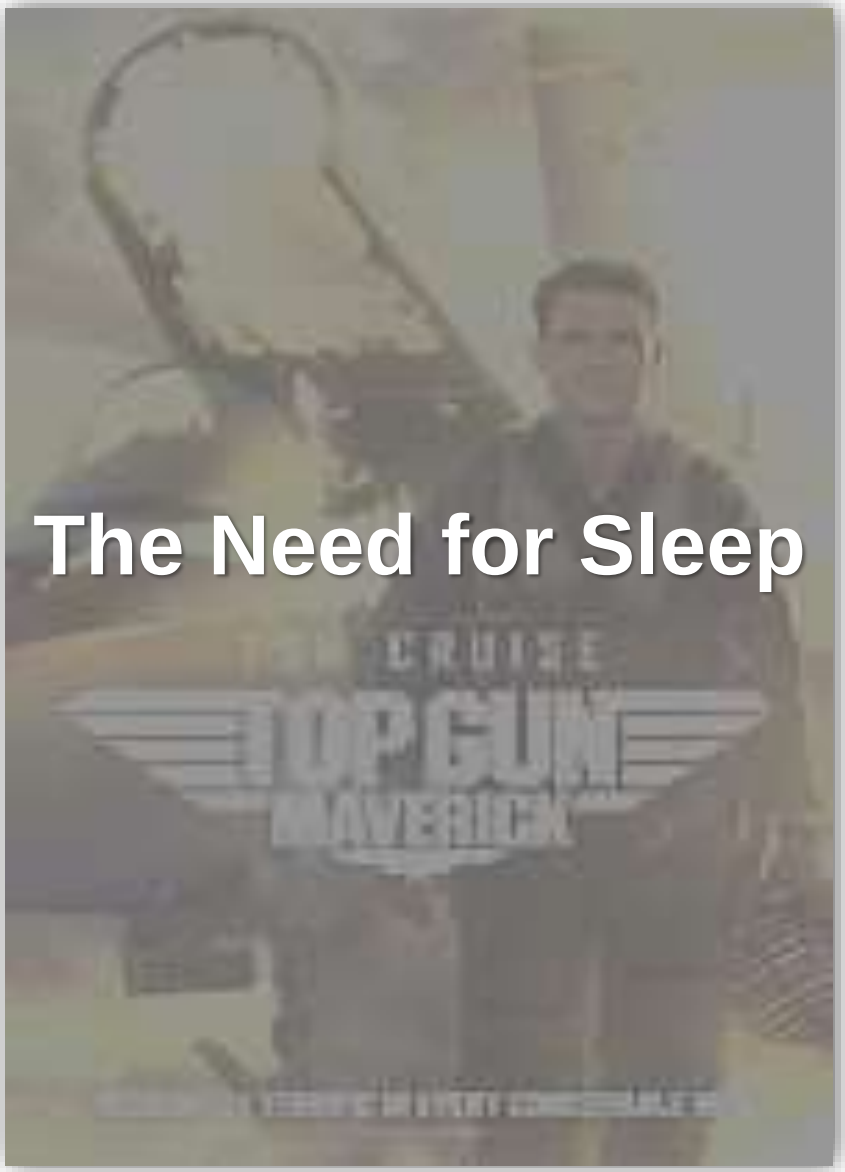
- **Sleep**
  - Quality and Quantity
  - Effects of not getting enough sleep (on one night or across multiple nights)
  - Recovery from sleep loss

- **Circadian rhythm** — daily cycles in physiology and behaviour that are driven by the circadian clock (a pacemaker in the brain)
  - Aspects of physiology and behaviour that show circadian rhythms include:
    - subjective feelings of alertness and sleepiness
    - ability to perform mental and physical work
    - ability to fall asleep and stay asleep (sleep propensity)

Basic Principles of Fatigue

The 4 basic principles of fatigue are:

1) The need for sleep
2) Sleep loss and recovery
3) Circadian effects on sleep and performance
4) The influence of workload


The Need for Sleep

The Need for Sleep

- We are meant to spend about 1/3 of our lives asleep.
- The optimal amount of sleep per night varies between individuals, but most healthy adults require between 7 and 9 hours.
- There is a widespread belief that sleep time can be traded off to increase the amount of time available for waking activities in a busy lifestyle.
- Sleep science makes it very clear that sleep cannot be sacrificed without consequences.

Sleep is not a tradable commodity!
It is a necessity and it is non-negotiable

The Need for Sleep

The exact function of sleep is unknown!

What science has shown is that sleep has vital roles in memory and learning, in maintaining alertness, performance, and mood, and in overall health and well-being. Sleep serves an important **restorative function**.

- Glymphatic function:
  - Cerebrospinal fluid flow in the brain is increased to aid in removal of wake-related toxins
  - Removal of extracellular beta-amyloid proteins associated with Alzheimer's disease is enhanced

- Connectivity function:
  - Strengthens newly-formed synapses in the brain
  - Aids in other complex processes that erase obsolete memories, consolidate new memories, & maintain plasticity (to help form new memories)

The Need for Sleep

The exact function of sleep is unknown!

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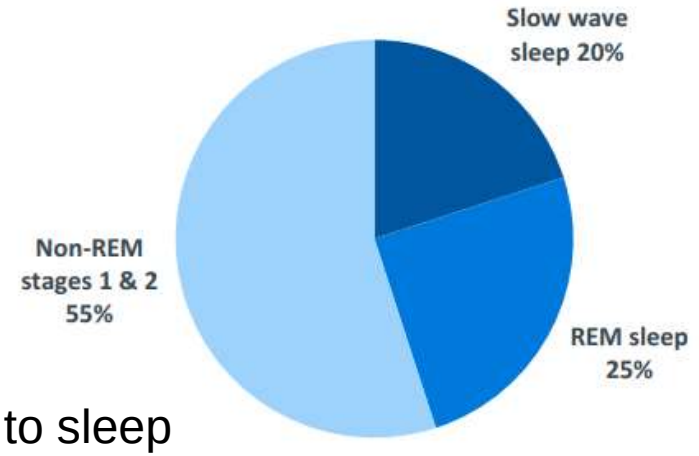
- Strengthens immune system:
  - Sleep is altered during infectious diseases
  - Improves antigen-specific immune defenses
  - Aids in disease recuperation

- Reduces caloric use:
  - Reduces metabolism so energy stores depleted while awake are restored

The Need for Sleep

Broadly divided into:

- Non-Rapid Eye Movement (Non-REM)
- Rapid Eye Movement (REM) Sleep



Non-REM stages

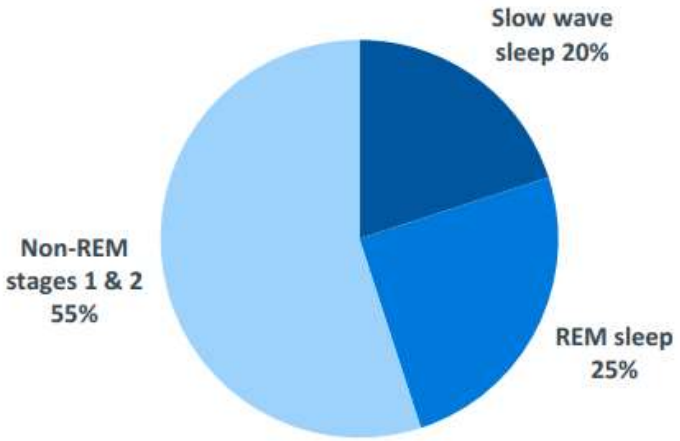
- Stage 1
  - Beginning transition between awake to sleep
  - If woken up at this stage, may not realize one was asleep
- Stage 2 – Light sleep
- Stage 3/4 – Deep sleep or “slow-wave sleep”
  - Muscles relaxed but not flaccid
  - Difficult to wake someone from this stage

“a quiet brain and quiet body”

The Need for Sleep

Broadly divided into:

- Non-Rapid Eye Movement (Non-REM)
- Rapid Eye Movement (REM) Sleep



REM sleep

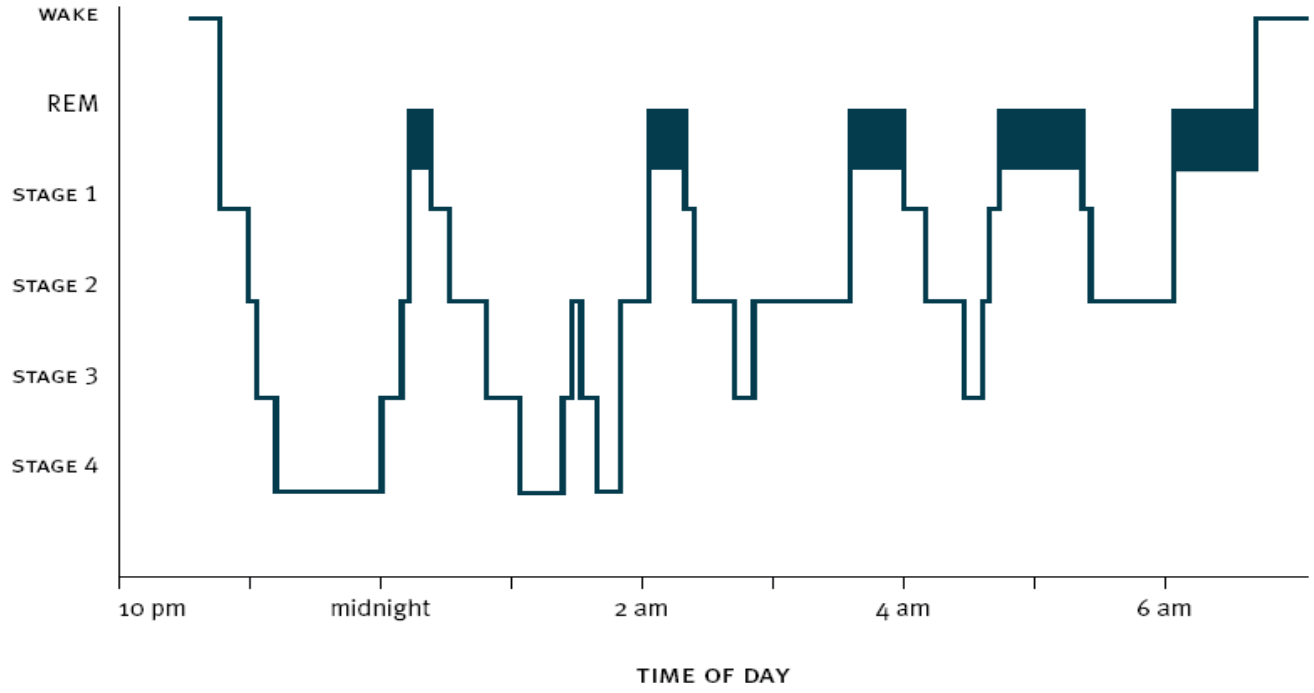
- Accounts for 20-25% of total sleep time
- Sleep for 90 minutes before 1st REM stage occurs
- 1st REM is 5-10 minutes, subsequently gets longer
- Information is consolidated and sorted/related to stored memories
- “Brain is repairing”

“busy brain and paralyzed body”

The Need for Sleep

Sleep Cycles

Non-REM / REM cycles with brief arousals or transitions to lighter sleep and even brief awakenings.



Each sleep cycle lasts 60-90min

Non-REM / REM cycle across the night in a young adult's sleep

The Need for Sleep

The Value of Sleep

The restorative value of sleep, or sleep quality, depends on going through **uninterrupted non-REM/REM cycles**, which suggests that both types of sleep are necessary and one is not more important than the other.

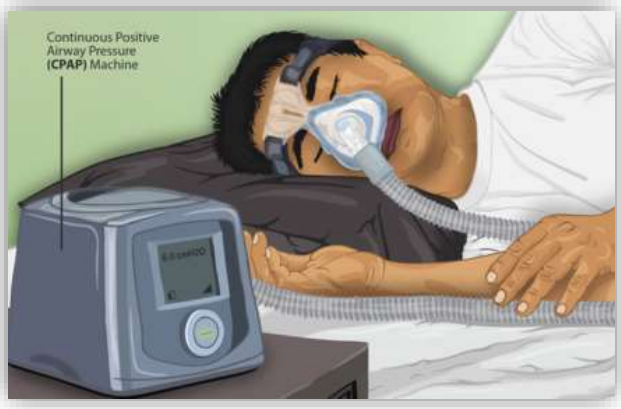
The more the non-REM/REM cycle is fragmented by waking up, or by arousals that move the brain to a lighter stage of sleep without actually waking up, the less restorative value sleep has in terms of how you feel and function the next day.

The Need for Sleep

Factors that affect sleep quality

- Age
  - Proportion of sleep time spent in slow-wave sleep declines with age
  - More fragmented sleep with age

The Need for Sleep



Factors that affect sleep quality

- **Sleep Disorders**
  - The quantity and quality of sleep are disrupted
  - Difficult or impossible to obtain restorative sleep
  - Higher risk for those whose operational requirements often restrict the time available for sleep
  - Fatigue management training should include basic information on sleep disorders and their treatment, where to seek help if needed, and any requirements relating to fitness for duty

The Need for Sleep

Factors that affect sleep quality

- **Environmental Conditions**
  - Environmental factors, including light, noise, temperature and comfort, can disturb sleep.
    - Bright light increases alertness. It is much easier to sleep in a dark room; heavy curtains or a mask can be used to block out light.
    - Noise, such as traffic noise, can be masked or reduced.
    - Falling asleep requires being able to lower core body temperature, so it is easier if the room is cooler rather than hotter.
    - A clean and comfortable sleep surface is also important. Individuals sleeping in a supine position is more restorative than sleeping in an inclined position.

The Need for Sleep

Factors that affect sleep quality

- **Food and Substances**

- Caffeine
  - Found in coffee, tea, energy drinks, colas, chocolate and some over-the-counter medication
  - Stimulates the brain, making it harder to fall asleep and disrupting the quality of sleep.
  - Variable impact on people due to tolerance
- Nicotine
  - Found in cigarettes; stimulant in the same way
- Alcohol
  - Disturbs sleep pattern.
  - When the body is processing alcohol, the brain cannot obtain REM sleep. Pressure for REM sleep builds up with more intense and disturbed REM periods later in the night.

The Need for Sleep

Continuous Wakefulness

- The longer an individual remains awake, the worse his/her alertness and performance become.
- This is due to an **increasing homeostatic pressure for sleep** associated with the longer period of wakefulness.
- **Sleep is the only way to reverse the effects of extended wakefulness**.

US NTSB

- Examined relationship between time since awakening and errors in 37 aircraft accidents (1978 -1990)
- Low homeostatic pressure (~5h) vs high homeostatic pressure (~13h)
- The latter made 40% more errors, primarily errors of omission
- Also made more procedural errors and tactical decision errors

The Need for Sleep

Naps

- Napping is an effective strategy for reducing fatigue
- A short-term mitigation that can be used before and during duty to help maintain performance and alertness
  - Before Duty
  - During Duty: Designated rest facility or controlled rest on flight deck

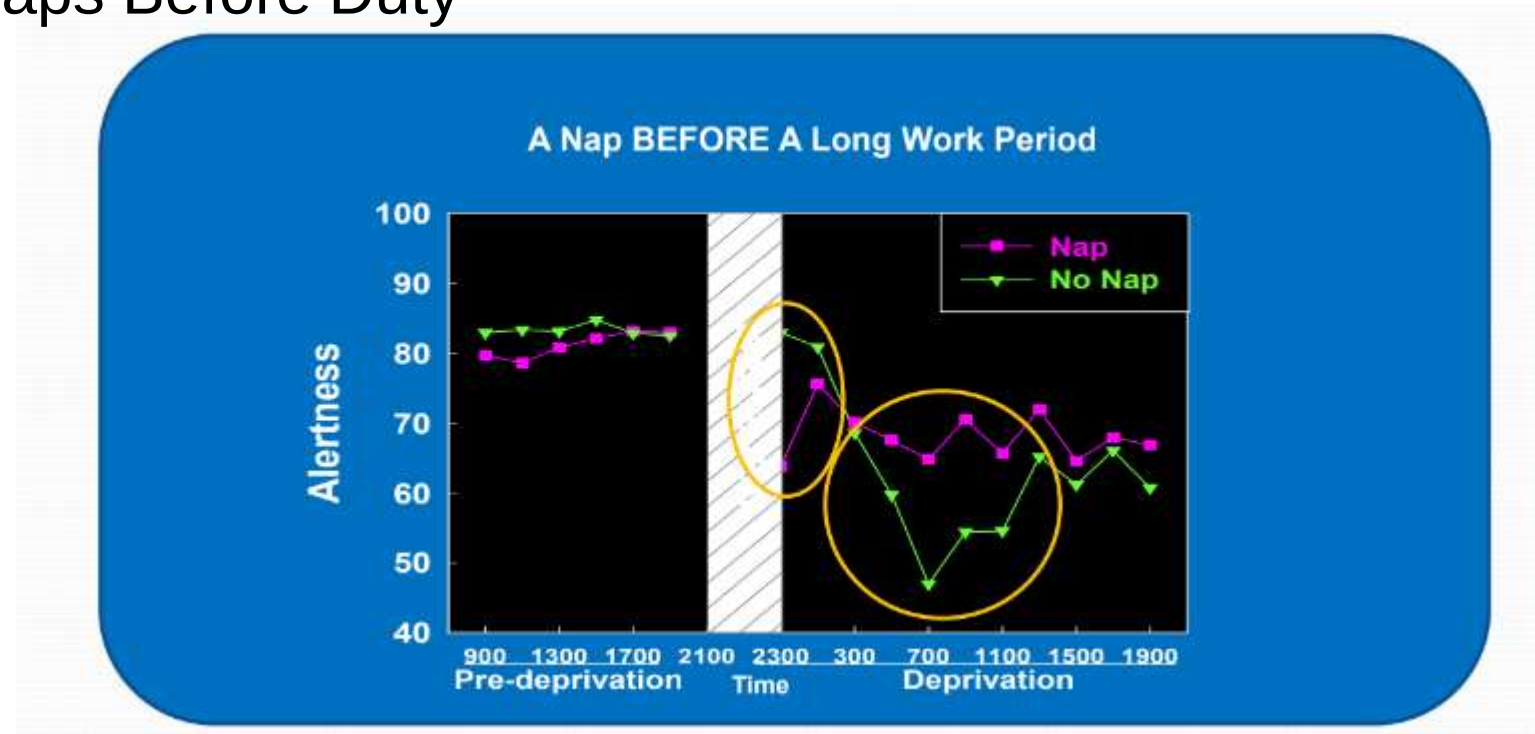
The Need for Sleep

Naps

- Napping is an effective strategy for reducing fatigue
- Optimize napping conditions as much as possible (cut out noise and light, reduce temperature)
- The length of the time given to nap will depend largely on the time of day and the available time away from duties, which may be difficult to control.
- Ideally, the nap period should allow enough time for individuals to fall asleep (it may take people longer than usual to fall asleep in these circumstances) and enough time after waking before recommencing duties to ensure that any sleep inertia has dissipated
- Note that napping should not be used as a means of extending a duty period because in order to completely recover from fatigue, one or more complete sleep periods are required

The Need for Sleep

Naps Before Duty



Caldwell JA, Caldwell JL. (1998). Comparison of the effects of zolpidem-induced prophylactic naps to placebo naps and forced-rest periods in prolonged work schedules. Sleep, 21:79-90.

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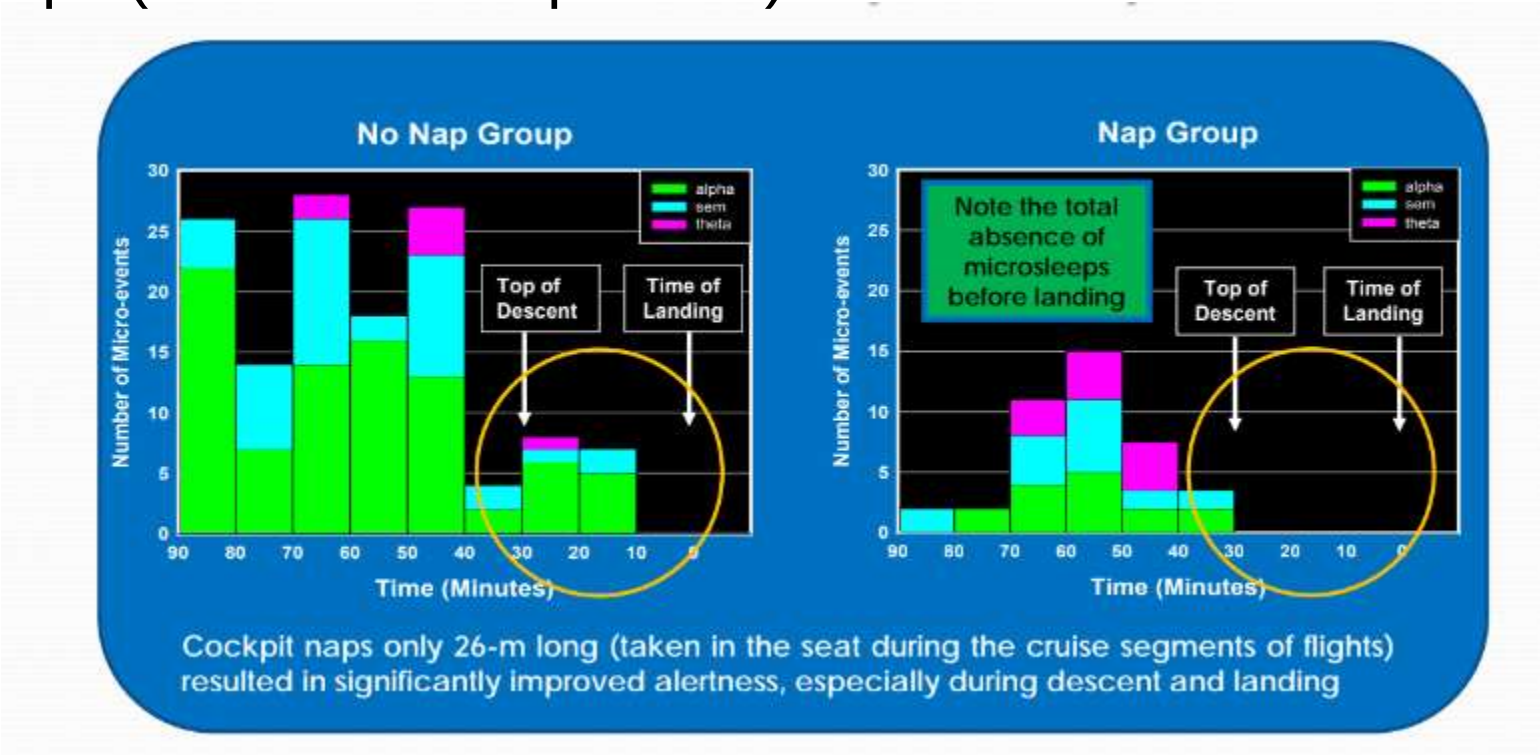
The Need for Sleep

Naps (Planned Cockpit Rest)



Rosekind MR et al. (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.

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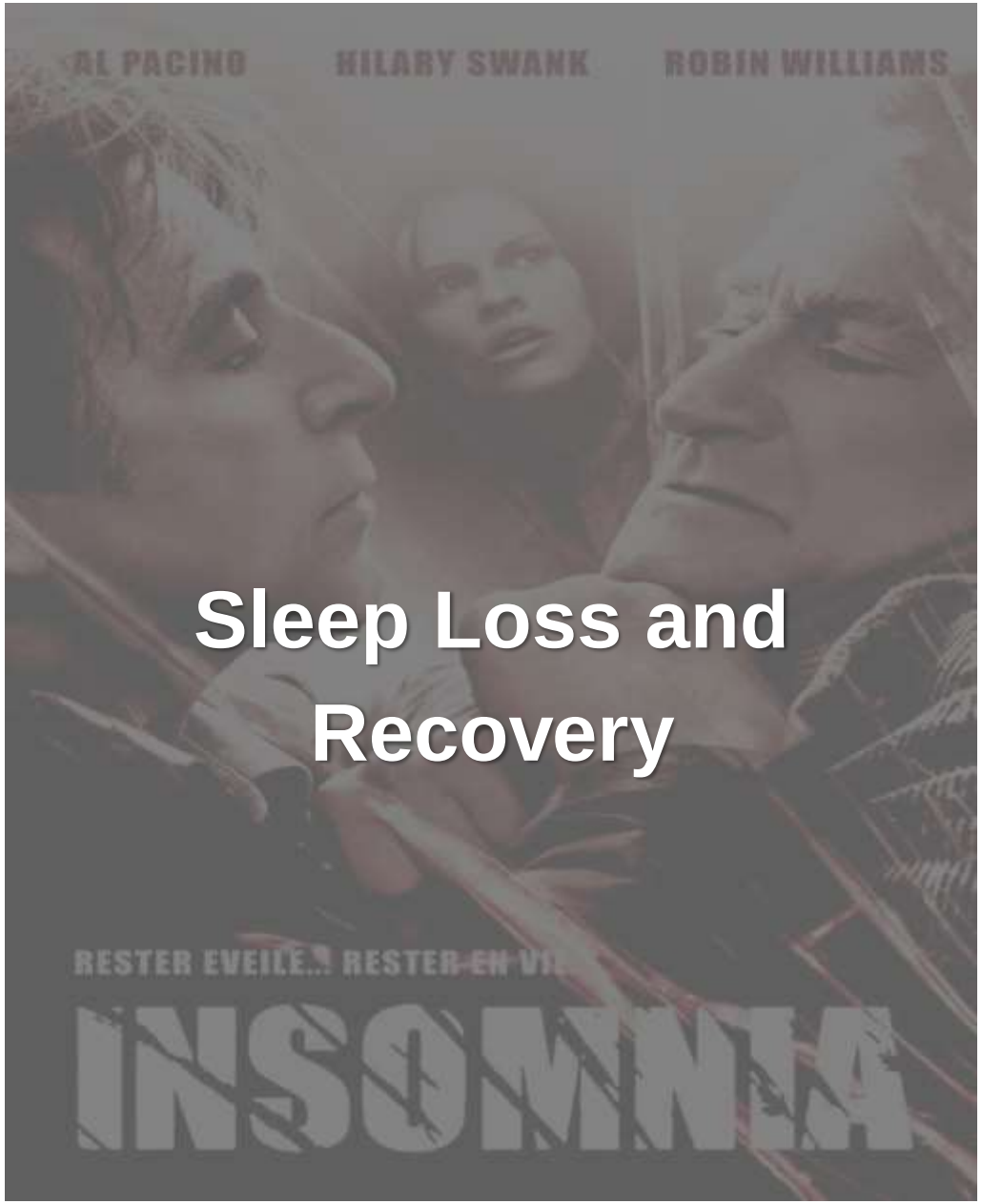
The Need for Sleep

Sleep Inertia

- Physiological state of impaired cognition and performance present immediately after awakening (especially executive functions)
- Persists during the transition of sleep to wakefulness
- Usually lasts 15-30 minutes for most people
- Important to note that sleep inertia is worse when awakening from
  - Deep sleep
  - Circadian trough
  - Sleep taken after sleep deprivation
- If controlled rest in flight is allowed, strict protocols should be in place to mitigate the risks of sleep inertia

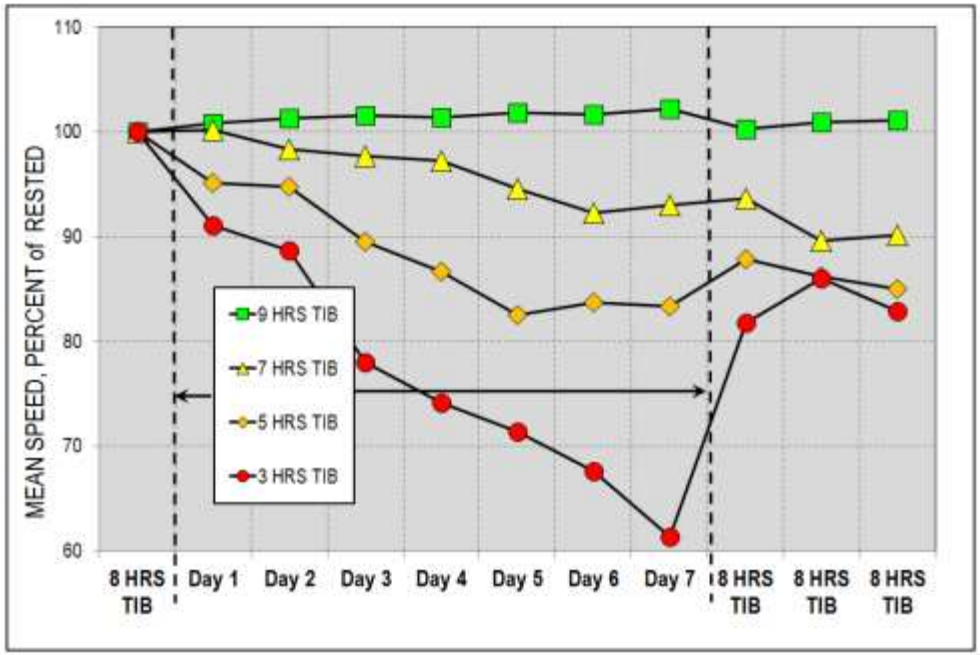


Sleep Loss and Recovery

Sleep Loss and Recovery

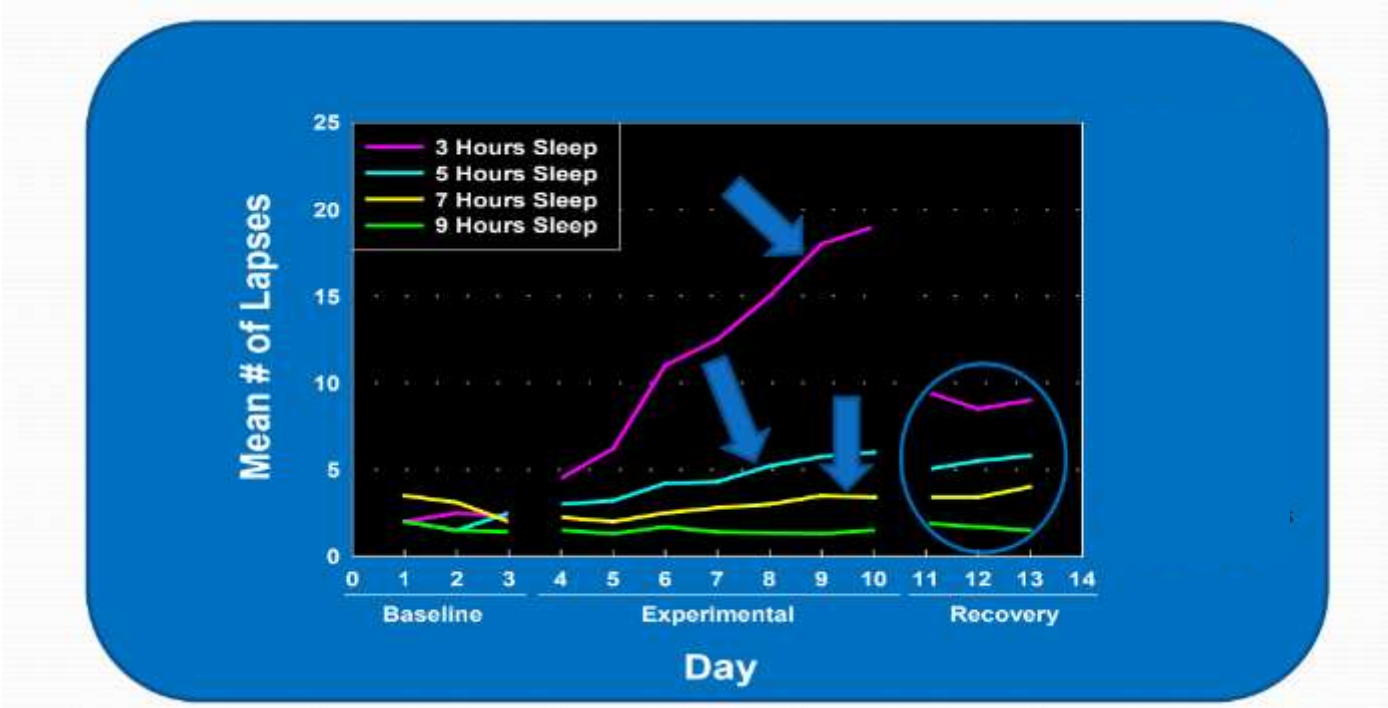
Sleep Loss and Performance

- The effects of restricting sleep night after night accumulate and performance progressively declines each day
- This is sometimes described as accumulating a **sleep debt**



Sleep Loss and Recovery

Sleep Loss and Performance



Johnson ML et al. (2004). Modulating the homeostatic process to predict performance during chronic sleep restriction. Aviation, Space and Environmental Medicine, 75(3 Suppl):A141-6.

Sleep Loss and Recovery

Sleep Loss and Performance

- Insufficient sleep impacts many aspects cognitive functioning
  - Studies show that the largest impact is on processing speed and attention

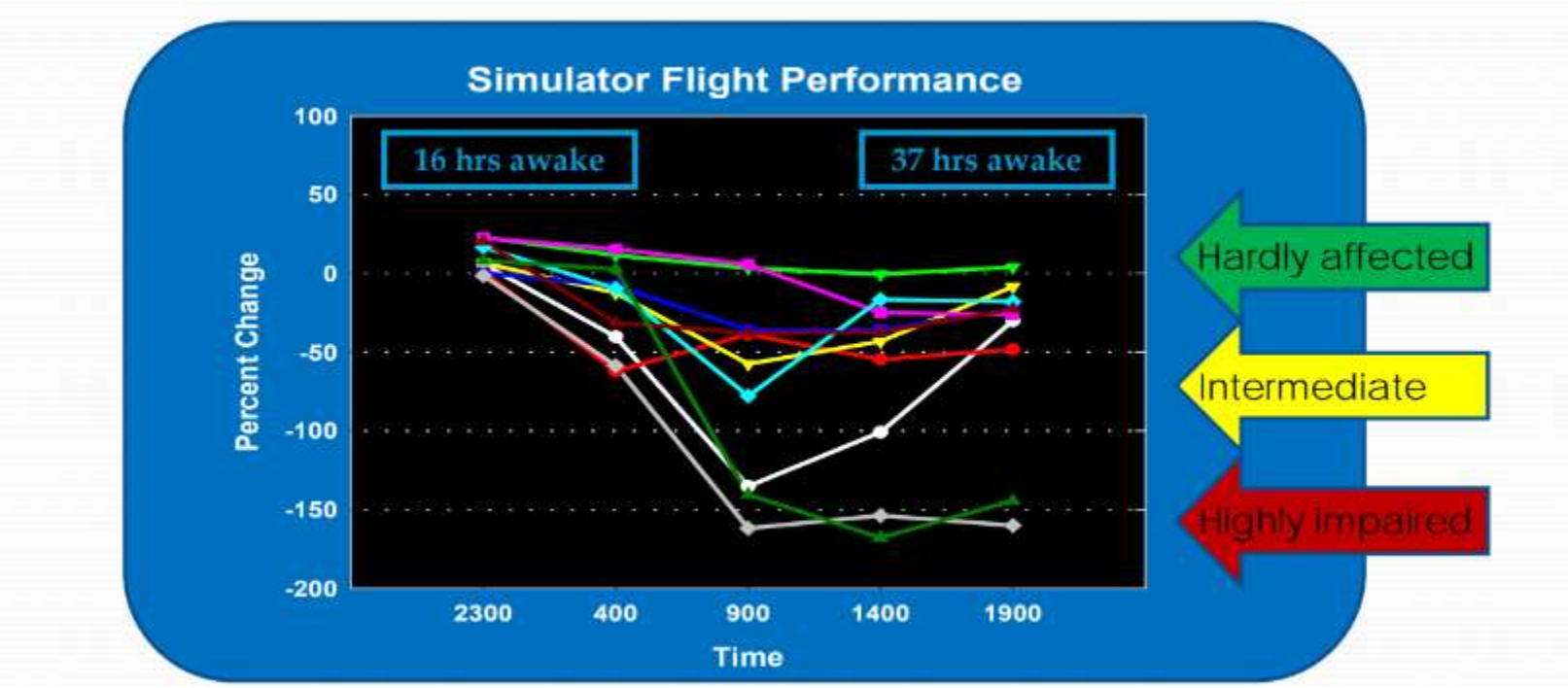
- Brain imaging studies suggest that the brain regions involved in more complex mental tasks are most affected
  - Anticipating events
  - Planning and determining relevant courses of action particularly under novel situations

- Studies assessing complex cognitive tasks do show changes as well (variable)
  - Short-term memory
  - Mental arithmetic
  - Executive functions
  - Language

Sleep Loss and Recovery

Sleep Loss and Variability of Performance

- Varying susceptibility

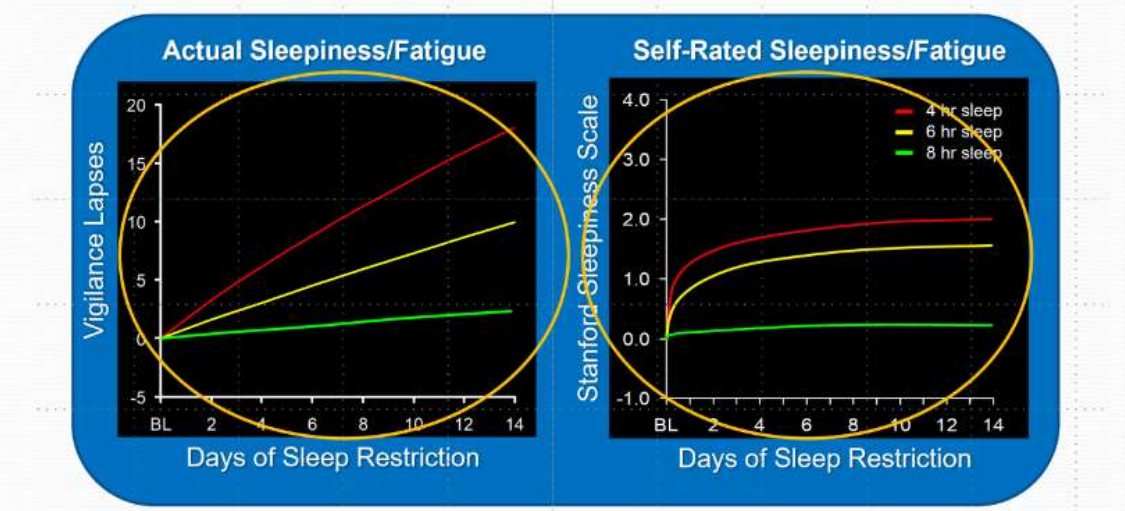


Caldwell JA et al. (2005). Are individual differences in fatigue vulnerability related to baseline differences in cortical activation? Behavioural Neuroscience, 119:694-707.

Sleep Loss and Recovery

Self-assessment of Fatigue

- People are **not very accurate** at judging their alertness and performance when fatigued
- People are aware of fatigue when first subjected to sleep restriction
- As sleep restriction continues, people become increasingly unreliable at assessing their own functional status



Van Dongen HPA et al. (2003). The cumulative cost of additional wakefulness: Dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. Sleep, 26:117-126.

Sleep Loss and Recovery

Microsleeps

- When sleep debt becomes overwhelming, people begin falling asleep uncontrollably for brief periods, known as **micro-sleeps**
- During a micro-sleep, the brain disengages from the environment
- More likely occurs during routine/mundane activities

Sleep Loss and Recovery

Sleep Recovery

- Prolonged sleep restriction may have effects on the brain that can continue to affect alertness and performance days to weeks later

- Lost sleep is not recovered hour-for-hour; recovery sleep may be slightly longer than normal sleep at night.

- **At least two consecutive nights of unrestricted sleep** are required for the non-REM/REM sleep cycle to return to normal
  - 1st night of recovery: slow wave sleep recovery
  - 2nd night of recovery: REM sleep recovery

- This does not equate to 48 hours off duty. A 48-hour break starting at midnight will not allow most people two consecutive nights of unrestricted sleep (most people go to sleep before midnight).

- Conversely, a 40-hour break starting at 20:00 will allow most people two consecutive nights of unrestricted sleep.

Sleep Loss and Recovery

Sleep Recovery

- Recovery of a normal non-REM/REM cycle may take longer if recovery sleep is not at night, or if the individual is not adapted to the local time zone.

- If sleep restriction continues over multiple nights, then the recovery of waking alertness and performance will normally require more than two consecutive nights of unrestricted sleep.

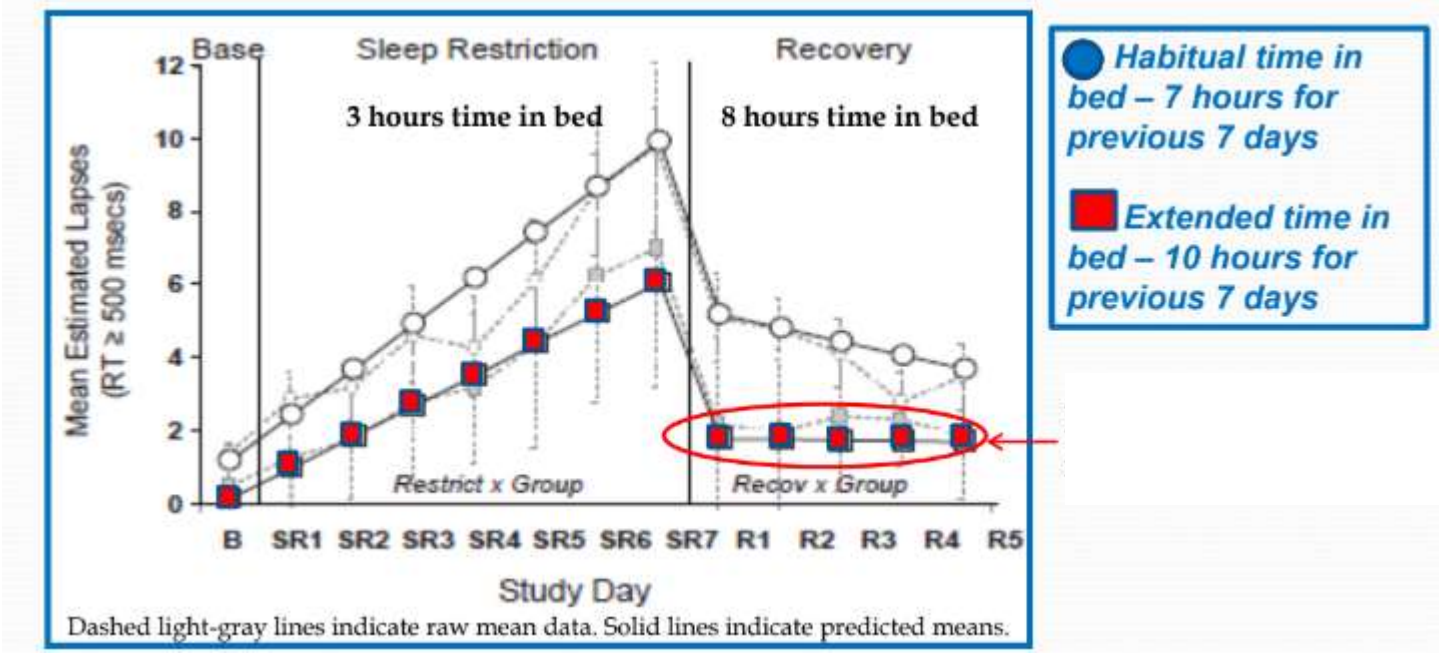
The earlier study showed that three 8-hour sleep opportunities at night are not enough to recover from 7 nights of sleep restricted to 7 hours per night.

Another study showed that extending sleep to 10-hours for one night is not enough to recover from the cumulative effects of 5 nights of sleep restricted to 4 hours per night.

- Longer periods of time off, such as blocks of annual leave, may be important for full recovery.

Sleep Loss and Recovery

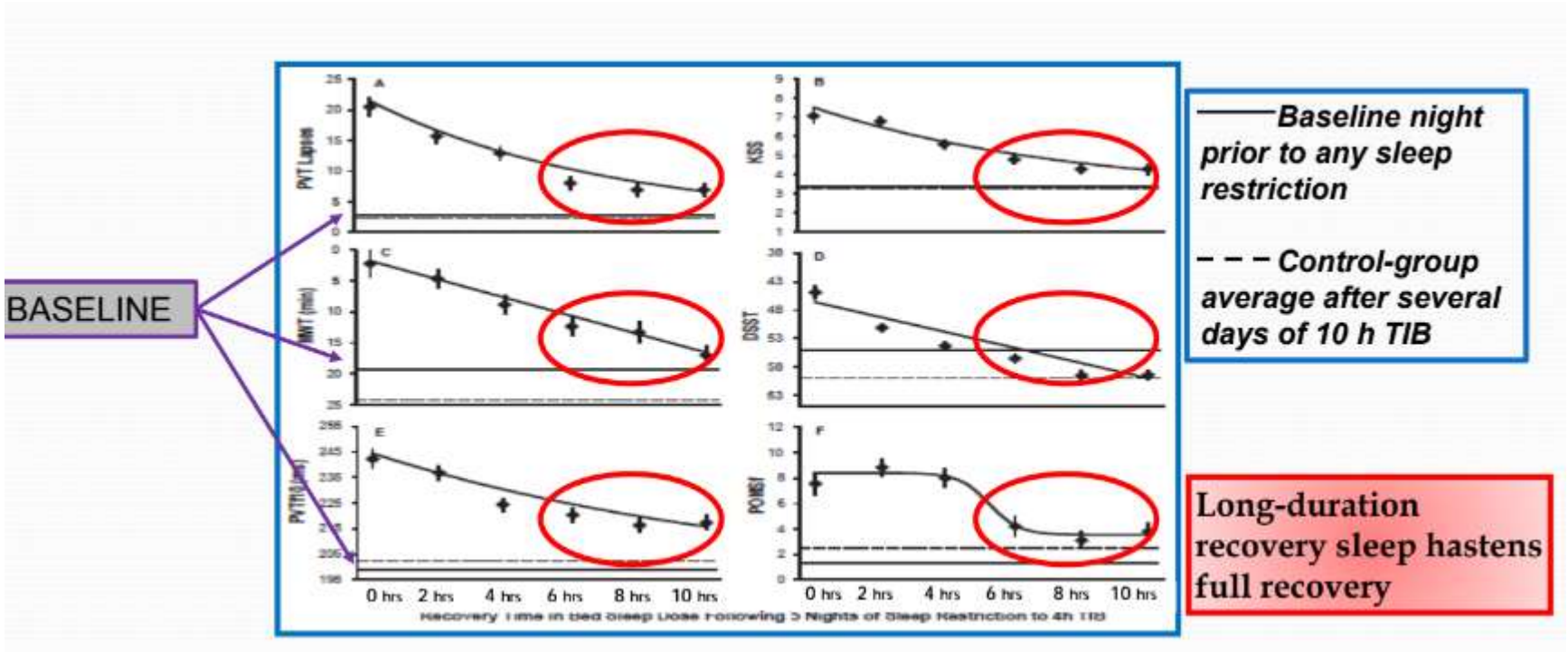
Pre-load



Dashed light-gray lines indicate raw mean data. Solid lines indicate predicted means.

Sleep Loss and Recovery

Sleep Extension



Banks S et al. (2010). Neurobehavioral dynamics following chronic sleep restriction: Dose-response effects of one night for recovery. Sleep, 33(8):1013-1026.

Sleep Loss and Recovery

Split Sleep

- Longer duration for sleep recovery is often studied and recommended, but may not always be possible in airline operations.
- The value of split sleep has been studied and it suggests that having a restricted sleep period at night plus a daytime nap has **equivalent recovery value** to an identical total amount of sleep taken in one consolidated block at night.
- One key advantage is that it reduces the length of time that an individual is continuously awake.

Sleep can also be preloaded. If one has an opportunity to sleep for sleep recovery, just proceed to sleep. Sleep as long as possible. Any sleep is better than no sleep for recovery.

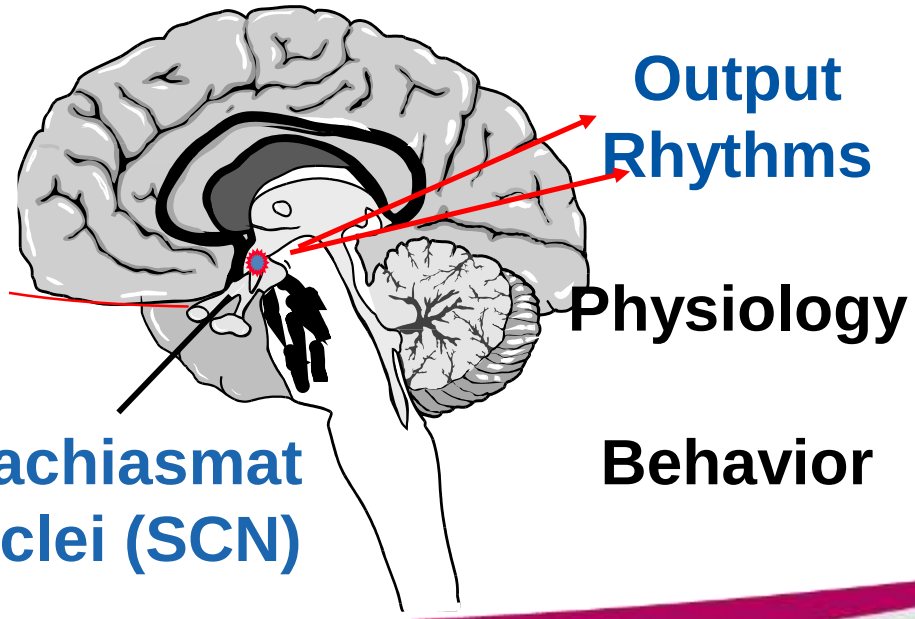

Circadian effects on
sleep and performance

Circadian Effects

Circadian Rhythm

- As mammals, humans have a circadian master clock located in a small cluster of cells (neurons) deep in the brain.

- The cells that make up the master clock are intrinsically rhythmic, generating electrical signals faster during the day than during the night.

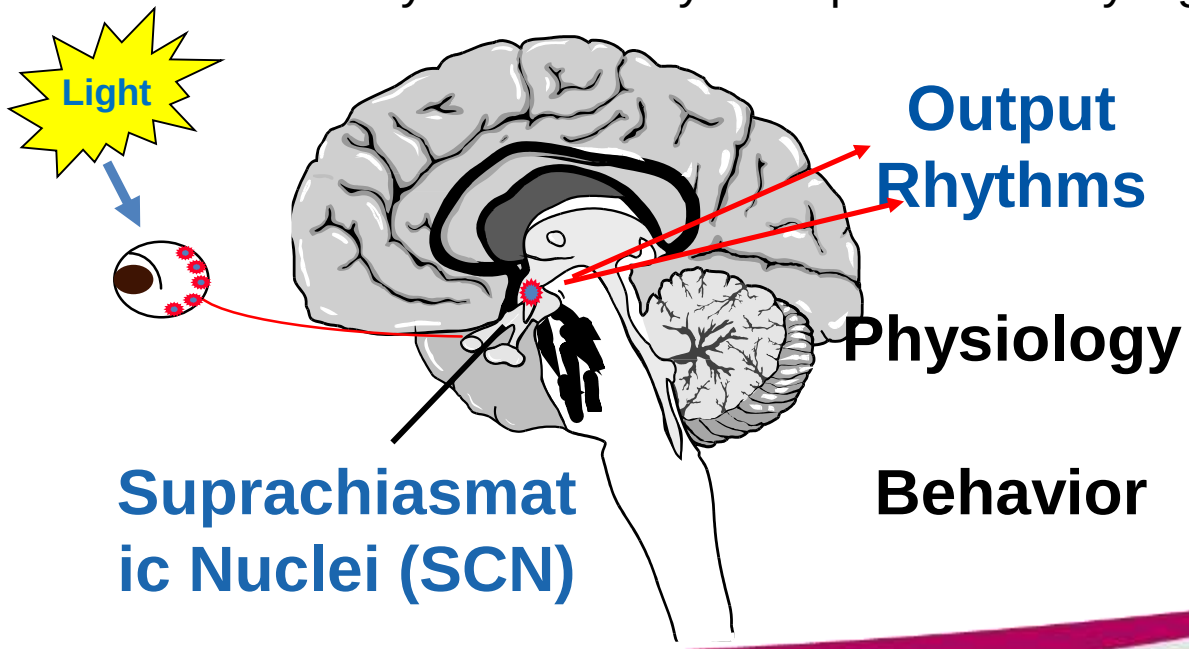


Circadian Effects

Circadian Rhythm

- The overall cycle for most people generated by the master clock is slightly longer than 24 hours.

- This master clock receives (light) through the retinal ganglion cells, and enables the circadian body clock to stay in step with the day/night cycle.



Circadian Effects

Circadian Rhythm

- The circadian body clock is one of two key processes that regulate sleep timing and quality (the other is the sleep homeostatic process).

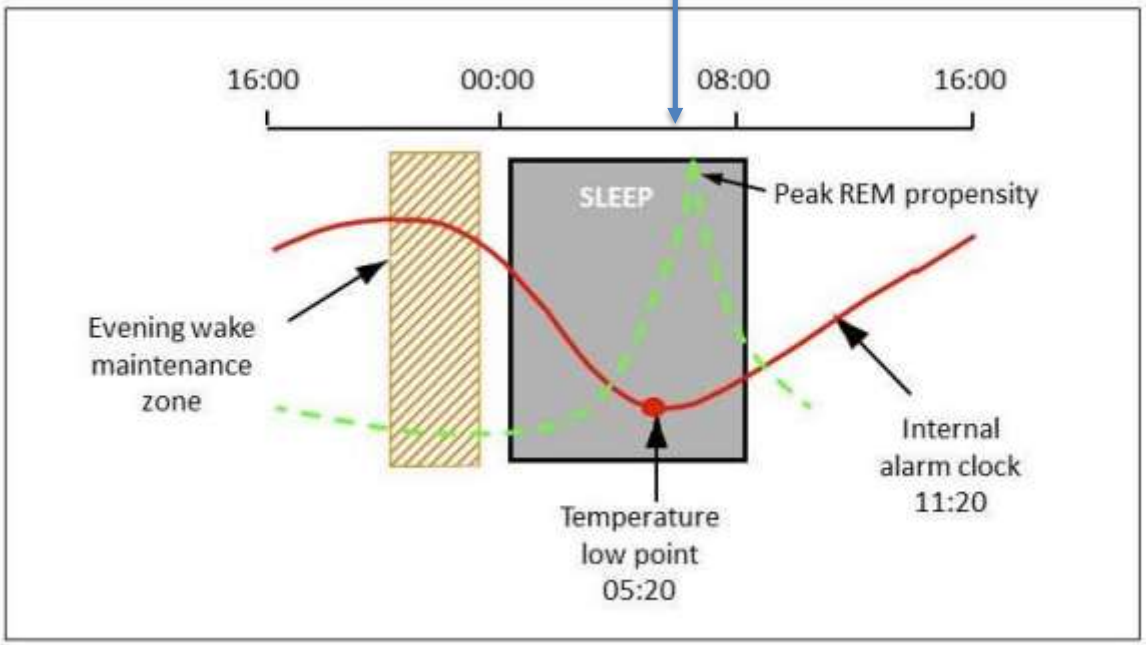
- The circadian body clock has connections to sleep-promoting and wake-promoting centres in the brain, which it modulates to control the sleep/wake cycle.

- It also influences the timing and amount of REM sleep.

Circadian Effects

The Window of Circadian Low (WOCL)

Circadian Rhythm



The circadian clock exerts strong influence over sleep, creating windows when sleep is promoted and windows when sleep is opposed.

Circadian Effects

Homeostatic Pressure

- The need for sleep builds up while you are awake and the only way to discharge this pressure is to sleep.
- This homeostatic process can be tracked by the amount of slow-wave sleep. Across time awake, the pressure for slow-wave sleep builds up.
- The longer you are awake, the more slow-wave sleep you will have in the first few non-REM/REM cycles when you next sleep.
- Across sleep, the amount of slow-wave decreases in each subsequent non-REM/REM cycle.

Circadian Effects

Two Peaks of Sleepiness

- The circadian body clock and the sleep homeostatic process interact to produce two times of peak sleepiness in 24 hours.
  - Sleepiness is greatest when people are awake during the WOCL, which occurs around 03:00 to 05:00 for most people on a normal routine with sleep at night.
  - Sleepiness increases again in the early afternoon - sometimes called the afternoon nap window (around 15:00 to 17:00 for most people).
  - Restricted or disturbed sleep at night makes it harder to stay awake during the next afternoon nap window.
  - “Evening types” vs “Morning types”

Circadian Effects

Effects of Light

- In general, light in the morning shortens the circadian body clock cycle and light in the evening lengthens the body clock cycle.
- Getting exposed to light in the morning allows the body clock to shorten its cycle, allowing it to “lock on” to a 24 hour cycle
- Getting exposure to light in the evening lengthens the cycle, and nudges the body clock cycle to phase shift.
- Exercise can also have the same effect

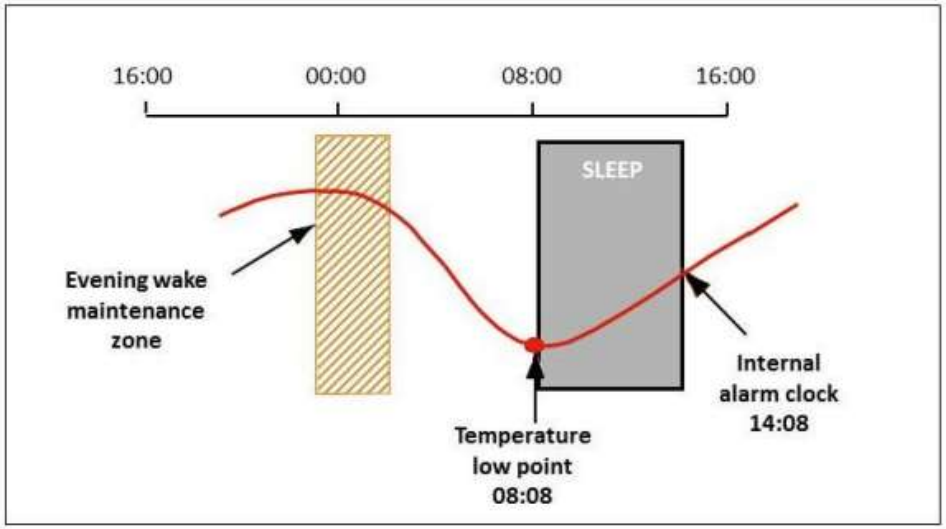
When adapting to a new time zone, advice is always to get exposure to sunlight in the day.

Circadian Effects

Shift Work

- Defined as any duty pattern that requires a crew member to be awake during the time in the circadian body clock cycle when they would normally be asleep

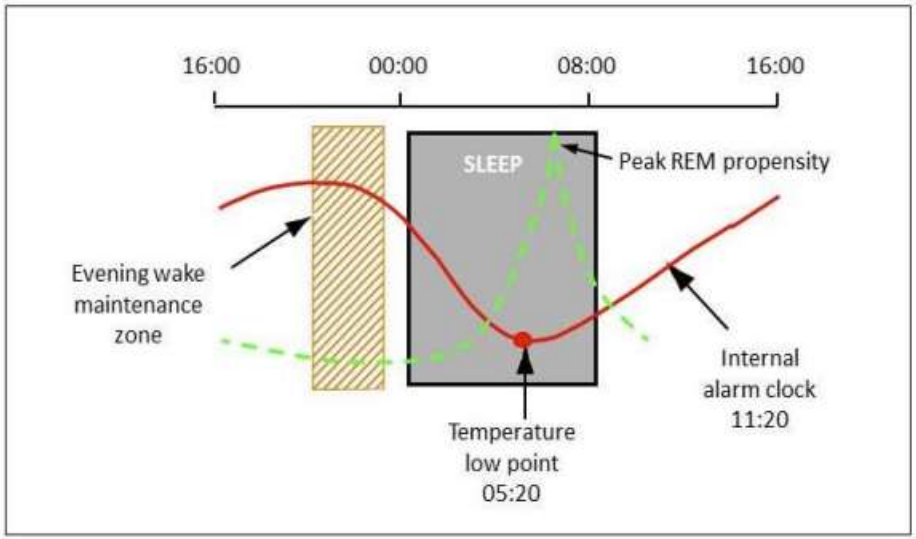
- The further sleep is displaced from the optimum part of the circadian body clock cycle, the more difficult it becomes to get adequate sleep



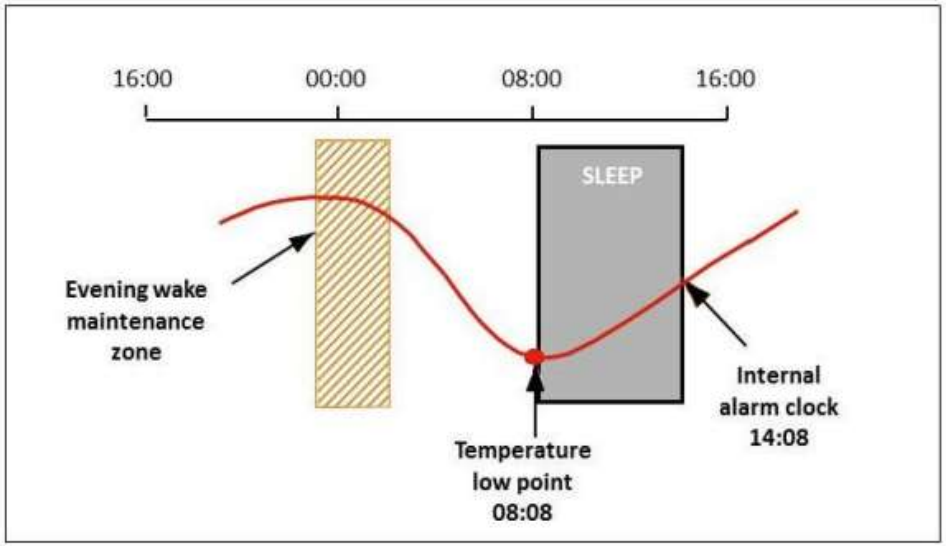
Circadian Effects

Shift Work

Off Day



Night Shift



Circadian Effects

Jet Lag

- Flying across time zones exposes the circadian body clock to sudden shifts in the day/night cycle.
- Because of its sensitivity to light and (to a lesser extent) social time cues, the circadian body clock will eventually adapt to a new time zone.
- Common symptoms include wanting to eat and sleep at times that are out of step with the local routine, problems with digestion, degraded performance on mental and physical tasks, and mood changes.
- Adjusting to the change takes a while
  - Going east, readjustment takes 1.5 days/time zone
  - Going west, readjustment takes 1.0 days/time zone

Circadian Effects

Jet Lag

- Studies have shown the following about jet lag and adaptation:
  - Adaptation generally takes longer when more time zones are crossed.
  - Adaptation is usually faster after westward travel (phase delay) than after eastward travel (phase advance) across the same number of time zones. The fact that the innate cycle of the circadian body clock is slightly longer than 24 hours (for most people) probably contributes to this. It is easier to lengthen the cycle to adapt to a westward shift.
  - After eastward flights across 6 or more time zones, the circadian body clock may adapt by shifting in the opposite direction, for example shifting 18 time zones west rather than 6 time zones east. When this happens some rhythms shift eastward and others westward (known as resynchronization by partition).

Circadian Effects

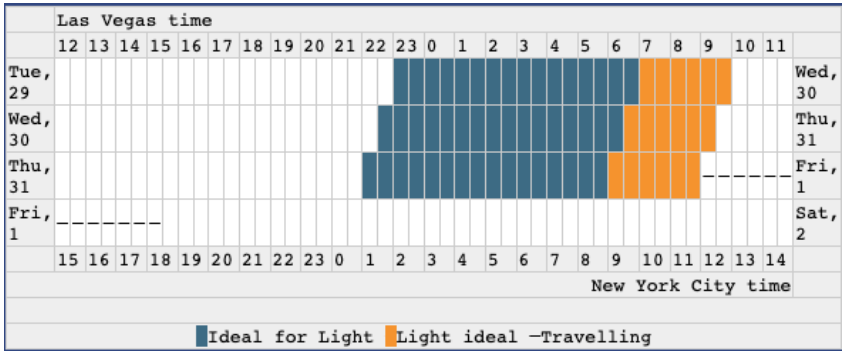
Jet Lag

- Rhythms in different functions can adapt at different rates, depending on how strongly they are influenced by the circadian body clock. Thus, during adaptation, rhythms in different body functions can be out of step with each other, as well as out of step with the day/night cycle.
- Adaptation is faster when the circadian body clock is more exposed to local time cues, including outdoor light, and exercising and eating on local time.
- Beginning a trip with a sleep debt increases the duration and severity of jet lag symptoms.

Circadian Effects

Jet Lag Management

- Use a biomathematical model to predict the worst times at your destination
- Purchase and use a jet-lag app for your smartphone (eg. Timeshifter)
- Use online Jet Lag Rooster by Sleepopolis or the British Airways jet-lag calculator



TIMESHIFTER

Circadian Effects

Jet Lag Management

- Blue-blocking glasses to avoid light at the wrong times
- Blue-enriched artificial light to add light at the right times

- Engage in exercise at some point between 1600H -1900H destination time
- Use a stimulant (caffeine) to promote on-duty alertness

- Use a sleep medication to promote off-duty sleep
- Promote good sleep hygiene for sleeping


The Influence of
Workload

Workload

Aspects to Consider

- Nature and amount of work to be done (including physical and mental demands; and task complexity and intensity)
- Time constraints (including the duration of the tasks; and whether timing is driven by task demands, external factors, or by the individual)
- Factors relating to the performance capacity of an individual (for example experience, skill level, effort, sleep history, and circadian phase)

Workload

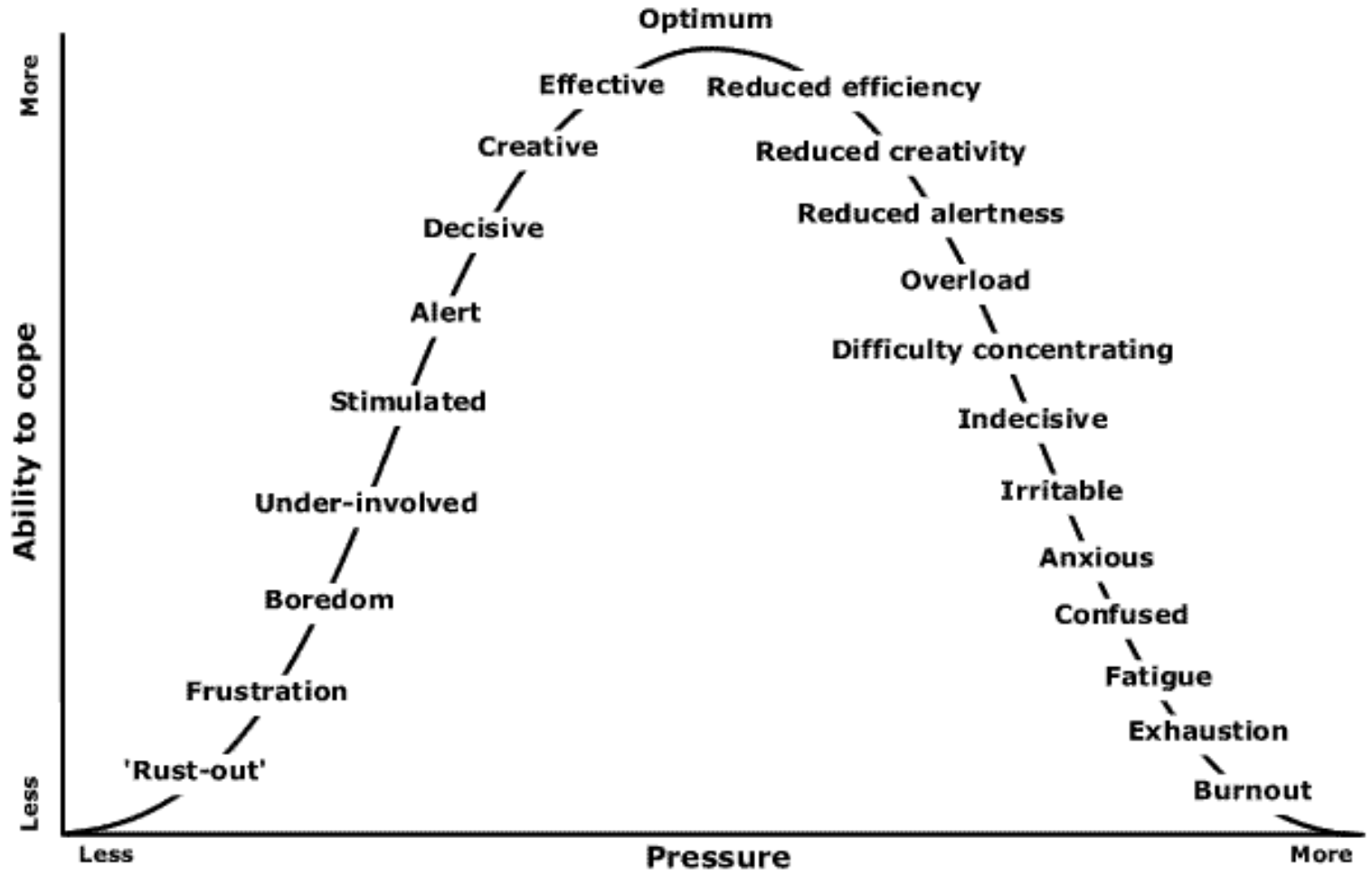
Aspects to Consider

- For each type of operation, the factors contributing to workload and the consequences of workload need to be considered.

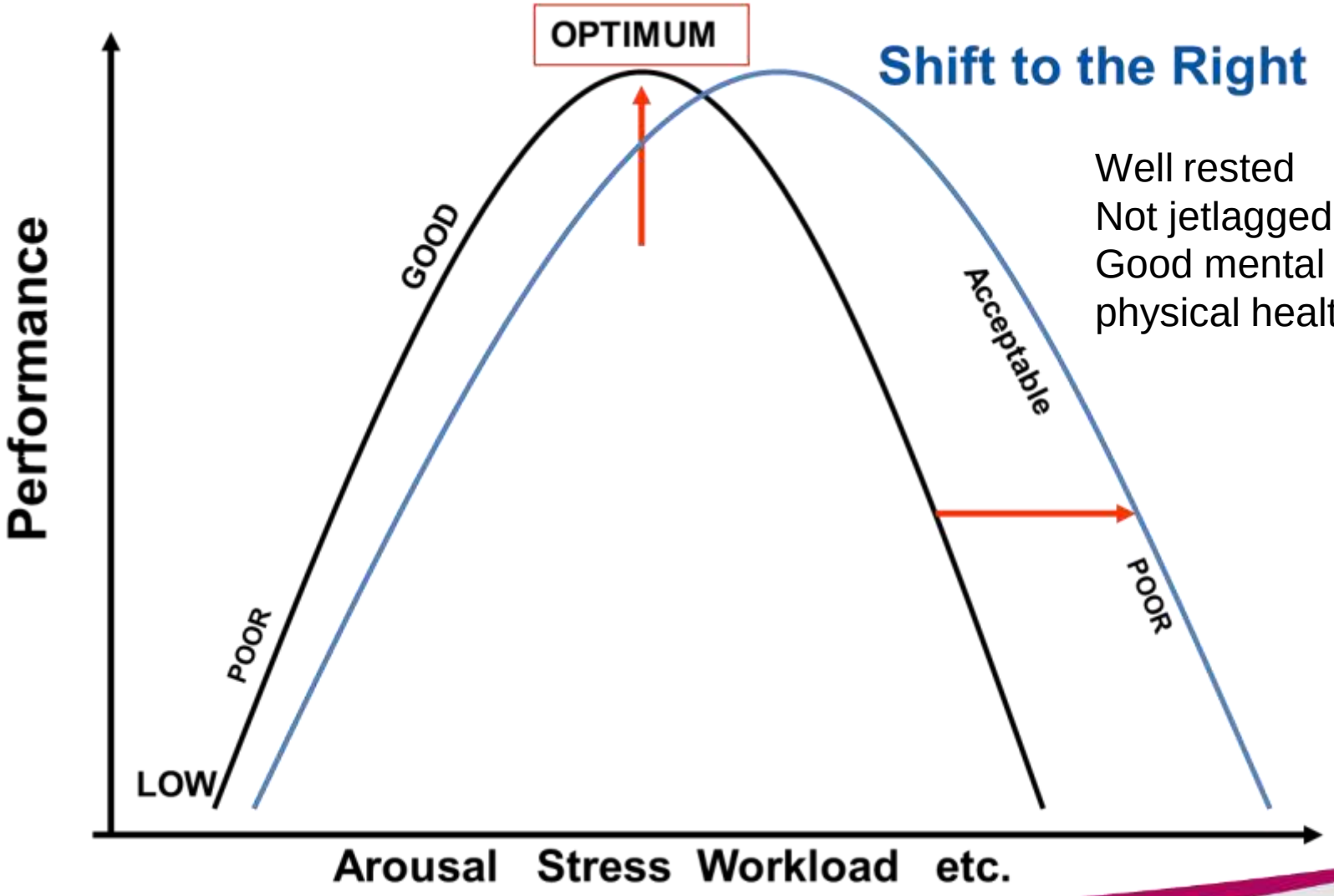


Workload can contribute to an individual's level of fatigue.
Low workload may unmask fatigue, leading to microsleeps.
High workload may exceed the capacity of a fatigued individual.

Workload

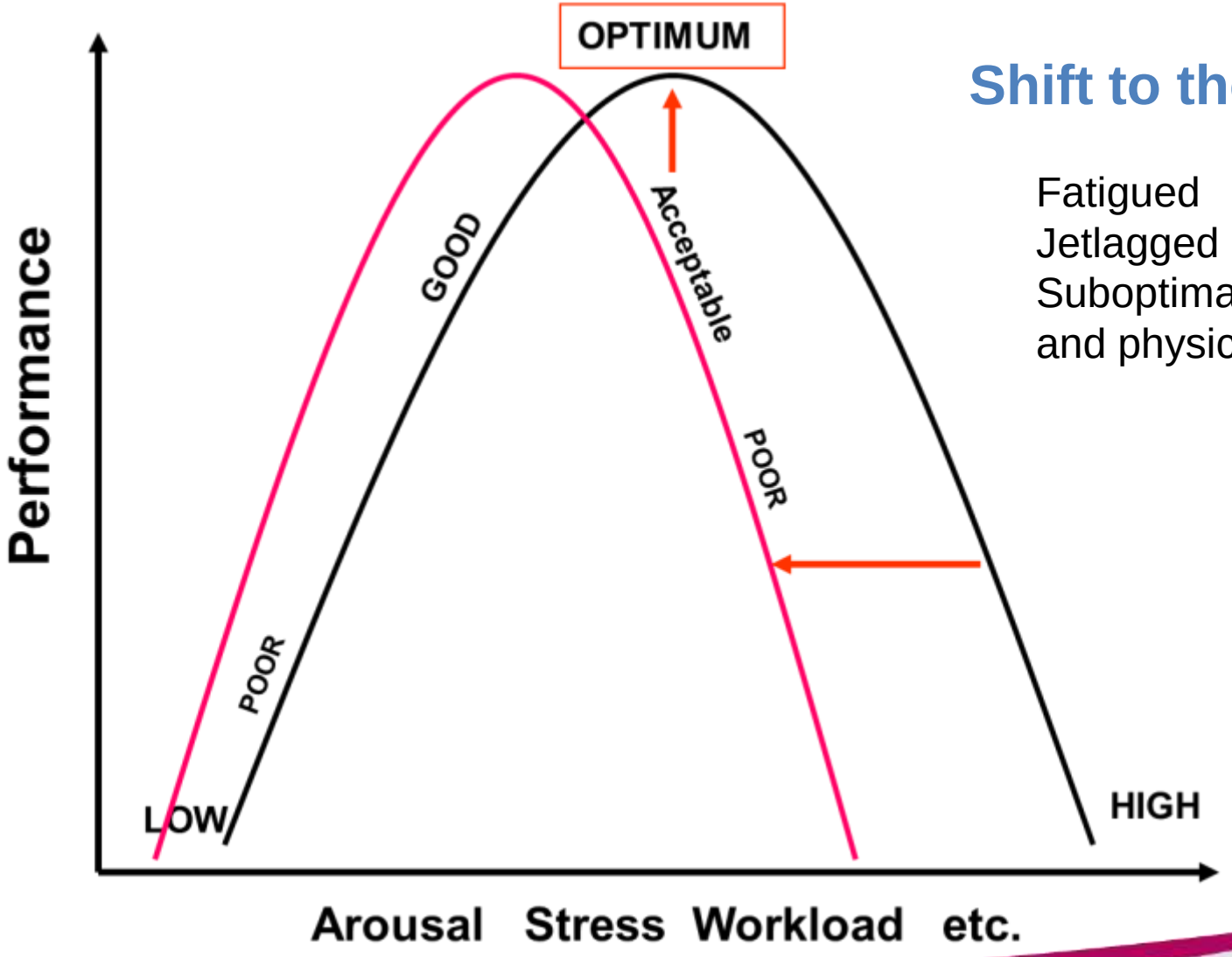

Optimum
Effective
Reduced efficiency
Creative
Reduced creativity
Decisive
Reduced alertness
Alert
Overload
Stimulated
Difficulty concentrating
Under-involved
Indecisive
Boredom
Irritable
Frustration
Anxious
'Rust-out'
Confused
Fatigue
Exhaustion
Burnout
Ability to cope
More
Less
Less
Pressure
More

Workload



Well rested
Not jetlagged
Good mental and physical health

Workload



Shift to the Left

Fatigued
Jetlagged
Suboptimal mental and physical health

Workload

Sources of Workload and Stress

- Time on task

- Air Traffic
- Ground Traffic
- Bad Weather

- Security Checks
- Customs and Immigration Checks
- Equipment Problems

- Fatigue
- Jetlag
- Shiftwork
- Social / Family

- Hypoxia
- Noise and Vibration
- Temperature Changes
- Low Relative Humidity
- Cockpit disharmony
- Communications (Noise)
- Disruptive Passengers / Emergencies

- Difficulty winding down

Workload

Factors Affecting Workload and Stress

- Number of crew (Flight & Cabin)
- Task and type of task
- Composition of crew
- Status of circadian acclimatization
- Current flight and duty duration
- Previous flight and duty duration
- Time of departure
- Opportunity for pre-flight rest/sleep
- Opportunity for in-flight rest/sleep
- Post-flight recovery and sleep

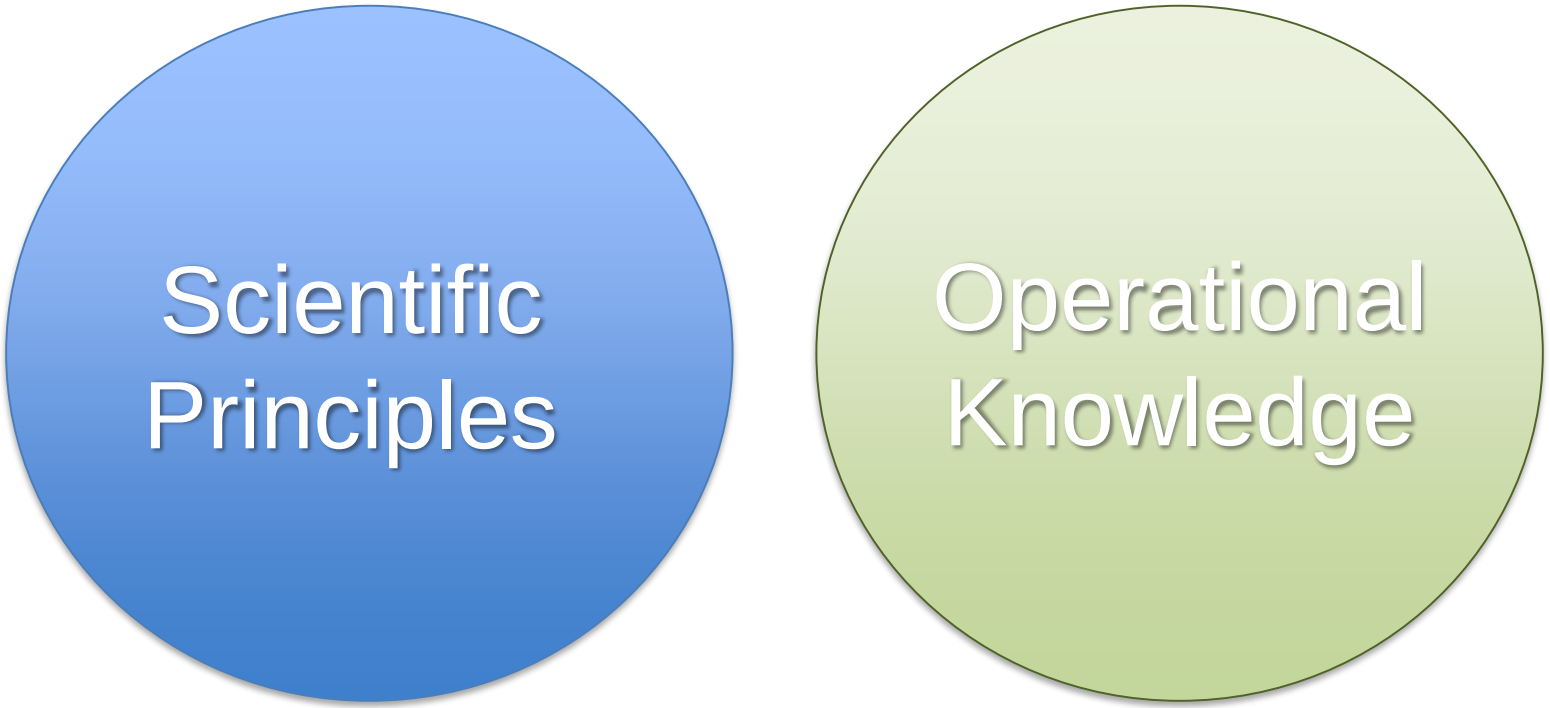
Rules and Regulations

Roster

Fatigue Management Approaches

CAAS

Fatigue Management Approaches



Fatigue Management Approaches

- Fatigue management refers to the methods by which service providers and operational personnel address the safety implications of fatigue.

Fatigue Management Approaches

- In general, ICAO Standards and Recommended Practices (SARPs) in various Annexes support two distinct methods for managing fatigue:
  - Prescriptive
  - Fatigue Risk Management System (FRMS)
- Important to know the various stakeholders in a fatigue management approach
  - State / Regulator
  - Service Provider / Operator
  - Individuals

Fatigue Management Approaches

State

- States' understanding of the context within which the service provider operate is crucial, in addition to understanding the basic principles of sleep science
  - Pressures on the service provider (cost, operations)
  - Prevailing organizational culture (safety)
  - Behaviors and customs of the workforce.

- States should recognize that the influence of organizational context will differ depending on the service provided (e.g. flight operations, air traffic services)

Fatigue Management Approaches

Factor	
Legal framework	• The ability to maintain the integrity of the safety reporting system and reporter confidentiality • The legal consequences of reporting different types of fatigue hazards
Commercial pressures	• Organizational mergers bringing together different labour agreements and different attitudes to fatigue management responsibilities • Bankruptcy and receivership
Staffing arrangements	• The ability to offer adequate recovery opportunities to avoid cumulative fatigue • Career stability • Changing employment arrangements (e.g. use of contractors and contractual obligations and constraints) • Sufficient staff to cover sickness and other absences • Sufficient staff to cover the specific operational demands
Staff demographics	• Age • Gender • Educational levels • Cultural background • Health standards
Acceptance of shared responsibilities for fatigue management	• Design of schedules to manage fatigue or for maximum time at work only • Development of fatigue management policies • Ability to detect hazards and assess fatigue risk • An operational person's ability to be removed from their safety relevant task if they consider themselves to be a safety risk
Fatigue management structure	• Fatigue is managed consistently using standard processes across the organization
Geographical location	• Topography • Remoteness • Weather • Time spent in commuting
Level of isolation of aviation professional during a duty period	• Pressures (commercial and personal) to complete the "mission" • Geographic separation from the support team - immediate support and supervision is not always readily available
Work conditions	• The quality of rest facilities and policies for their use • Standard of layover accommodation • Level of automation • Level of authority and responsibility • Availability of support staff • Environmental factors (noise, temperature, lighting) • Availability of food and water

Factor (continued)	
Irregular operations	• Frequency of the need to use discretionary extensions to prescribed limits • Frequency of disruption to schedules and the assignment of unscheduled duties
Workload	• Airport traffic density • Task intensity
Interactions with other aviation professionals	• Use of standard phraseology • The need to communicate in multiple languages
Experience levels	• Similar operational demands can result in higher workload levels for inexperienced aviation professionals than for experienced aviation professionals • Experienced aviation professionals may need to support and oversee inexperienced personnel, adding to their workload
Lifestyle influences	• Social opportunities • Cultural differences

Fatigue Management Approaches

Concept of Shared Responsibility

- Effective fatigue management in the workplace requires recognition of the shared responsibility between the service provider and the individual, even though the means by which these responsibilities are met may differ according to the fatigue management approach used.

- Aspects of the organizational context will influence how individuals discharge their fatigue management responsibilities. The service provider should be able to demonstrate to the State how well that shared responsibility is understood and implemented.

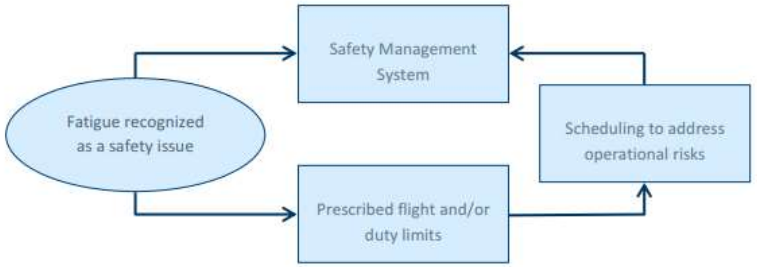
Fatigue Management Approaches

- The service provider is responsible for providing:
  - Adequate **resourcing** for fatigue management
  - Working environment that has appropriate emphasis on **controls and/or mitigations** for fatigue-related risk
  - Robust **fatigue reporting** mechanisms
  - Evidence of **appropriate responses** to fatigue reports
  - **Schedules** that enable fatigue on duty to be maintained at an acceptable level, as well as providing adequate opportunities for rest and sleep
  - **Training** for all organizational stakeholders on how the organization's fatigue management approach works and how individuals can better manage their own fatigue.

- Individuals are responsible for:
  - Making optimum use of non-work periods to get **adequate sleep**
  - Coming to work **fit for duty**
  - Using personal **fatigue mitigation strategies** while on duty
  - **Reporting fatigue** issues
  - Responsible use of individual authority (e.g. pilot in command discretion)

Prescriptive Approach

- The service provider schedules rosters within prescribed limits, according to their specific context and to the risks that generate fatigue within their operation.
- The effectiveness of scheduling practices is then monitored as part of their SMS.
- Through their oversight practices, the State ensures that the service provider is managing their fatigue risk to an acceptable level within the constraints of the prescriptive limitations and requirements using existing SMS processes.
- As fatigue is an issue that will affect safety within an organization, a service provider's SMS should include fatigue of safety critical workers as a hazard regardless of whether that group of workers is governed by prescriptive regulations.



Prescriptive Approach

Factors to Consider when Prescribing Limits

- Adequate sleep opportunities prior to duty periods
- Limit the duration of work periods and identify minima for non-work periods to allow for adequate recovery
- Limit consecutive and total work periods over defined periods of time, in order to prevent cumulative fatigue
- Consider the impact of commencing duties at different times of the day
- Consider the number and direction of time zone changes experienced (where relevant)
- Consider the impact of undertaking duties within a WOCL
- Consider whether the duty is being undertaken by a single operational person or a team
- Consider the impact of workload during the work period
- Avoid extended periods of being awake when assigning unscheduled duties (e.g. standby)

Prescriptive Approach

Prescribed Limits

- Total Flying Hours (28 days, 365 days)
- Maximum Flight Duty Period (single, dual, augmented)
- Maximum Duty Period

- In-Flight Rest
- Controlled Rest on Flight Deck

- Minimum Rest Period
- Standby and Availability

- Pilot/Commander's Discretion

Other Considerations

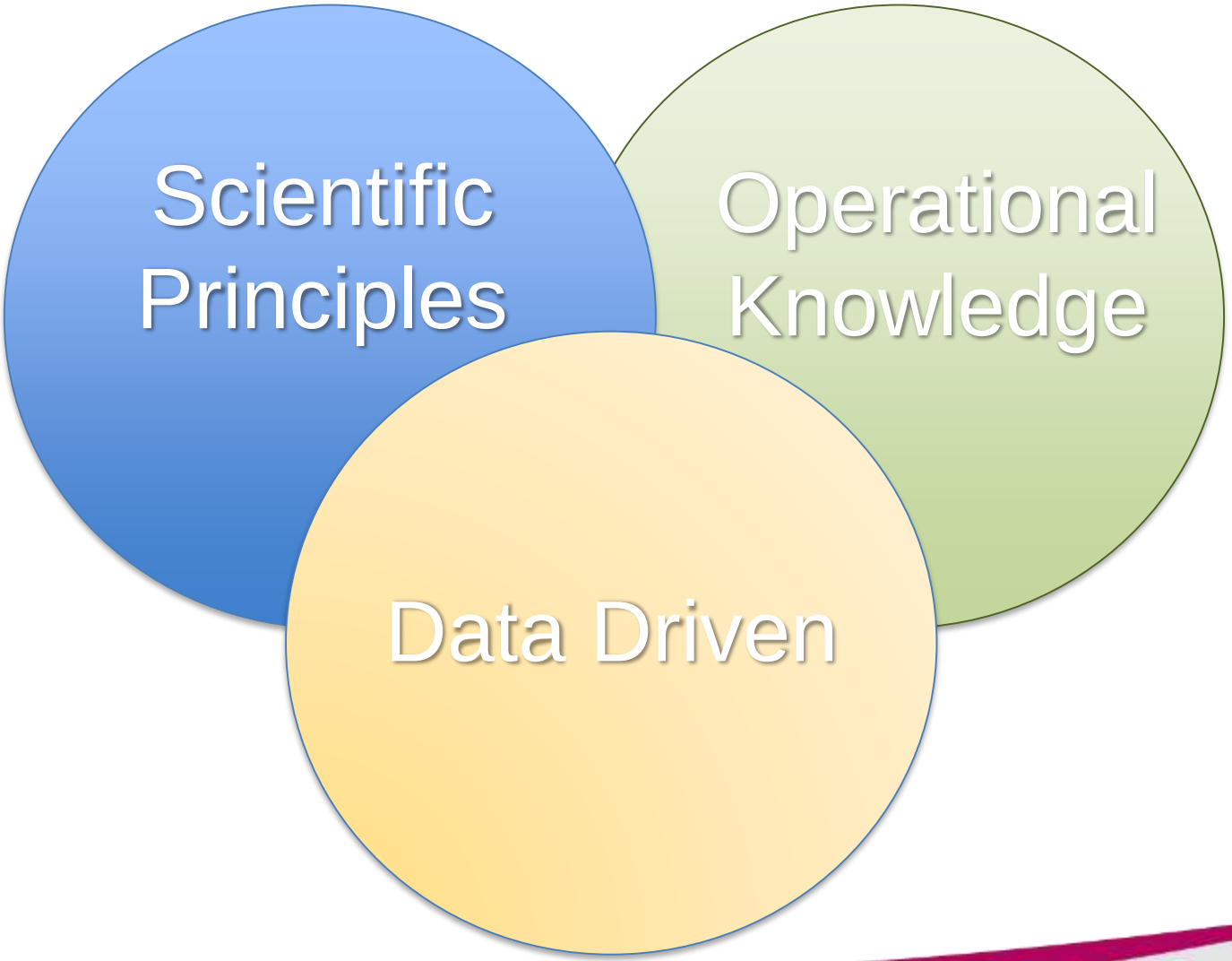
- Breaks taken during duty periods
- Stability of work patterns
- Assignment of unscheduled duties (including those associated with managing operational disruptions on-the-day)
- Recovery value associated with non-work periods
- Meeting other physiological needs

FRMS Approach

What is FRMS

- An alternative to prescriptive rules
- A **data-driven** means of continuously monitoring and managing fatigue-related safety risks, based upon **scientific principles** and knowledge as well as **operational experience** that aims to ensure relevant personnel are performing at adequate levels of alertness
- Requires a level of **trust and confidence** among service provider and workforce

Fatigue Management Approaches



FRMS Approach

Expectations and Confidence

- Service provider:
  - Meet its FRMS responsibilities with the necessary level of commitment, skills and resources
  - Use an individual's fatigue data and information for the express purpose of managing fatigue risks
  - Maintain confidentiality of personal information
  - Involve operational personnel in the identification of appropriate fatigue mitigation strategies

- Workforce:
  - Meet their individual responsibilities for managing their fatigue level prior to and during work periods
  - Provide unbiased feedback on the effectiveness of the mitigation of fatigue risks
  - Be receptive to the intent of the FRMS to improve safety and efficiency rather than for personal, financial or industrial gain.

FRMS Approach

Components

FRMS Approach

- **Define** FRMS policy
- **Scope** of FRMS operations be clearly defined
- The policy shall
  - reflect the **shared responsibility** of management, flight and cabin crews, and other involved personnel
  - clearly state the **safety objectives** of the FRMS
  - be **signed by the accountable executive** of the organization
  - be **communicated**, with visible endorsement, to all the relevant areas and levels of the organization
  - declare management **commitment to effective safety reporting**
  - declare management **commitment to the provision of adequate resources** for the FRMS
  - declare management commitment to **continuous improvement** of the FRMS
  - require that **clear lines of accountability** for management, flight and cabin crews, and all other involved personnel are identified
  - require **periodic reviews** to ensure it remains relevant and appropriate

FRMS Approach

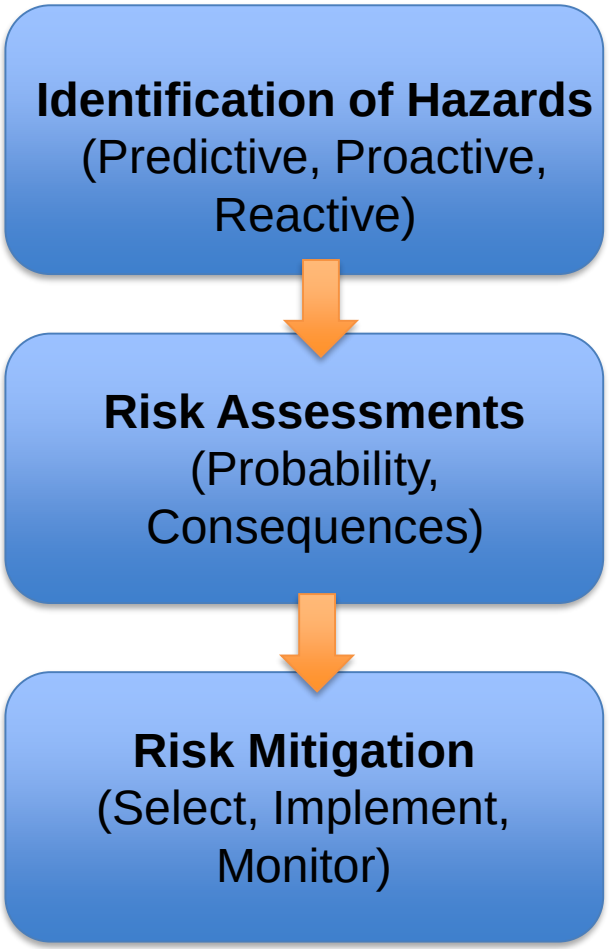
An operator shall develop and keep current FRMS **documentation** that describes and records:

- FRMS **policy and objectives**
- FRMS **processes and procedures**
- **Accountabilities, responsibilities and authorities** for these processes and procedures
- **Mechanisms for ongoing involvement** of management, flight and cabin crew members, and all other involved personnel
- FRMS **training** programmes, training requirements and attendance records
- Scheduled and actual **flight times**
- **Duty periods and rest periods** with significant deviations and reasons for deviations noted
- FRMS **outputs** including findings from collected data, recommendations, and actions taken

FRMS Approach

Components

Fatigue Risk Assessment



FRMS Approach

Components

Safety Assurance

- Provide for **continuous** FRMS performance **monitoring**
  - Hazard reporting and investigations
  - Audits and surveys
  - Reviews and fatigue studies

- Provide a formal process for the **management of change**
  - Identification of changes in the operational environment
  - Identification of changes within the organization

- Provide for the **continuous improvement**
  - Elimination and/or modification of risk controls
  - Routine evaluations of facilities, equipment, documentation and procedures
  - Determination of the need to introduce new processes and procedures to mitigate emerging fatigue-related risks

FRMS Approach

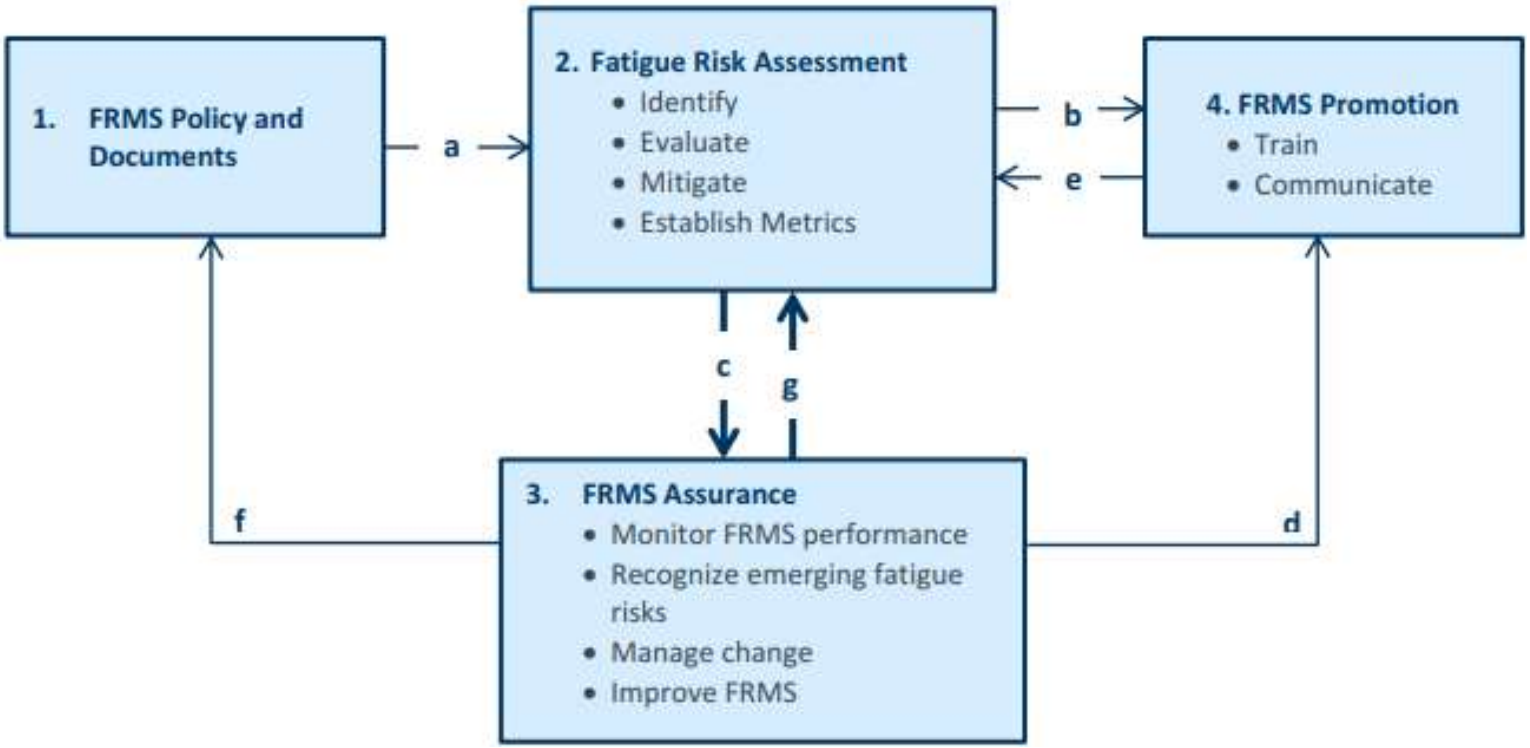
Components

Safety Promotion

- **Training programmes** to ensure competency
- Effective FRMS **communication plan** that
  - Explains FRMS policies, procedures and responsibilities to all relevant stakeholders
  - Describes communication channels used to gather and disseminate FRMS-related information

FRMS Approach

How the Components Interact



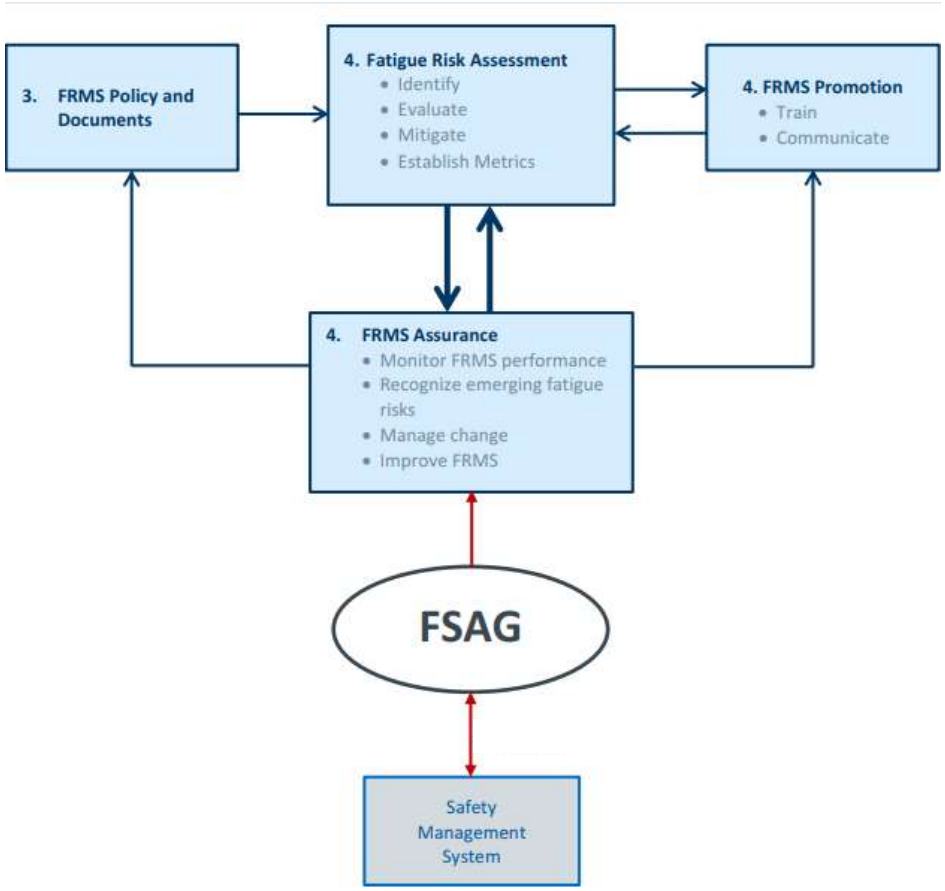
FRMS Approach

Fatigue Safety Action Group (FSAG)

- To be established by service provider, although not required by SARPs
- Principal functions of FASG:
  - Oversee the development of the FRMS
  - Assist in FRMS implementation
  - Oversee the ongoing operation of the fatigue risk assessment processes
  - Contribute as appropriate to the FRMS assurance processes
  - Maintain the FRMS documentation
  - Be responsible for ongoing FRMS training and promotion
  - Provide necessary input on all aspects of fatigue risk to the SMS

FRMS Approach

Fatigue Safety Action Group (FSAG)



FRMS Approach

- The oversight of FRMS, as a performance-based approach, requires extra resources, and a well-trained State inspectorate.

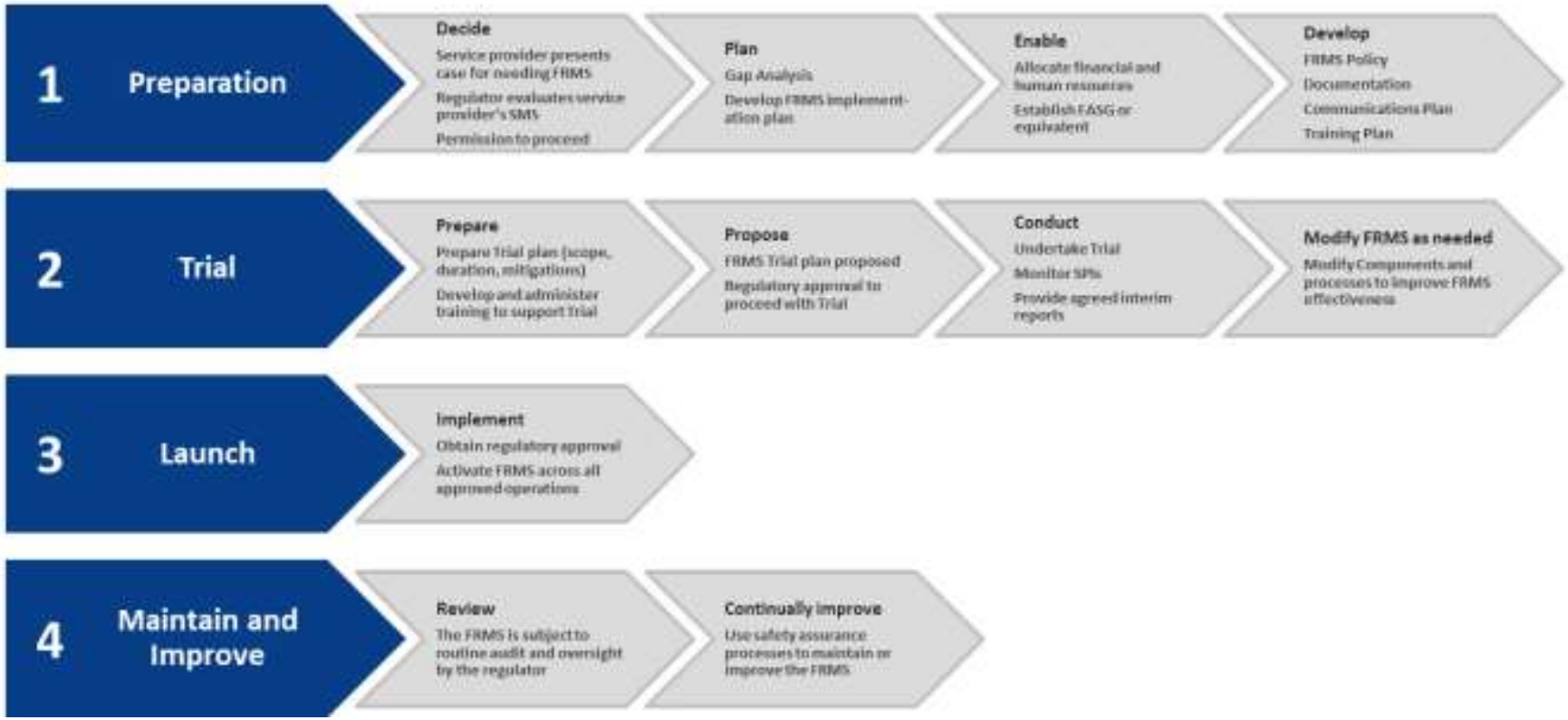
- The State is not obliged to offer FRMS regulations. Consideration should be given to whether the relevant service providers within that State want or need to implement FRMS, or whether it is more appropriate in their context to offer only the prescriptive limitations regulations.

- FRMS requires the proactive and predictive management of fatigue-related risks based on the analysis of relevant data and information. Much of this data must be provided by individuals and be considered both confidential and sensitive.

- Careful consideration needs to be given as to whether the State's legal protections currently in place facilitate the collection and protection of such information before deciding to offer FRMS regulations.

FRMS Approach

Four stages of Implementing FRMS



FRMS Approach

Advantages of FRMS

- Far more superior approach – fatigue risk is mitigated potentially at the individual level
- Significant risk reduction of hazards
- Stakeholders at all levels are educated to the risks and mitigation efforts
- Strengthens overall safety culture in relation to fatigue risks
- Increased operational flexibility
- Improved productivity and employee satisfaction

FRMS Approach

Biomathematical Models and Technology

- Biomathematical fatigue models can assist with developing optimal crew schedules
  - Predict times at which performance should be optimal
  - Identify times where restorative sleep will be maximized
  - Determine the impact of proposed work/rest schedules on overall fatigue and performance
  - Assist in the development of work schedules that reduce fatigue-related risk

FRMS Approach

Biomathematical Models and Technology

- Biomathematical fatigue models can assist with developing optimal crew schedules

- The System for Aircrew Fatigue Evaluation (SAFE)
- The Boeing Alertness Model (BAM)
- The Circadian Alertness Simulator (CAS)
- The Fatigue Risk Index (FRI)
- The Sleep, Activity and Task Effectiveness Model and associated Fatigue Avoidance Scheduling Tool (SAFTE-FAST)
- The Fatigue Assessment Tool by InterDynamics (FAID)
- The Sleep Wake Predictor (SWP)
- The Unified Model of Performance (UMP) and associated 2B-Alert

FRMS Approach

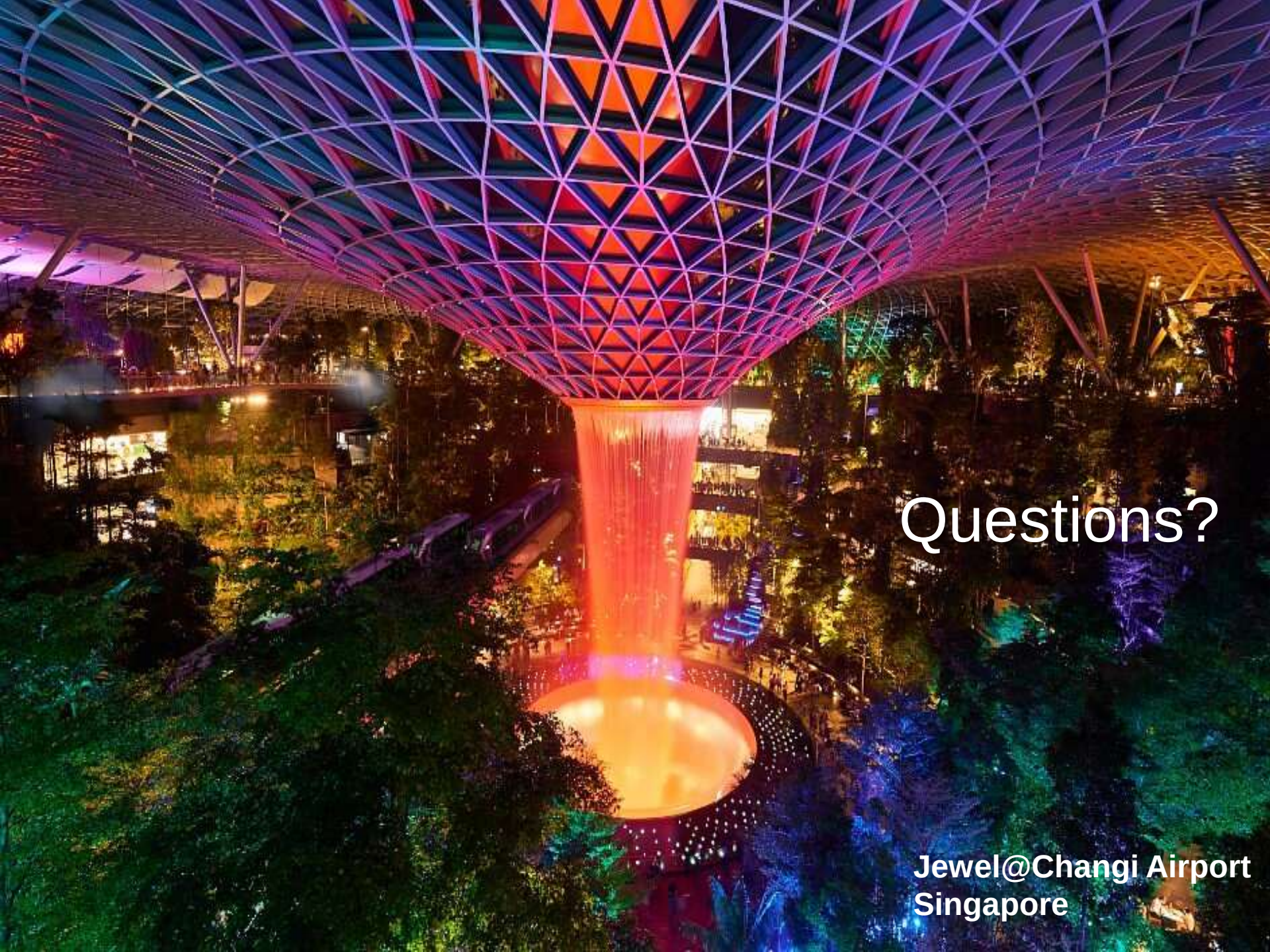
Biomathematical Models and Technology

- Actigraphy

- Humans are not accurate when measuring the quantity of sleep they have had
- Also not good in tracking the impact of changes to sleeping habits and schedules

Achieved the Learning Objectives

- Learn about the **importance of fatigue in aviation** and its **impact on aviation safety**
- Understand and apply the **basic science principles of fatigue** in relation to the aviation environment
- Gain **basic knowledge on fatigue management approaches** supported by ICAO SARPS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