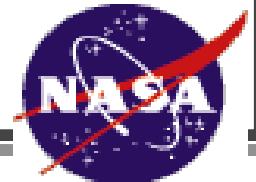


Best Practices for Fatigue Risk Management in Non- traditional Shiftwork

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What is “non-traditional” Shiftwork?



Why worry about Fatigue?

“I don’t need that much sleep anyway.”

“Fatigue doesn’t really affect me.”

“I don’t get jet-lagged.”

“Those of us who have made it this far made it for a reason. We aren’t like the people you study.”

“When you are engaged in something really exciting or important, your adrenaline kicks in and overcomes your fatigue.”

“Although neither man was really tired after the first half of the picture-snapping, Conrad considered closing the hatch and resting until the next night pass. He asked the Hawaii CapCom if there was enough oxygen. The answer was yes. But the skies were clear over the United States, and they might want to take more pictures there. In that case, said Conrad, the hatch would stay open. Soon the crew marveled at the view of their home area-Houston. They passed quietly across Florida and out over the Atlantic with nothing to do. Suddenly, Gordon broke the silence to announce that they had just taken a catnap. ‘There we were. . . , he was asleep hanging out the hatch on his tether and I was asleep sitting inside the spacecraft,’ Conrad reported. ‘That’s a first,’ John Young answered, ‘first time sleeping in a vacuum.’”

What do you need to know about Fatigue Risk Management?

- Physiological limits to performance
 - How do we become fatigued?
 - What countermeasures are available for fatigue?
- Assessment
 - Assess the problem
 - Assess the solution
- Fatigue in non-traditional shiftwork
 - Real world examples
 - Mitigations

Physiological Limits to Performance

- **Circadian time of day**
- **Number of hours awake**
- **Cumulative sleep debt**
- **Time since awakening**

Modifiers of Physiological Response

- **Individual differences in susceptibility**
- **Sleep disorders**



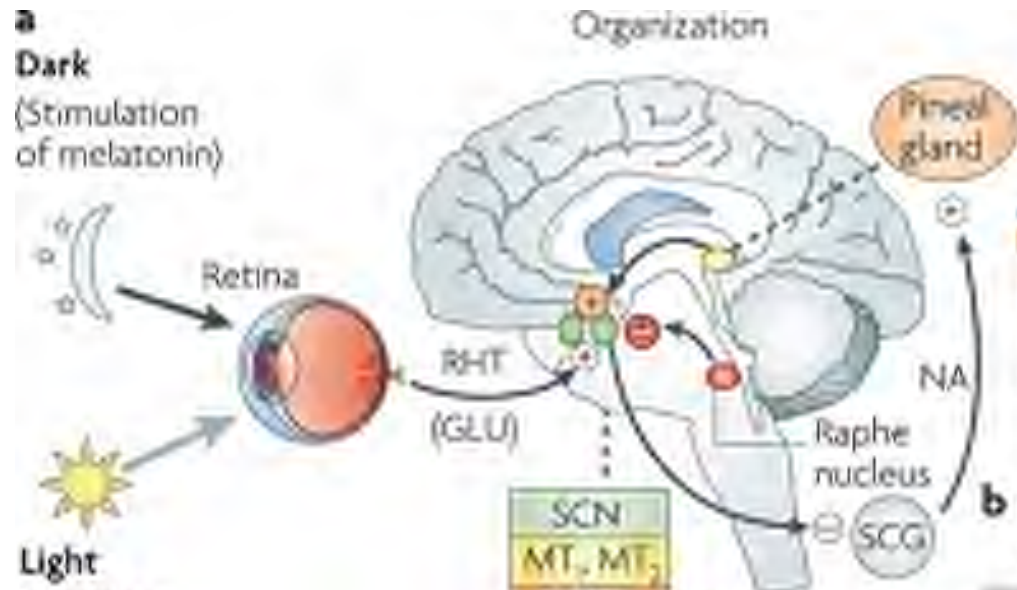
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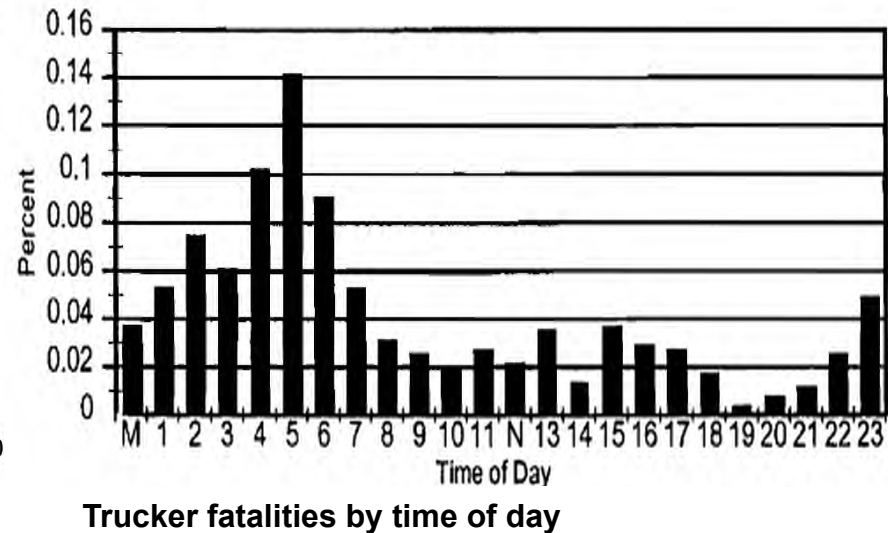
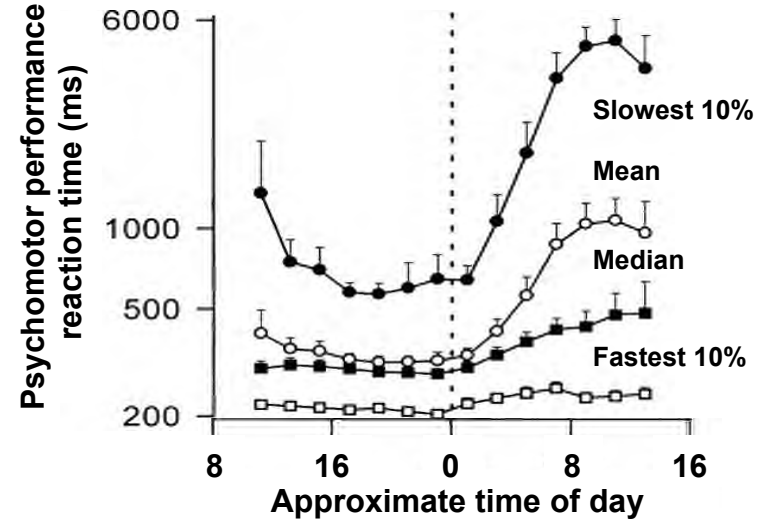
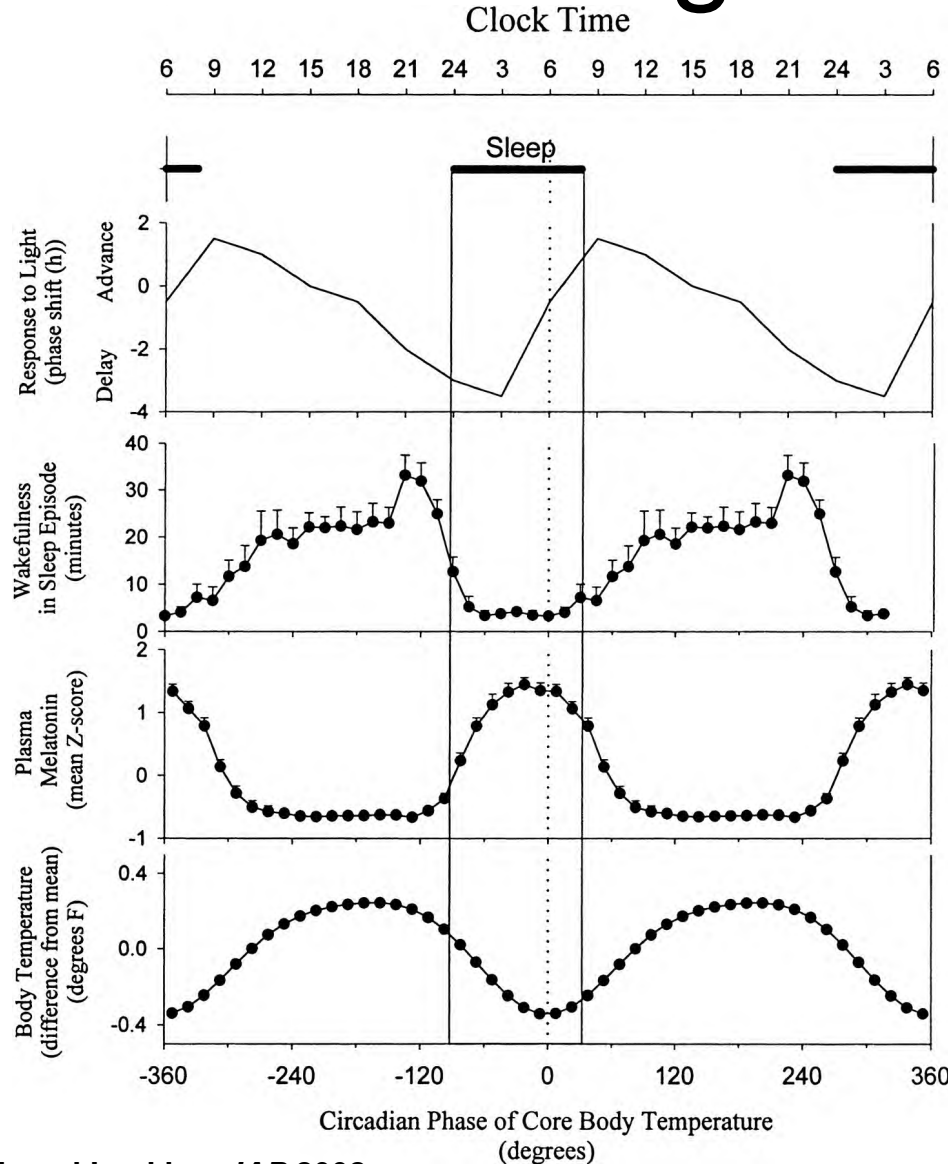
The Circadian Pacemaker

- Located in the suprachiasmatic nuclei in the hypothalamus
- Endogenous period ~24.2
 - Reset by daily light exposure
- Controls daily variation in alertness, performance, hormone production etc.



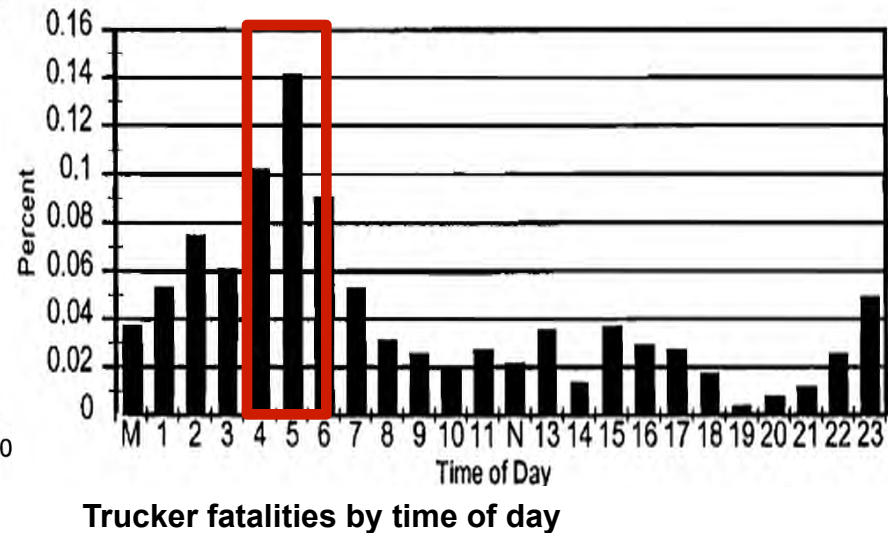
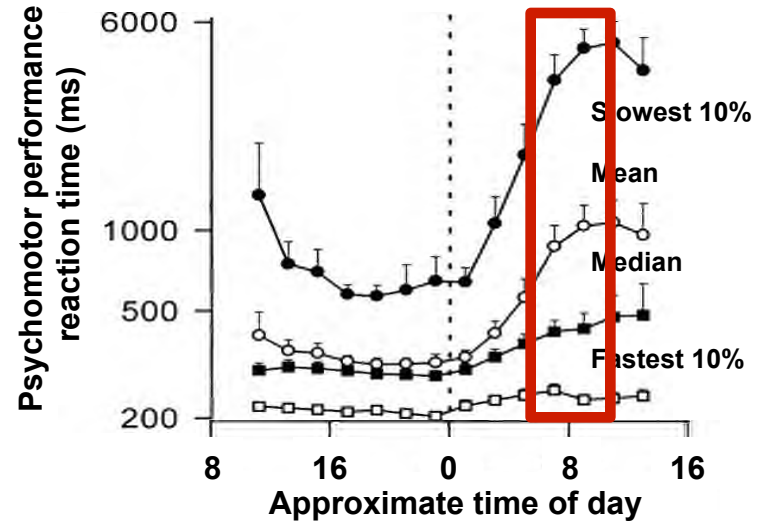
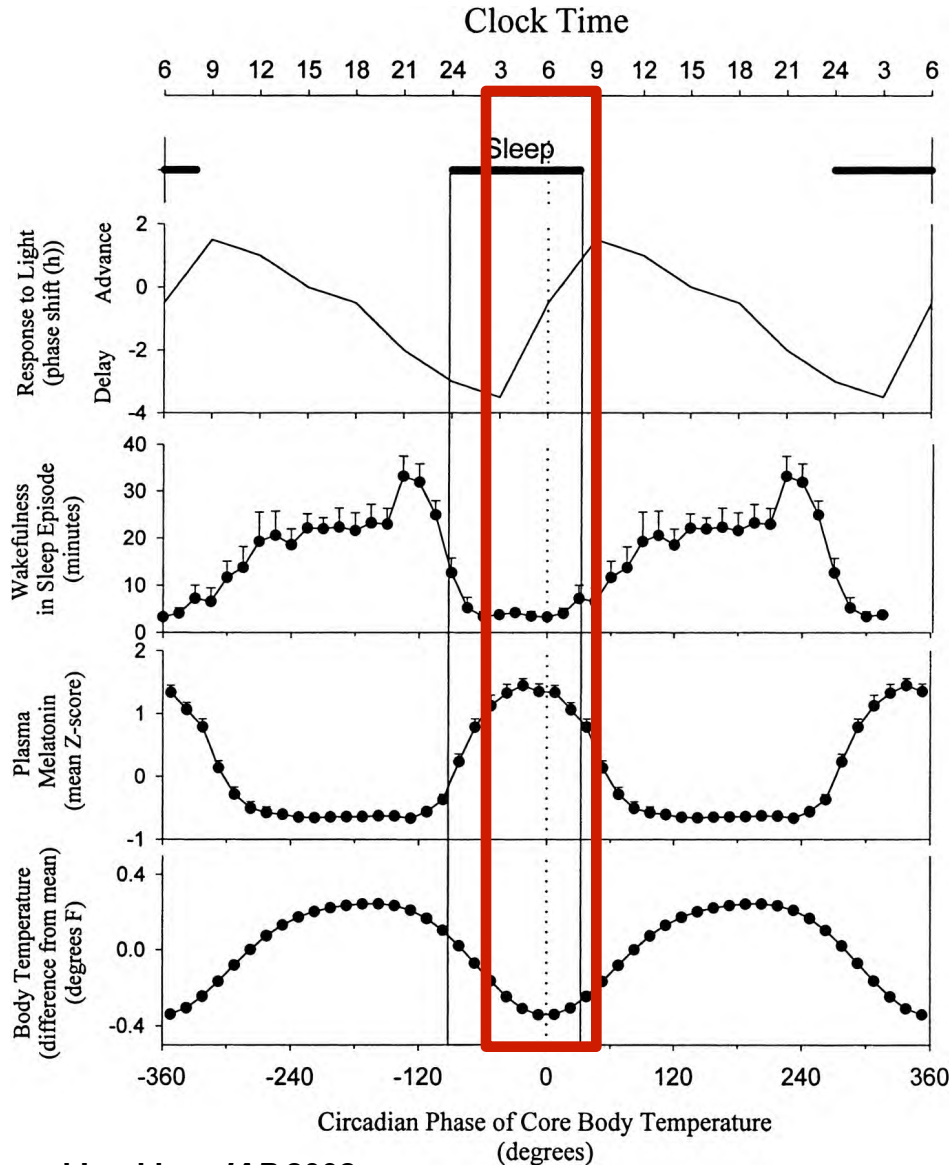
Bodinat *et al.* Nature Reviews Drug Discovery (August 2010)

Circadian Control of Biological Function

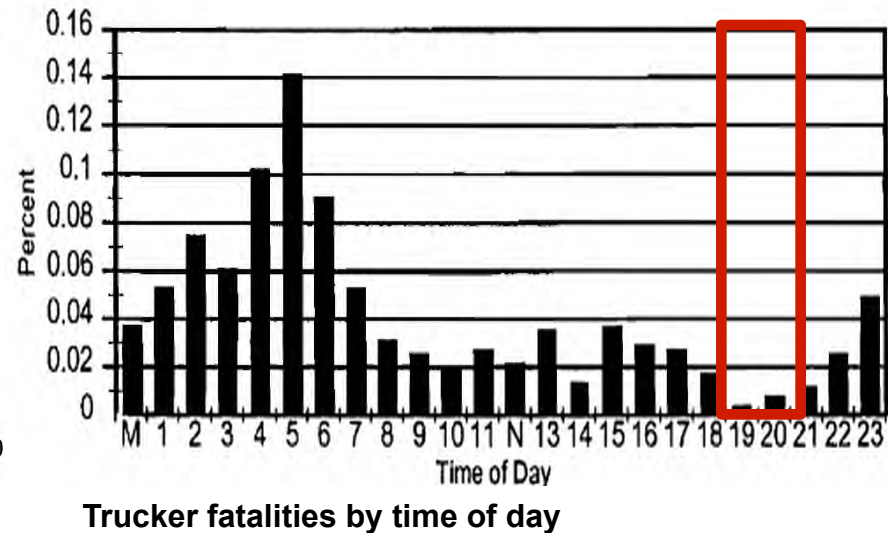
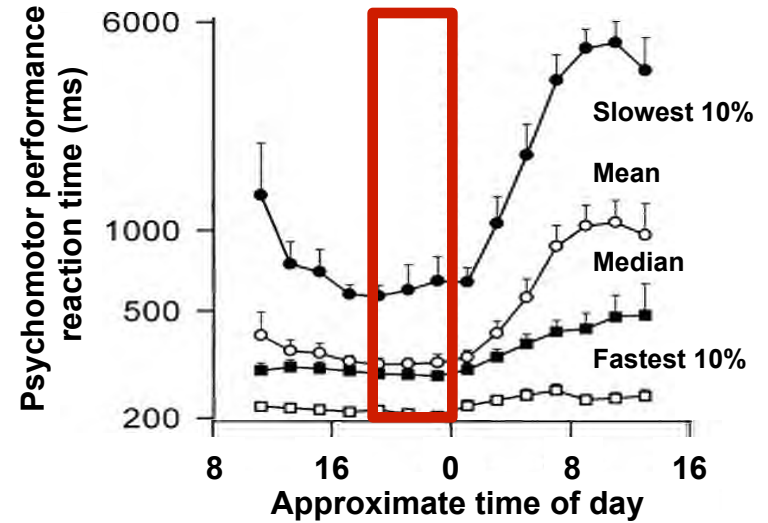
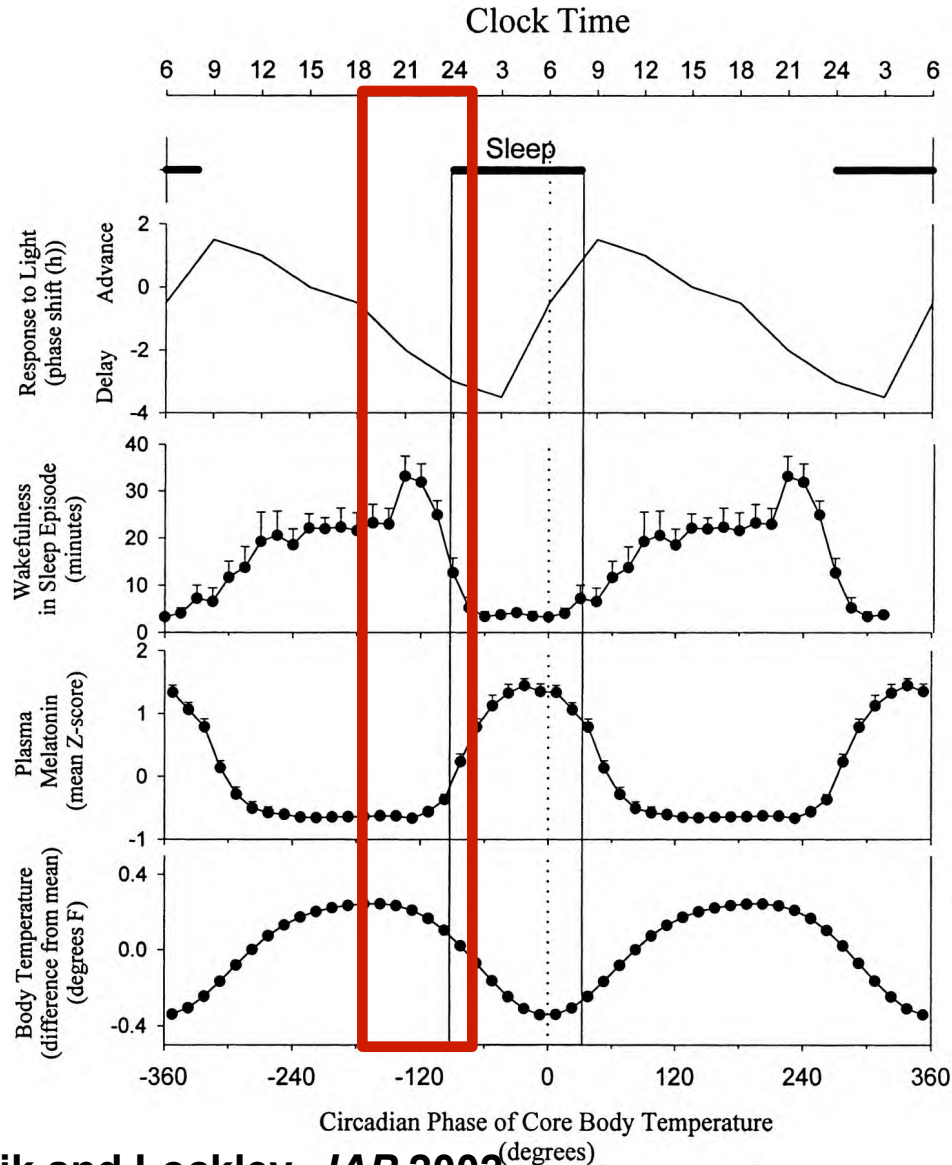


Circadian Nadir =

Poorest Performance and Highest Sleep Drive

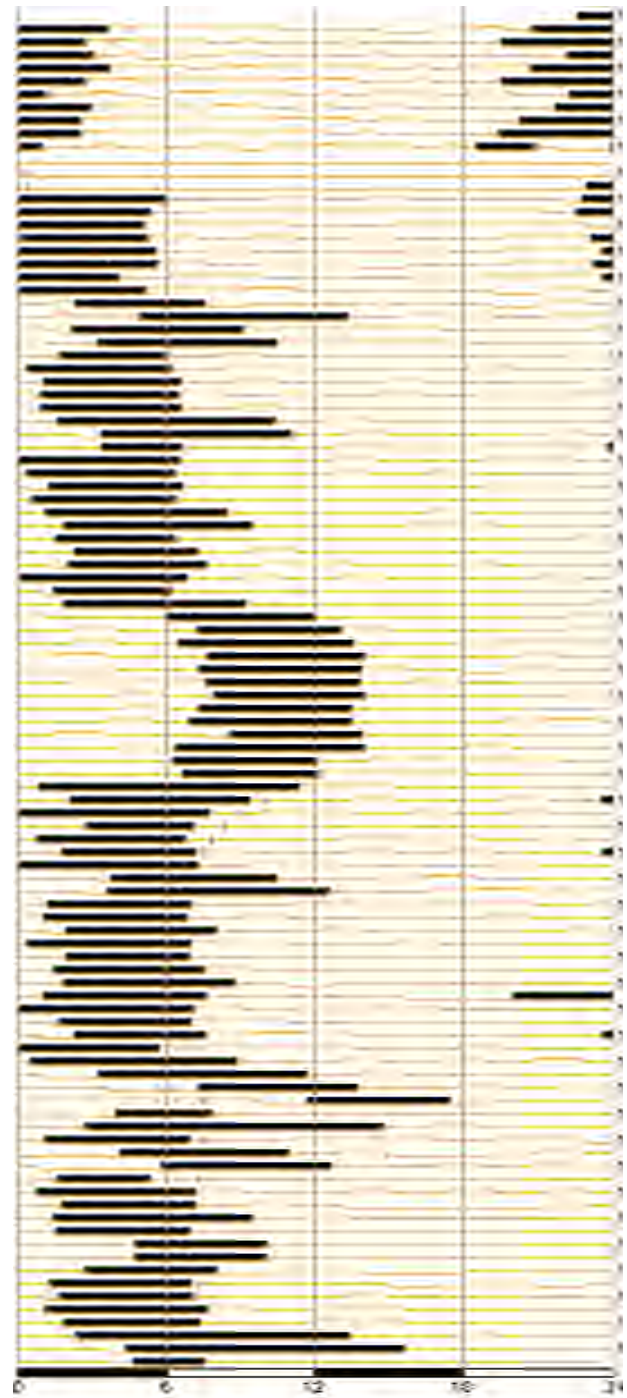


Circadian Wake Maintenance Zone = Lowest Sleep Drive

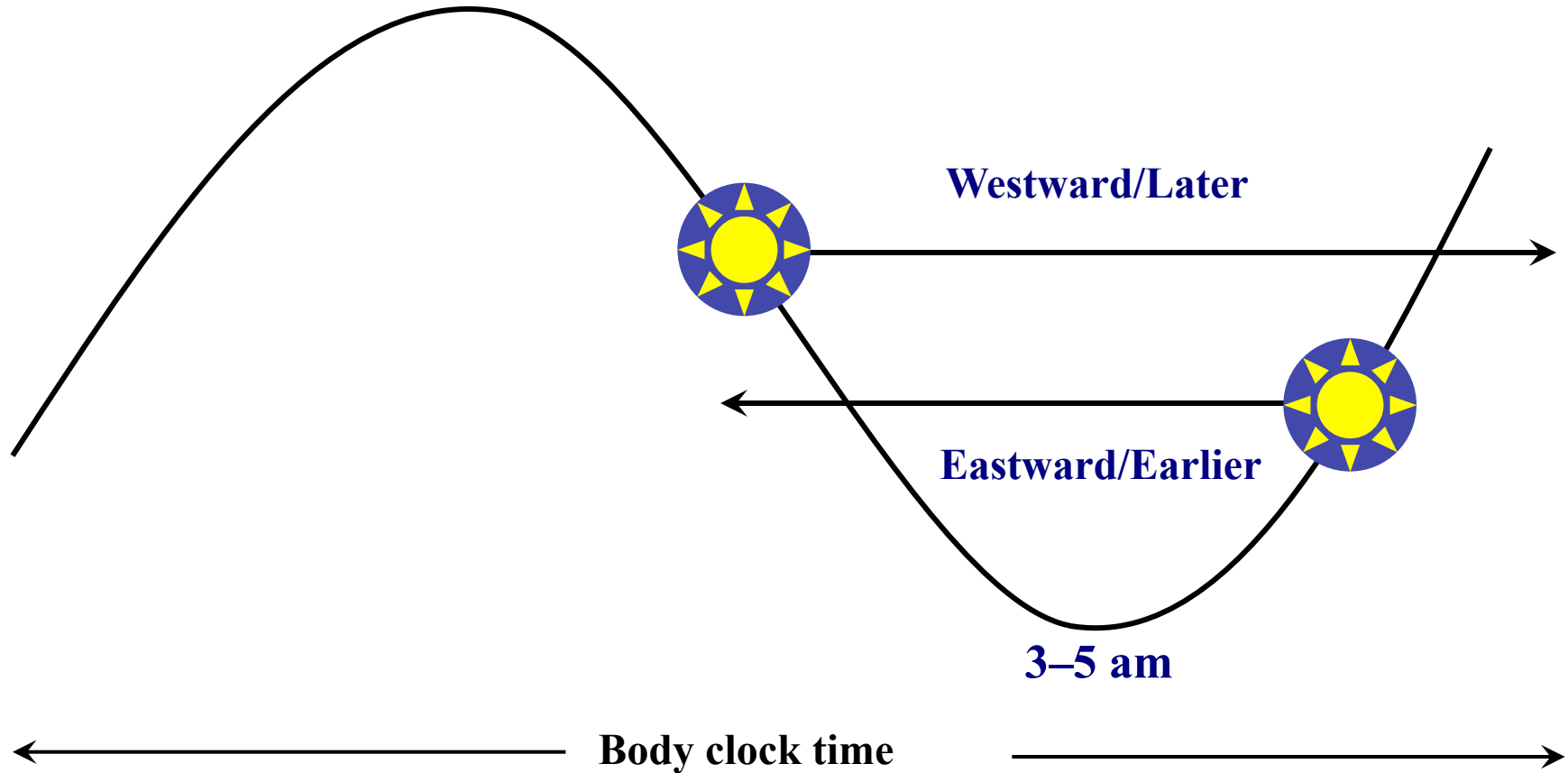


Causes of Circadian Misalignment

- Night work
- Irregular schedules
 - prevent regular bed- and waketimes leading to circadian misalignment
- Early morning starts
 - Circadian wake maintenance zone prevents early bedtime



Circadian Resetting by Light



Going West/Shifting Later:
Going East/Shifting Earlier:

Get evening light; avoid morning light
Get morning light; avoid evening light

Simple rules don't apply to big shifts



Strategies for Managing Circadian Desynchrony

- When designing schedules:
 - Shift sleep later, not earlier
 - Shift erratic schedules in the same general direction
- Light exposure before bed will help shift circadian timing later and light upon waking will shift circadian timing earlier for modest phase shifts
 - Provide teams with light exposure schedules
 - Blue wavelength light has a stronger effect
- Provide shift working teams with an eye mask in the morning and black out windows
 - Recommend that teams wear sunglasses to avoid light exposure at the wrong time (if safe)
- For extreme situations chronohypnotics may be useful with physician oversight
 - Traditional hypnotics do not shift the clock
 - Chronohypnotics shift the clock earlier, not later

Physiological Limits to Performance

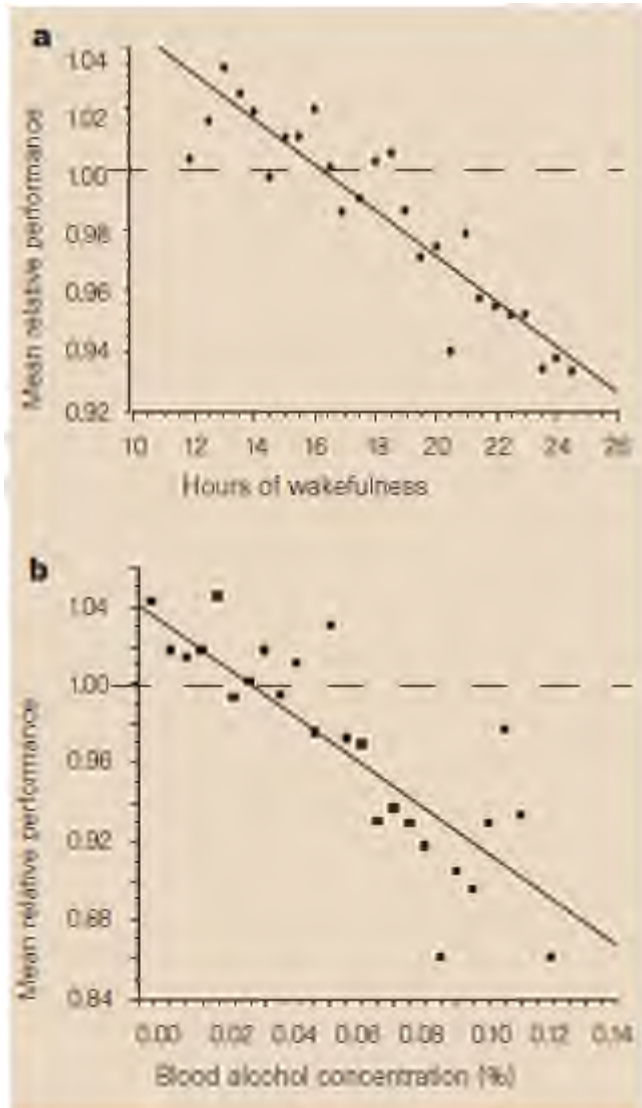
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- Time since awakening

Modifiers of Physiological Response

- Individual differences in susceptibility
- Sleep disorders



Impairment from Acute Sleep Loss is like Impairment from Alcohol



Dawson and Reid 1997, *Nature*

Causes of Acute Sleep Deprivation

Work Related:

- Emergent problems
- Lack of depth/training in team
- Motivated employees

Personal Commitments:

- Family commitments after work
- Commuting
 - Increased danger of incident after extended work hours

Managing Acute Sleep Deprivation

Countermeasures for sleep loss during extended work shifts:

- Caffeine
- Light exposure
- Power naps (~ 30 minutes)
- Exercise
- Prescription wake-promoting medications for extreme circumstances with physician oversight
- Taxi vouchers
- Protect time to avoid “burning the candle at both ends”

Strategic Use of Caffeine



- Plan timing: use 15-30 minutes before a vulnerable period
- Use “little and often” for sustained performance
 - ~50 mg every hour
- Use only when needed not out of habit for maximal effect
- Avoid within 3-4 h of bedtime
 - ~6 h half-life

Physiological Limits to Performance

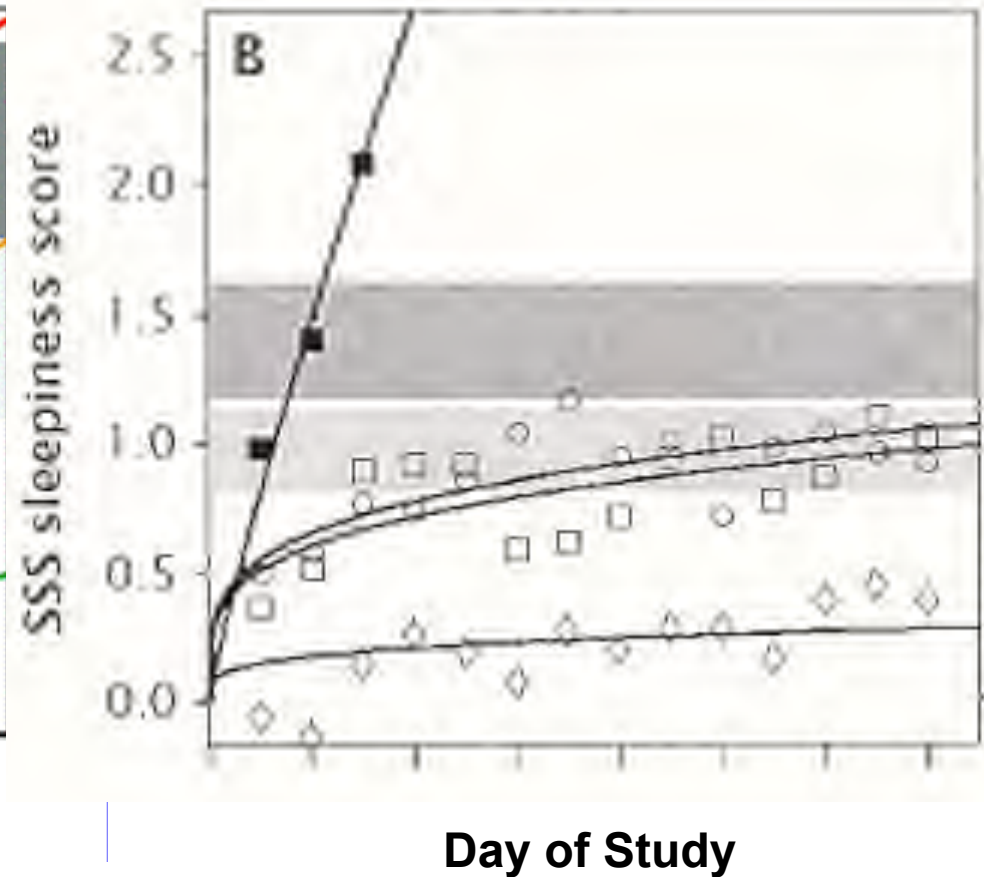
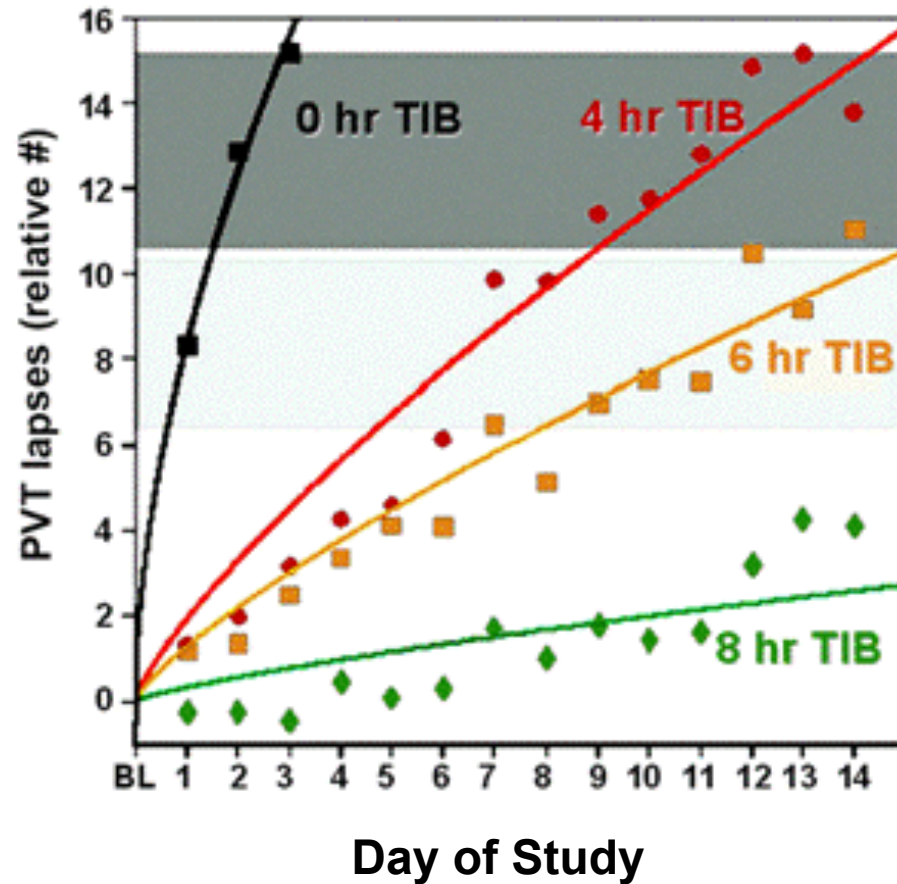
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We're *supposed* to feel functional when we are sleep deprived



Causes of Chronic Sleep Loss

- Planned off-duty times may be cut short due to mission demands, family commitments, traffic etc.
- Exposure to light-emitting devices
 - Viewing a computer screen/smartphone in bed
- Adequate time for sleep on a work break may not be timed to allow for sleep
 - Environment (noise, light, temp)
 - Phone/email notifications
 - Uncomfortable bed
 - Circadian misalignment

Managing Chronic Sleep Loss

- Off duty time should allow for 8 hours of sleep AND time for meals, commuting, showering
- Avoid light exposure in the hour before bed, especially light emitting devices
- Set the “do not disturb” function on your phone
- When possible take naps to “catch up”
- Make the most of your sleep
 - Tell the front desk/family, put a big note on your door
 - Bring ear plugs
 - Use an eye mask
- For individuals who may not experience enough quality sleep, use checklists and backup review at work

Physiological Limits to Performance

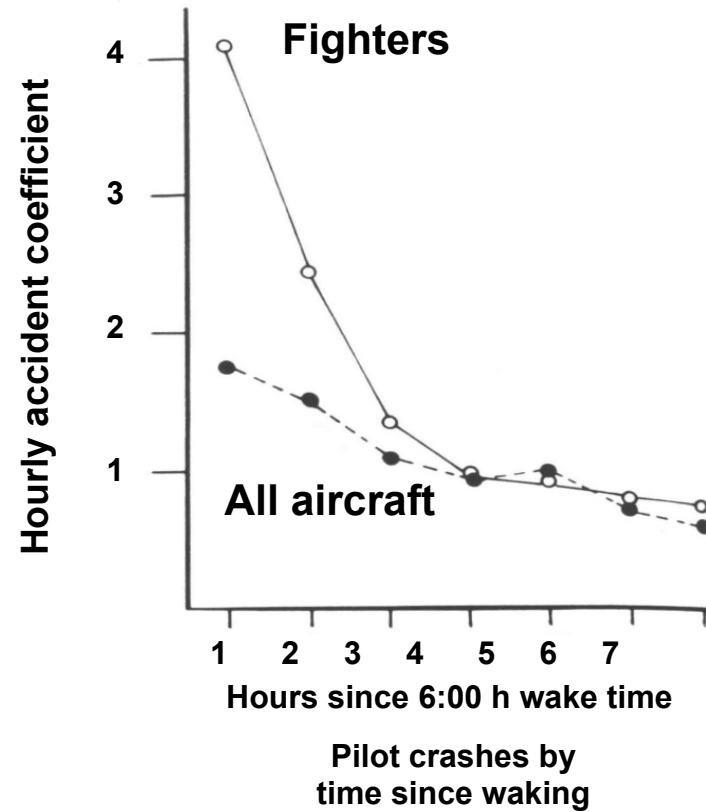
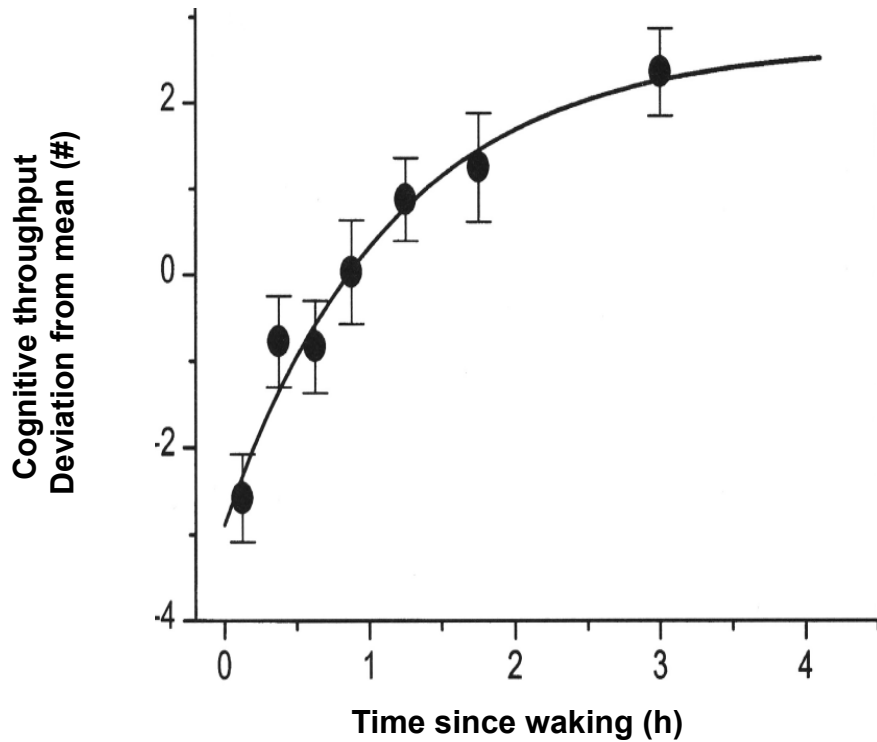
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Sleep Inertia



Sleep Inertia Duration

- Performance impairments associated with sleep inertia are greatest in the first half hour after awakening.

The length of impairment depends on:

- Depth of sleep – the deeper the sleep you awake from, the longer the sleep inertia will last
- Sleep deprivation – the more sleep deprived you are, the longer the sleep inertia will last
- Circadian rhythm – sleep inertia is more prominent at your body's circadian nadir

Managing Sleep Inertia

- Limit power naps to 30-45 minutes
- Delay making important decisions/driving until after sleep inertia has subsided
- Use bright light upon waking
- Consider a “caffeine-nap”
 - Take caffeine, then take a nap
- Get enough sleep at the right time

Physiological Limits to Performance

- Circadian time of day
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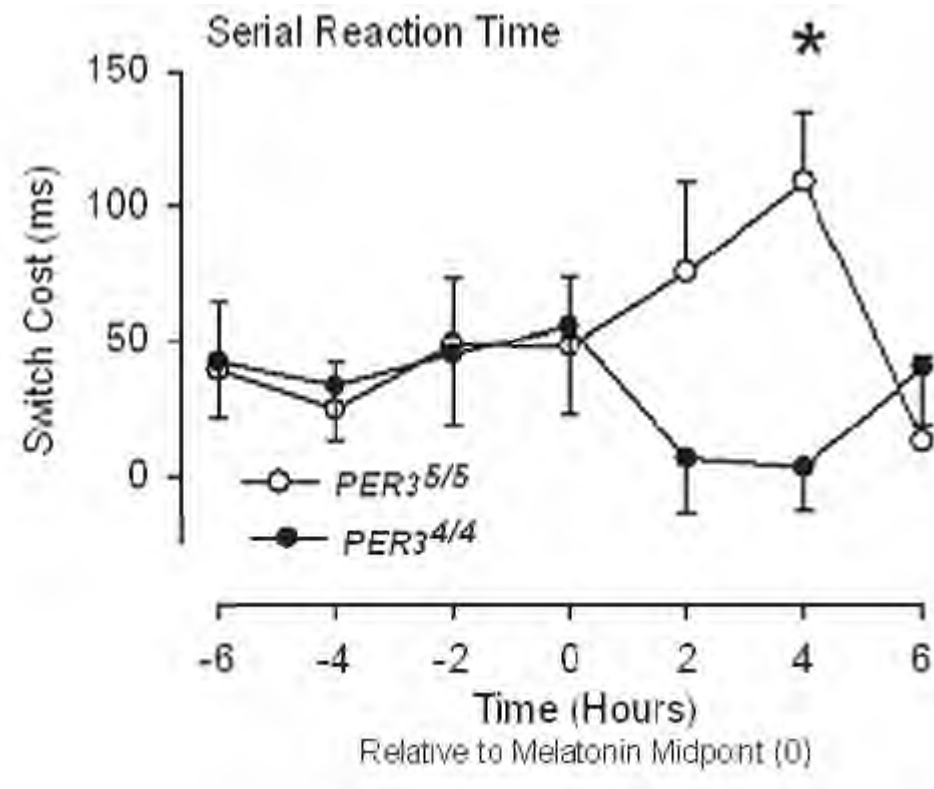
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Individual differences

- Genetic polymorphisms have been identified suggesting some **may be more susceptible** to impairment associated with sleep loss



Groeger *et al.* 2008, *Sleep*

Individual Sensitivity to Wake Promoting Drugs

- ADORA2A genotype confers caffeine sensitivity
- Individual differences in response to other drugs unknown



Sleep Disorders Screening

In the LAST month, how many times
did you nod off or fall asleep...

	Never	Once or twice a week	Two or three times a week	More than three times a week
during meetings at work				
on the telephone				
while driving				
while stopped in traffic				

Sleep Disorders Screening

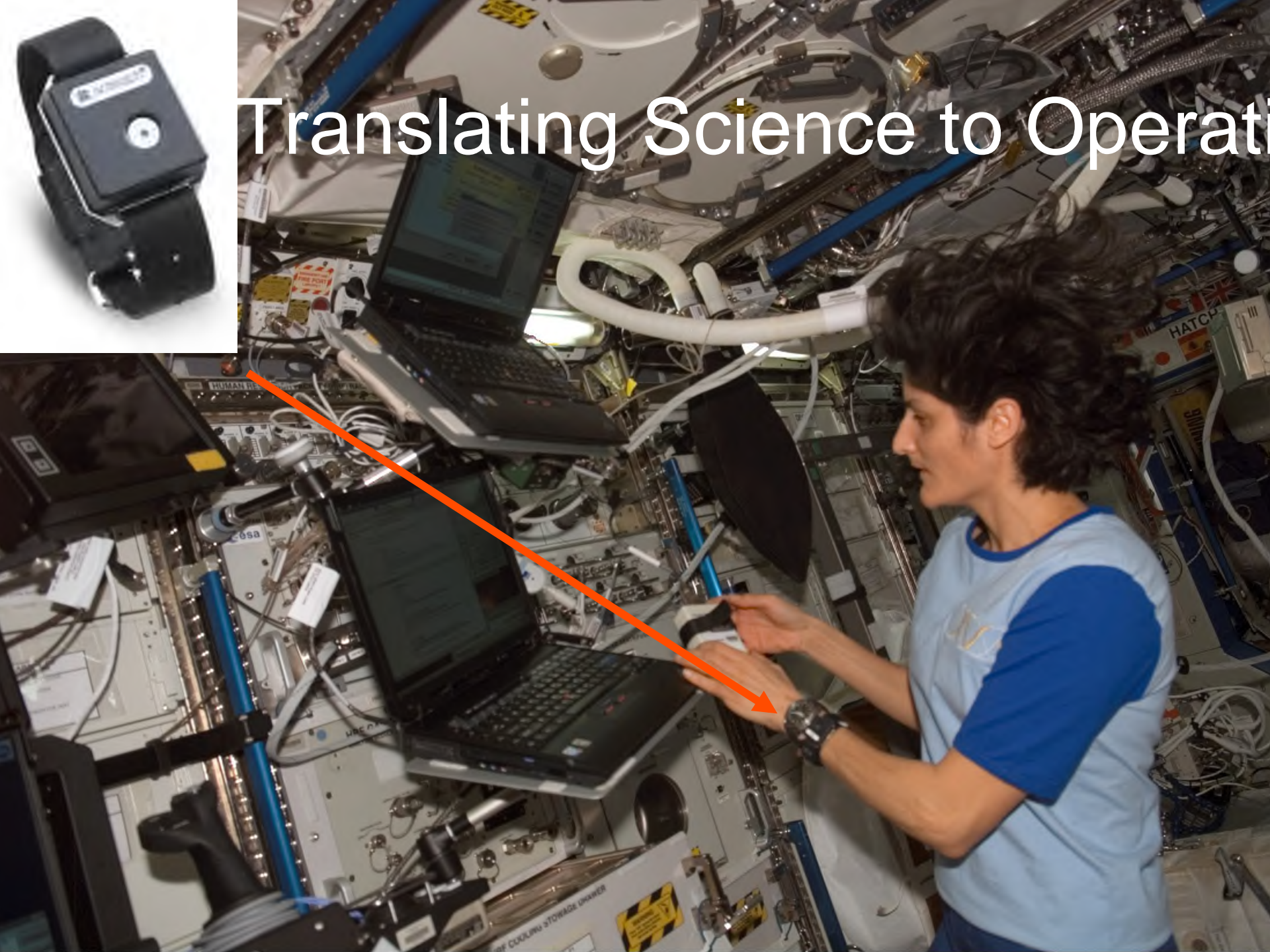
In the LAST month, how many times did you nod off or fall asleep...

	Never	Once or twice a week	Two or three times a week	More than three times a week
during meetings at work				
on the telephone	Low Risk			High Risk
while driving				
while stopped in traffic				

Managing Sleep Disorders and Vulnerability to Sleep Loss

- Review health status of individuals in key roles with the potential for extended duty and/or rotating shifts
- Complete a simple sleep disorders screen with teams that have high workload
 - Epworth Sleepiness Scale
 - Pittsburgh Sleep Quality Index
- If medication or caffeine is considered as a countermeasure, have the individuals trial it prior to the intense workflow
- Consider providing the following to employees:
 - Taxi vouchers
 - Blackout shades
 - Eye masks
 - Use earplugs
 - Nap room

Translating Science to Operations



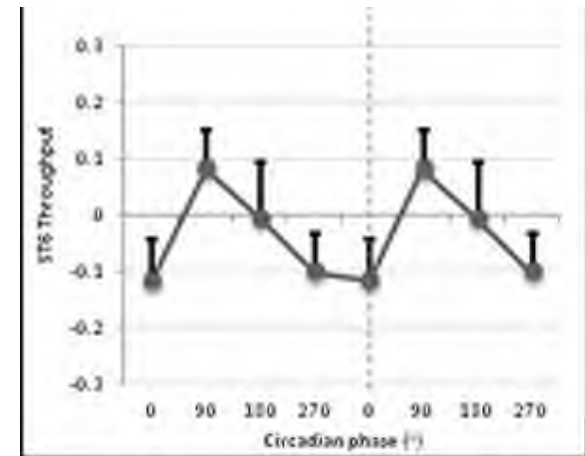
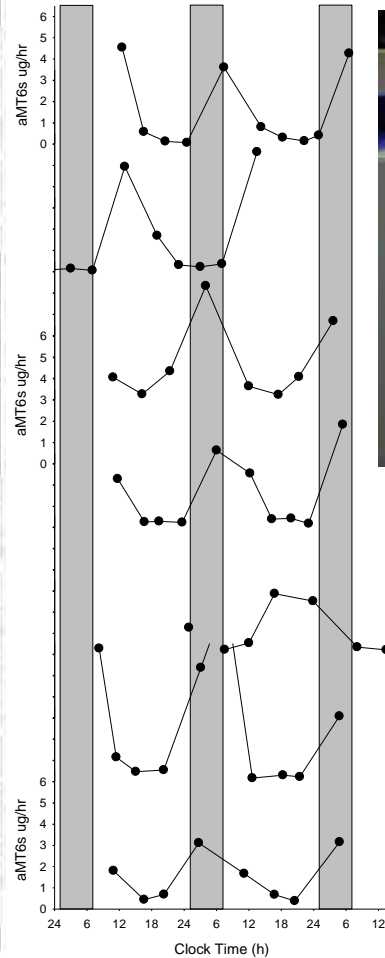
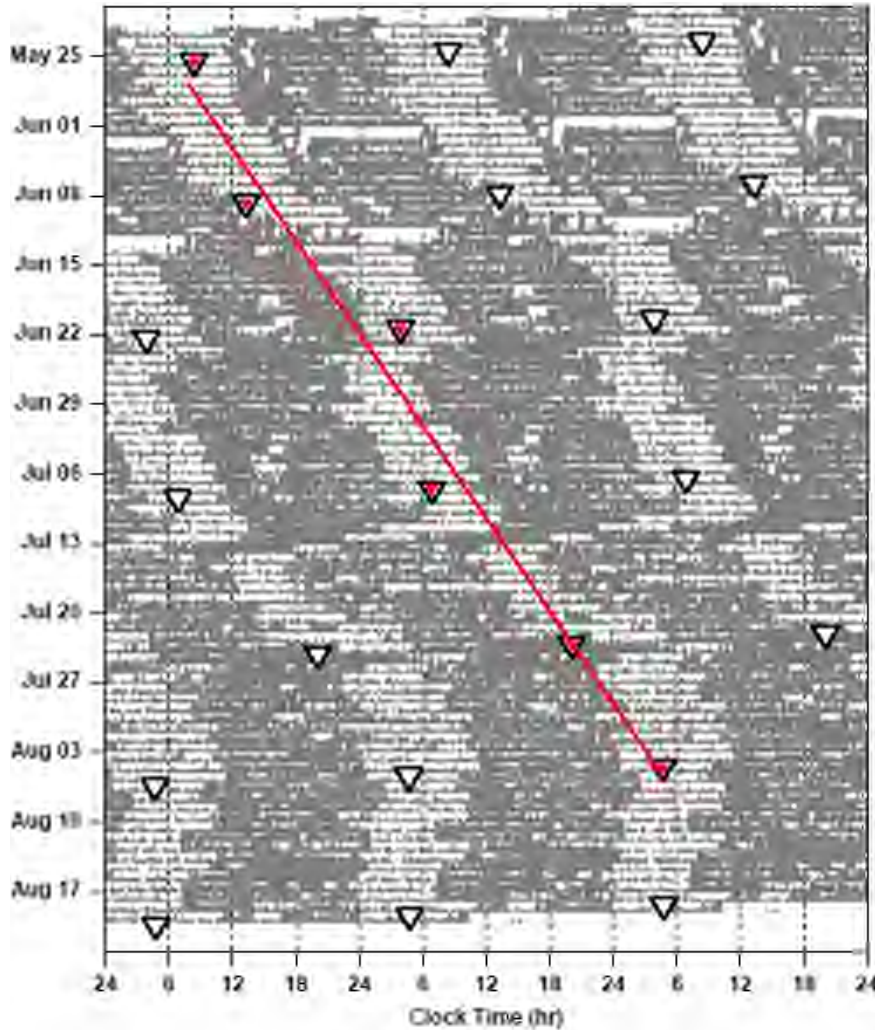
Assess Needs

- Engage mission managers/team leads
 - Give a talk about risks/benefits to fatigue risk management
 - Identify mission requirements and associated staffing constraints
- Calculate how many individuals are available for each role
- Calculate “coverage time” (e.g. around the clock, only at downlink etc.)
- Calculate the probability of unplanned extensions of duty
- Use a biomathematical model to estimate circadian phase and the impact of different schedules
 - e.g. Circadian Performance Simulation Software, SAFTE FAST, Fatigue Meter, Boeing Alertness Model, the unified model of performance, the University of Washington model
 - Do not RELY on model predictions, use them as best guesses about fitness for duty

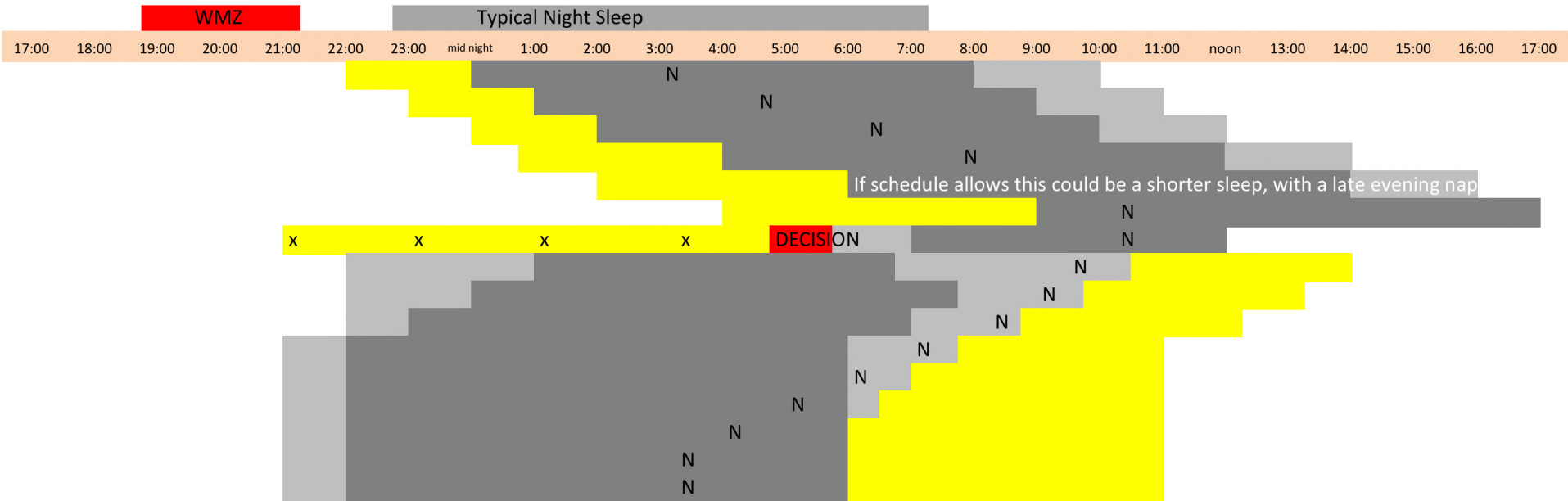
Assess Program Implementation

- Constant objective monitoring is essential in managing not traditional shiftwork
- Actigraphy
 - Measures sleep wake state
- Tests of cognitive function throughout shifts
- Self-rating measures

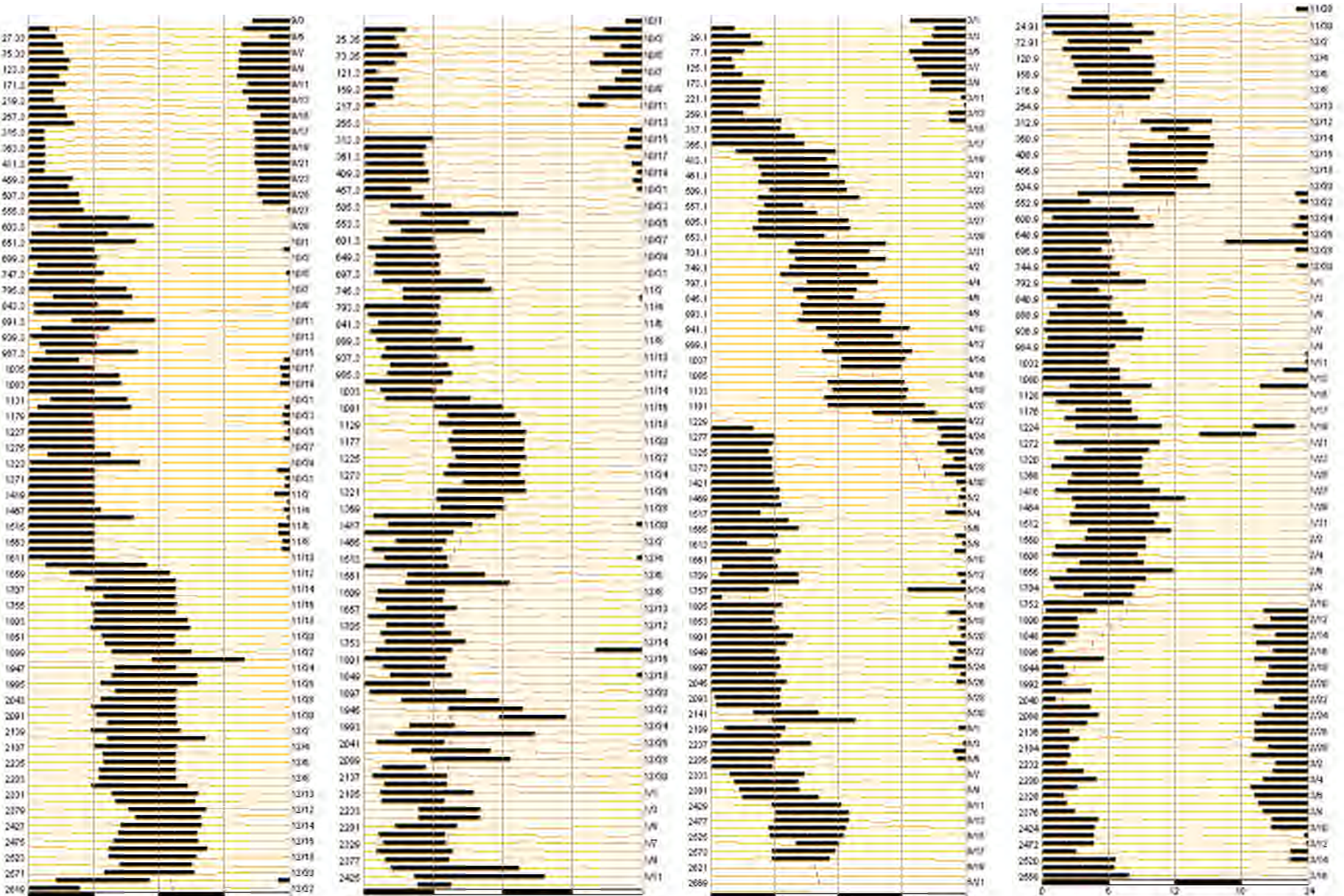
Real World Example: Phoenix Mars Lander



Real World Example: New Horizons Hazard Team Schedule



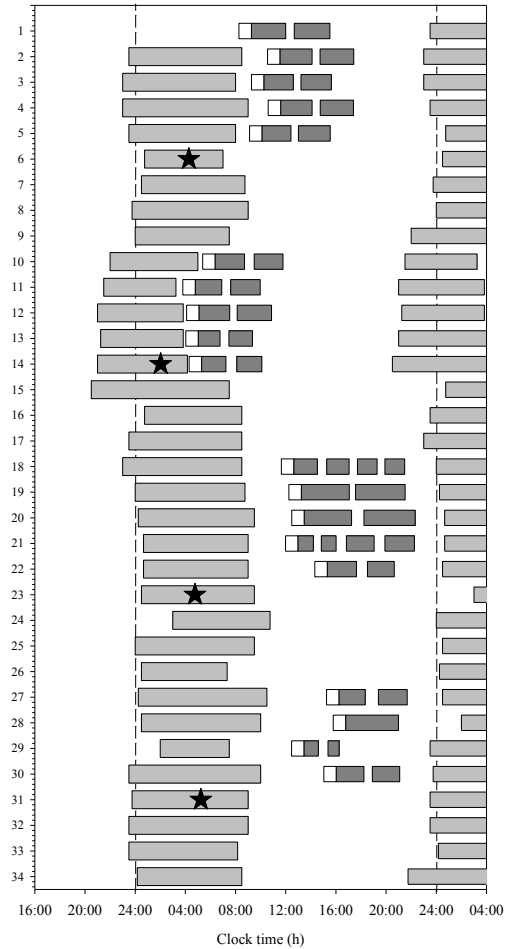
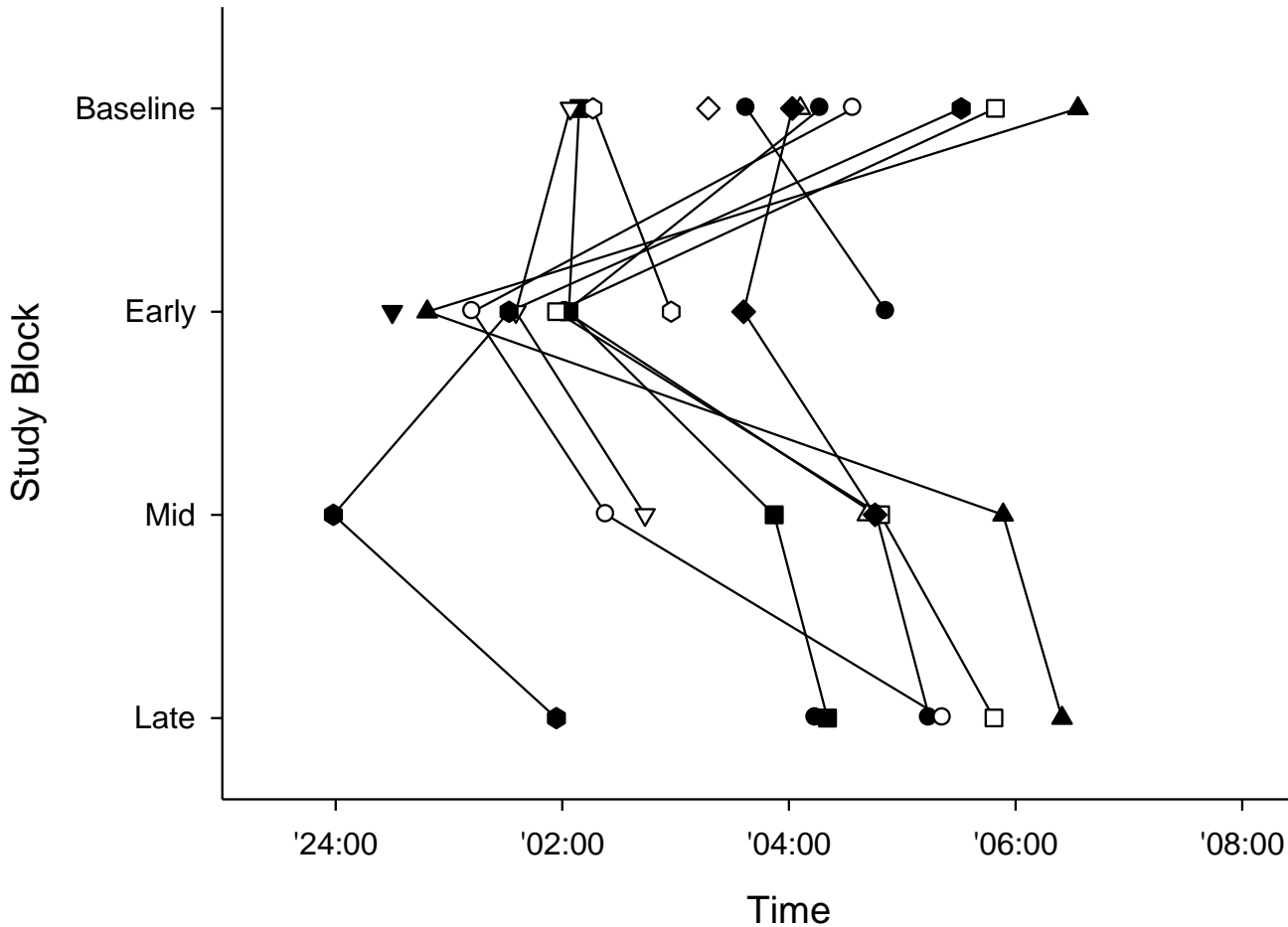
Circadian Misalignment During Spaceflight



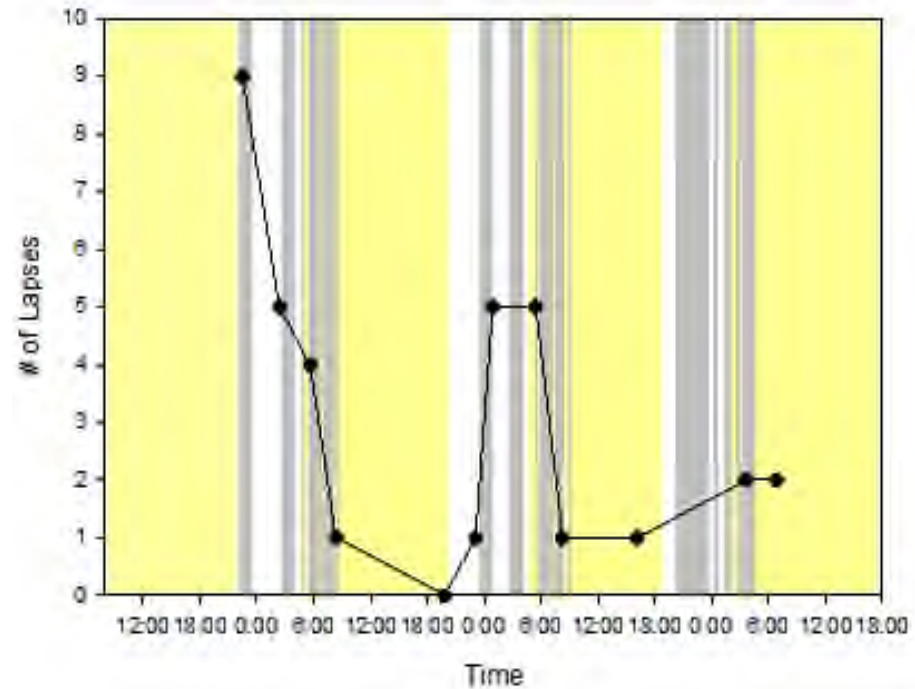
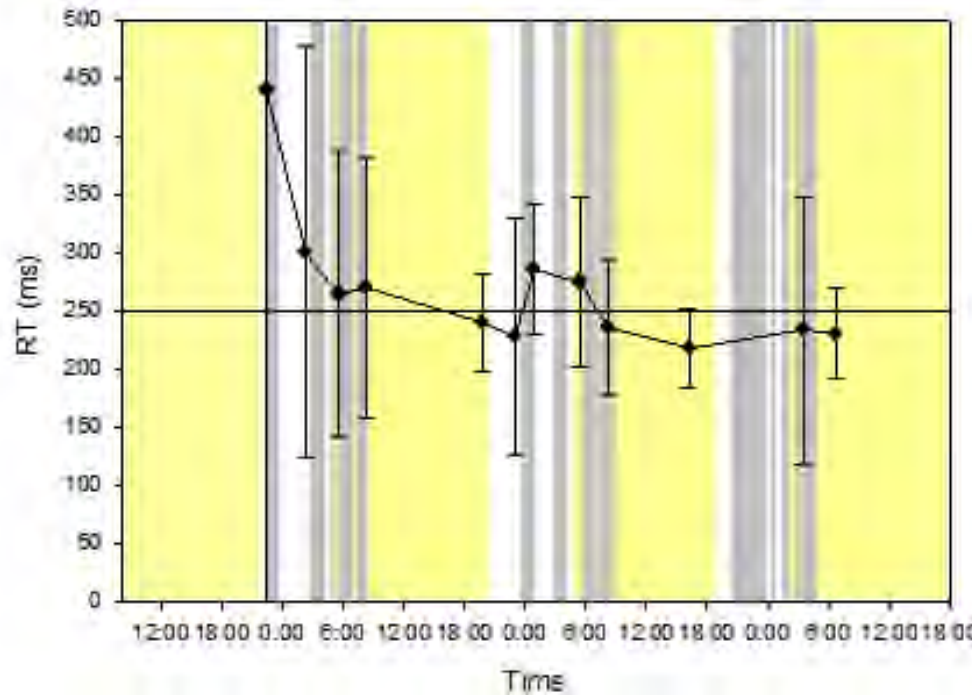
Effect of Predicted Circadian Alignment on Sleep Outcomes

	Aligned	Misaligned	
	Mean (SD)	Mean (SD)	p-value
Actigraphy Sleep Duration (h)	6.4 (1.2)	5.4 (1.4)	<0.01
Latency (m)	10.3 (15.0)	13.2 (25.2)	0.26
Number of Awakenings	1.7 (1.9)	1.7 (1.7)	0.38
Sleep Efficiency	89% (7%)	90% (7%)	0.26
Sleep Quality	66.8 (17.7)	60.2 (21.1)	<0.01
Alertness	57.9 (21.7)	53.5 (21.5)	0.13

Short Haul Aviation



Real World Example: 72 hour Continuous Operations



Managing Fatigue During Extended Duty Shifts



Determinants of Alertness and Performance

Circadian Rhythms

- The internal biological clock
- Controls sleep AND wake timing along with other biological function
- On a normal schedule worst performance/highest sleep drive will be between 3-5 AM
- Reset each day through daily light exposure
- Can be shifted by strategic control of light/dark as in jet-lag
- Blue light is the most potent synchronizer of the circadian rhythm

Acute Sleep Loss

- Defined as staying awake beyond the threshold of the homeostatic sleep drive (> 16 h)
- Performance deteriorates with time awake

Chronic Sleep Loss

- Defined as obtaining insufficient sleep over time, resulting in accumulation of sleep debt
- Sleep loss may be due to restricted sleep opportunity or fragmented sleep due to disruption
- Most individuals need 8-8.5 h of sleep
- Humans are very bad at recognizing when they are suffering from sleep deficiency, leading to a misconception about personal sleep need

Sleep Inertia

- Defined as the time it takes for your brain to fully “wake up” from sleep
- Associated with performance impairment from 30 minutes to 2 h following waking
- The magnitude of impairment arising from sleep inertia depends on the stage of sleep and circadian phase from when one was awoken

Individual Differences and Sleep Disorders

- Some individuals are more sensitive to sleep loss
- Untreated sleep disorders cause excessive daytime sleepiness and performance impairment even in an optimal sleep environment
- Individual susceptibility to sleep loss due to individual differences and sleep disorders may exacerbate cognitive impairment during irregular work episodes

Fatigue Countermeasures

Plan Circadian Friendly Schedules

- Shift sleep later whenever possible rather than earlier
- Use light (preferably blue) in the evening to enhance sleep shifts
- Use black out shades or an eye mask to prevent light exposure at the wrong time
- If shifting sleep earlier is required, then use bright light in the morning and keep it dark in the evening, even if you are not sleeping
- Avoid use of phones and devices that emit light in the hour before and after sleep times

Plan for Extended Duty Shifts and Acute Sleep Loss

- Use caffeine “little and often,” 50 mg every hour during extended wakefulness
- Take a 30-45 minute “power nap”
- Turn up the lights, go outside in the sun or turn on a blue light
- Take a taxi home

Mitigating Chronic Sleep Loss

- Allow enough time off for sleep, commuting, eating and showering
 - Mission leads should send people home to rest and monitor on-duty time
- Optimize sleep quality, use ear plugs, eye mask, black out shades
- Put a note on your hotel room door, discuss sleep needs with family
- When possible sleep in or take a nap to “catch up”
- Avoid light emitting devices before, during and after sleep
- Set the “do not disturb” function on your phone
- If you are not getting enough sleep

Avoiding Sleep Inertia

- Allow at least 30 minutes to wake up from sleep before making big decisions or driving
- Limit power naps to 30-45 minutes
- Consider taking caffeine right before a short nap to mitigate sleep inertia
- Turn on bright lights right away upon waking

Accounting for Individual Differences and Sleep Disorders

- If you have a sleep disorder, especially sleep apnea, ensure that you are compliant with your physician’s treatment
- If you think you have a sleep disorder talk to your physician before the intense workflow begins
- If you feel sleepy, then you are already passed the point of when you should sleep – prioritize sleep as soon as possible

Thank You



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