National Sleep Foundation
Sleep Health & Safety 2014
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Sleep in High Stress Occupations

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Disclosure

I have no relevant financial relationship with any commercial interest to disclose.

Physiological Limits to Performance

- Circadian time of day
- Number of hours awake (acute sleep debt)
- Cumulative sleep debt (chronic sleep debt)
- Time since awakening (sleep inertia)

Modifiers of Physiological Response

- Individual differences in susceptibility to sleep loss
- Sleep disorders

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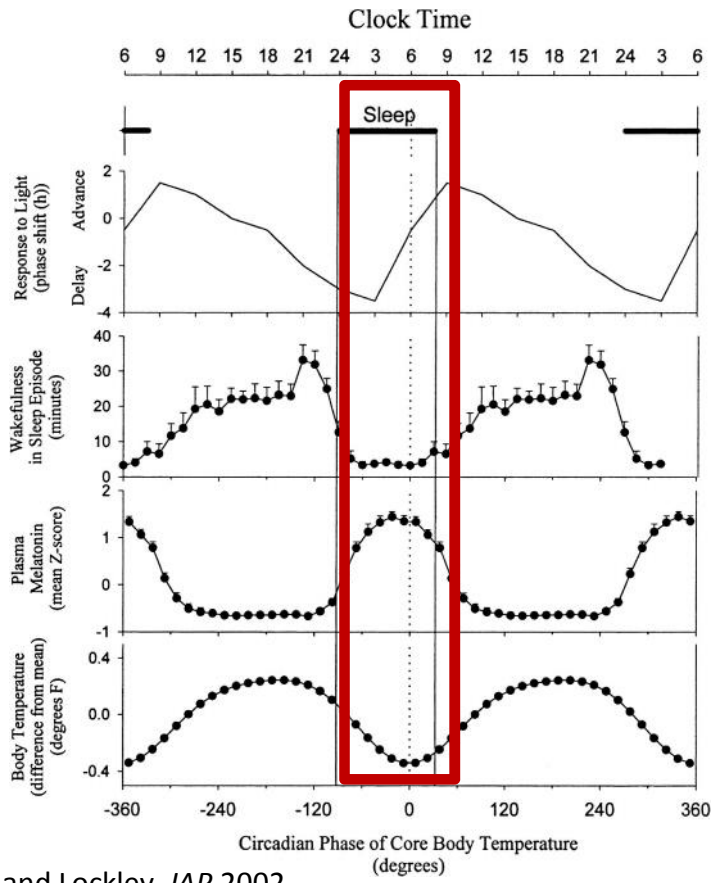
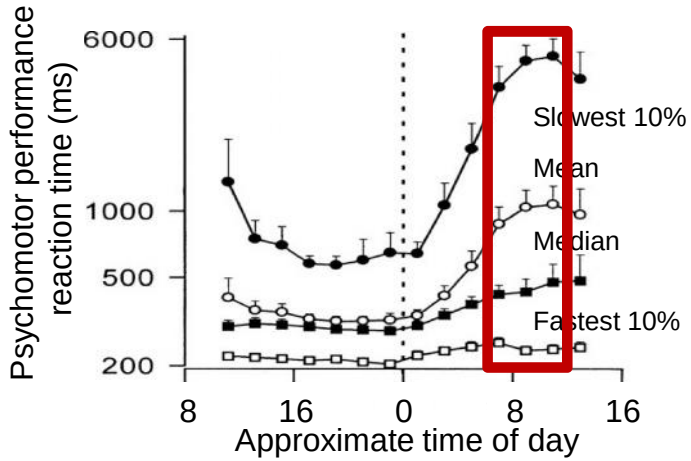
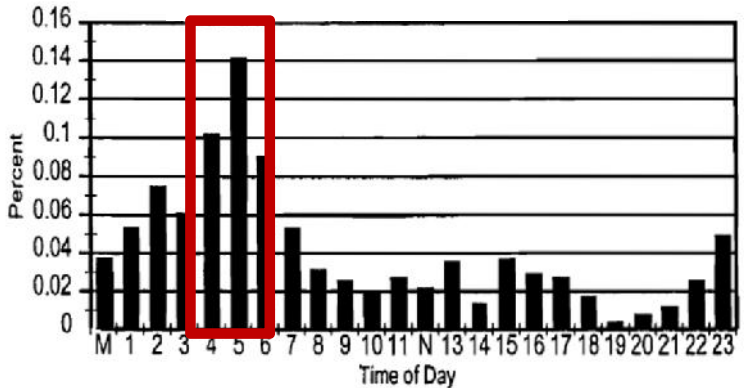
Circadian Nadir = Poorest Performance

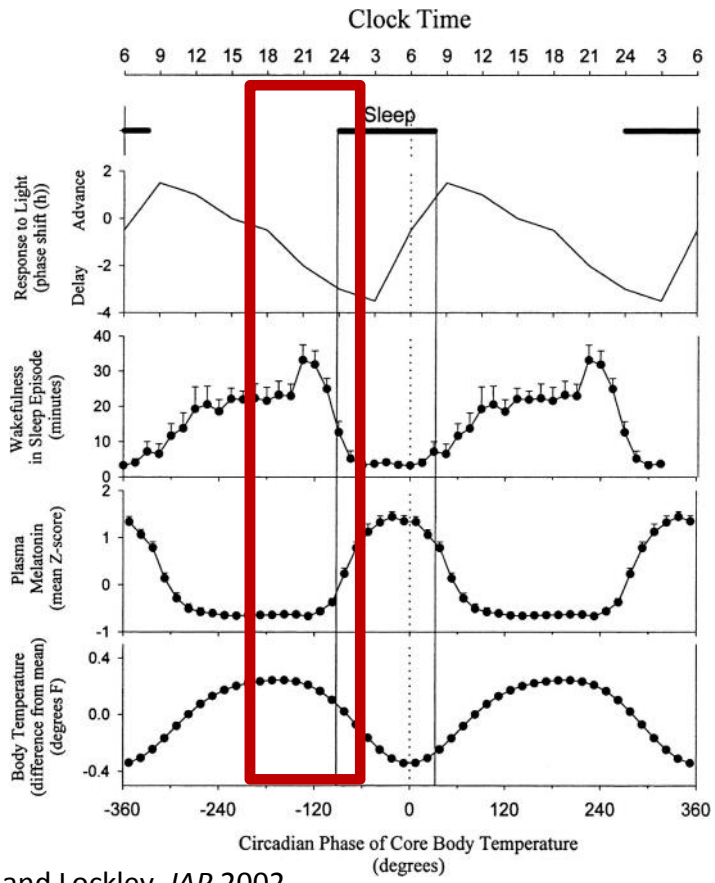


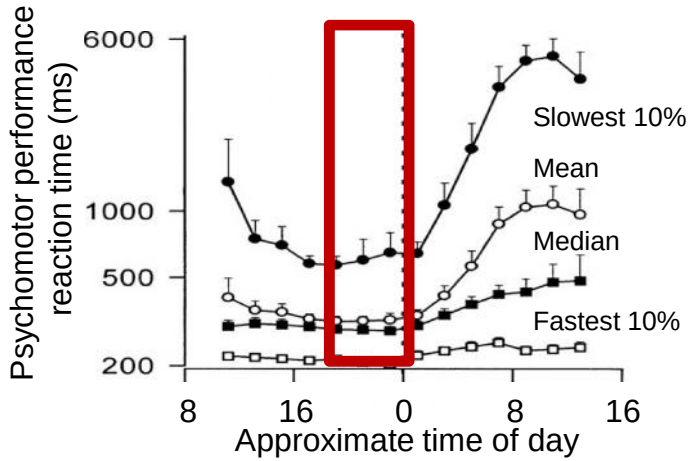


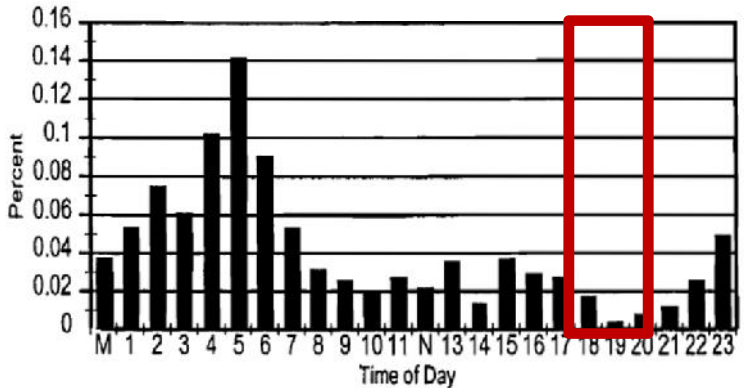


Dijk and Lockley, *JAP* 2002

Wake Maintenance Zone = Peak in Wakefulness







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FEATURE

Wide Awake on the Sea of Tranquillity **07.20.06**

This installment of Science@NASA's Apollo Chronicles explains why Neil Armstrong and Buzz Aldrin couldn't fall asleep in the Sea of Tranquillity.

Neil Armstrong was supposed to be asleep. The moonwalking was done. The moon rocks were stowed away. His ship was ready for departure. In just a few hours, the Eagle's ascent module would blast off the Moon, something no ship had ever done before, and Neil needed his wits about him. He curled up on the Eagle's engine cover and closed his eyes.

But he could not sleep.

Neither could Buzz Aldrin. In the cramped lander, Buzz had the sweet spot, the floor. He stretched out as much as he could in his spacesuit and closed his eyes. Nothing happened. On a day like this, sleep was out of the question.

The Eagle was not a sleepy place. The tiny cabin was noisy with pumps and bright with warning lights that couldn't be dimmed. Even the window shades were glowing, illuminated by intense sunshine outside. "After I got into my sleep stage and all settled down, I realized there was something else [bothering me]," said Armstrong. The Eagle had an optical telescope sticking out periscope-style. "Earth was shining right through the telescope into my eye. It was like a light bulb."

To get some relief, they closed the helmets of their spacesuits. It was quiet inside and they "wouldn't be breathing all the dust" they had tramped in after the moon walk, said Aldrin. Alas, it didn't work. The suit's cooling systems, so necessary out on the scorching lunar surface, were too cold for sleeping inside the Eagle. The best Aldrin managed was a "couple hours of mentally fitful drowsing." Armstrong simply stayed awake.

National Aeronautics
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CREW PARTICIPATION

n = 80 Missions

n = 60 Subjects

n = 26 Flights

PREFLIGHT:

- 2 weeks at L-90
  - "Normal sleep"
- L-11 through launch
  - Shift in sleep/wake cycle

THROUGHOUT SPACEFLIGHT MISSION

POSTFLIGHT:

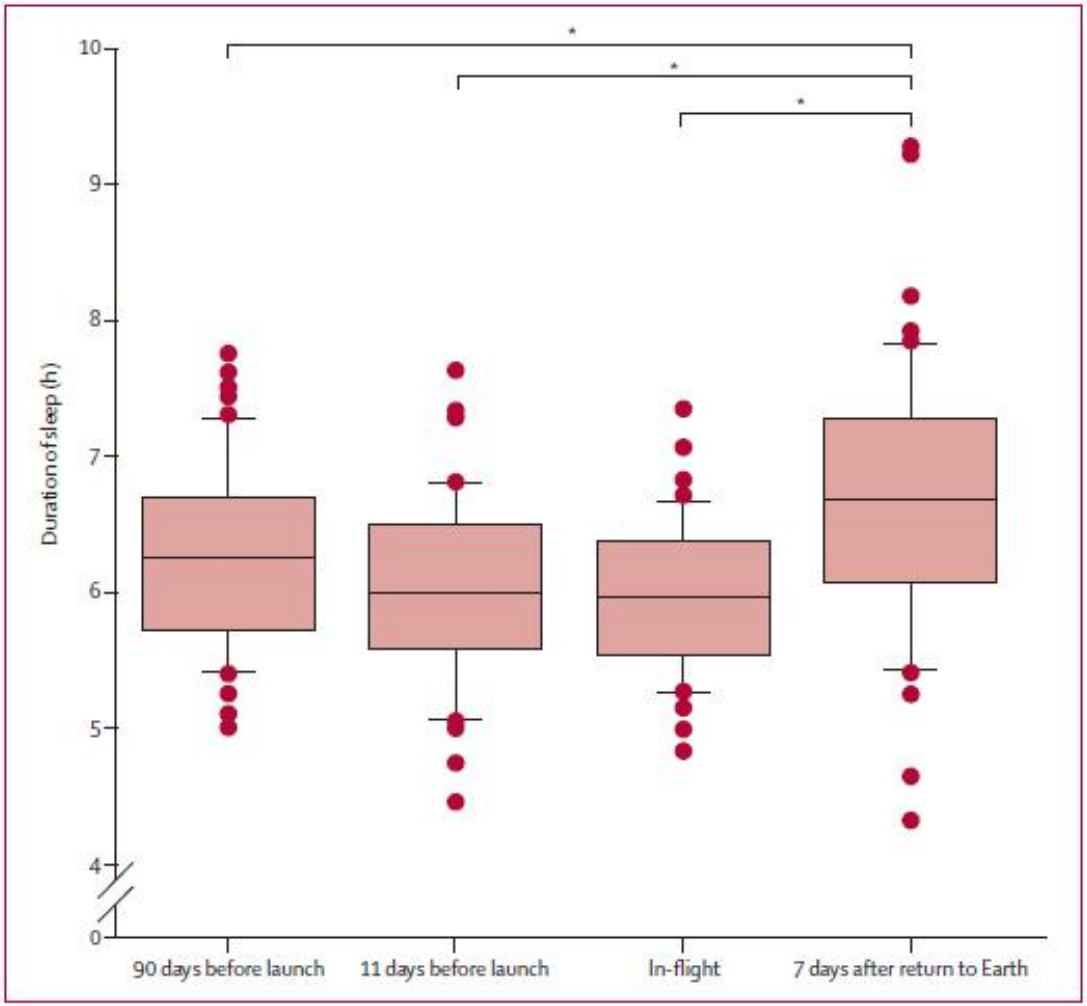
- R+0 through R+7

Self-Reported Causes of Sleep Disruption in Space

Most common reported causes of sleep disturbance	Percentage of disturbed nights[a]				
	L-90	L-11	Inflight	R+7	p
Voids	79 (54·9)	89 (68·5)	89 (25·5)	39 (50·0)	<0·0001
Noise	30 (20·8)	17 (13·1)	83 (23·8)	8 (10·3)	0·0081
Too cold	6 (4·2)	2 (1·5)	19 (5·4)	0 (0·0)	0·0593
Other crewmembers	0 (0·0)	0 (0·0)	11 (3·2)	0 (0·0)	0·0103
Too hot	8 (5·6)	4 (3·1)	65 (18·6)	4 (5·1)	<0·0001
Mission duties	8 (5·6)	12 (9·2)	32 (9·2)	4 (5·1)	0·3974
Physical discomfort	14 (9·7)	3 (2·3)	38 (10·9)	27 (34·6)	<0·0001

Barger *et al. Lancet Neuro*, 2014

Sleep Duration by Study Condition



Barger *et al. Lancet Neuro*, 2014

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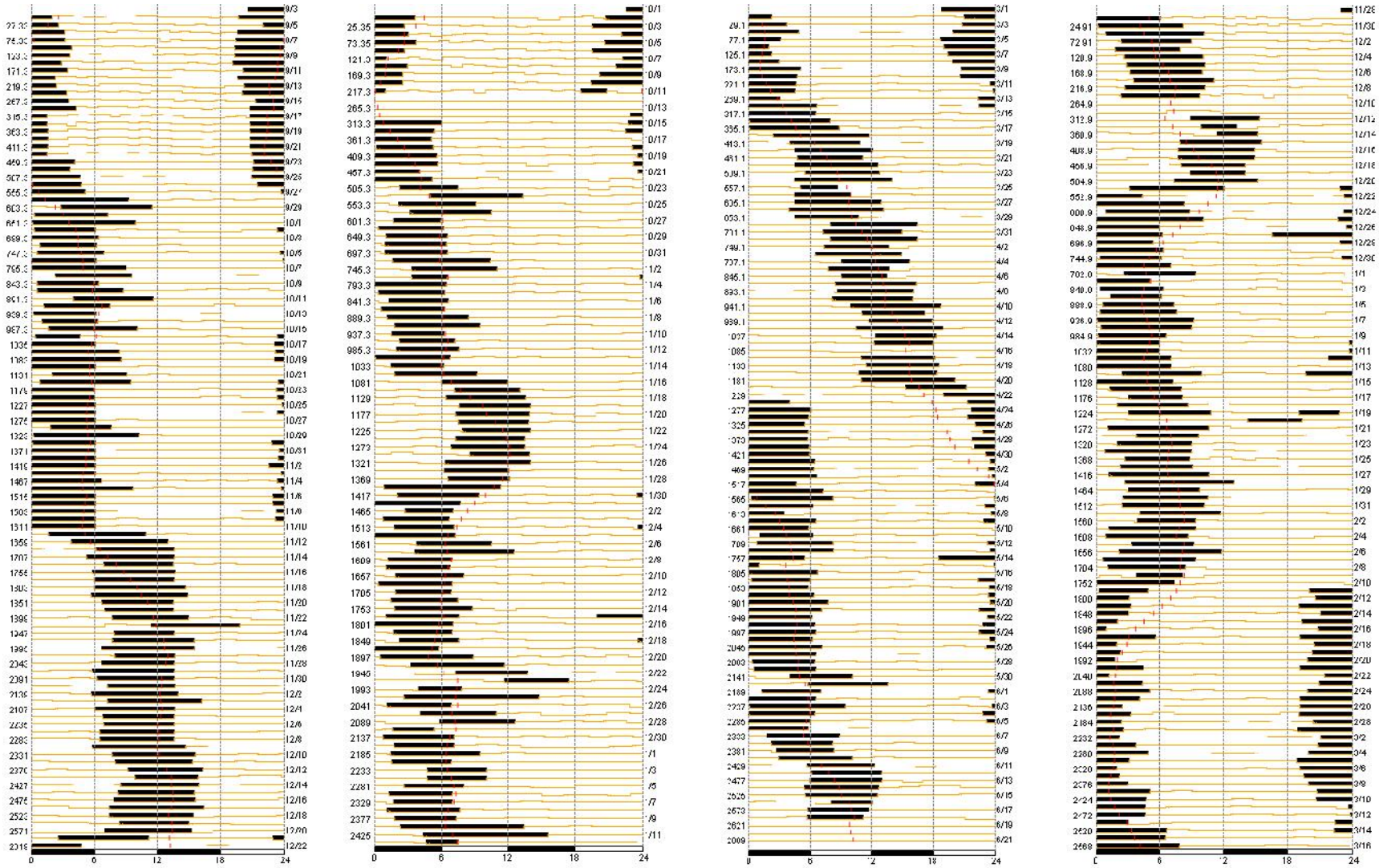
Sleep Outcomes by Sleep Medication Use and Non-use

	Nights without sleep-promoting drugs		Nights with sleep-promoting drugs		Difference between nights with and without drugs (95% CI)		p value	
	Shuttle (n=252)	ISS (n=255)	Shuttle (n=355)	ISS (n=69)	Shuttle (N=49)	ISS (N=9)	For difference (shuttle)	For difference (ISS)
Total sleep time (actigraphy; h)	5·82 (0·88)	6·17 (1·10)	6·00 (0·57)	6·75 (1·86)	0·19 (–0·01 to 0·38)	0·58 (–0·52 to 1·68)	0·0808	0·3884
Sleep efficiency (actigraphy; %)	86·6% (7·3)	87·0% (9·8)	87·9% (5·6)	90·6% (5·5)	1·3 (–0·2 to 2·8)	3·6 (–2·2 to 9·4)	0·0438	0·4227
Sleep latency* (diary; min)	35·16 (25·90)	20·95 (18·52)	24·12 (16·20)	12·48 (7·72)	–11·01 (–19·43 to –2·60)	–8·47 (–21·42 to 4·47)	0·0013	0·0254
Sleep quality (diary)†	57·98 (20·39)	59·45 (16·35)	65·97 (13·91)	66·62 (17·92)	8·59 (3·32 to 13·87)	7·17 (–3·14 to 17·48)	0·0419	0·5168
Alertness (diary)†	61·50 (17·74)	47·39 (24·40)	66·00 (15·98)	50·36 (23·95)	5·22 (1·57 to 8·87)	2·97 (–3·93 to 9·87)	0·1909	0·1837
Disturbed sleep (diary; %)	61·4% (36·5)	41·0% (25·2)	50·6% (34·4)	49·1% (43·0)	–14·1 (–23·6 to –4·5)	8·1 (–32·4 to 48·7)	0·0525	0·1119

Data are mean (SD), unless otherwise indicated. n represents the number of nights, whereas N is number of crew members. Mean, SD, mean difference, and 95% CI are based on raw data and p values are from statistical models.Data are mean (SD), based on raw data, or number (%); p values are from statistical models. *We excluded latency times of >240 min.†Ratings are from a 100 mm non-numeric visual analog scale. ISS=International Space Station. EVA=extra-vehicular activity.

***Table 3*: Sleep outcomes on nights aboard space shuttle and ISS missions with and without sleep-promoting drugs**

Barger *et al. Lancet Neuro*, 2014



Flynn-Evans *et al., In preparation*, 2014

Consequences of Circadian Misalignment

- 13% of nights misaligned during the L-11 block
- 20% of nights misaligned during flight
  - 27% of nights misaligned during vehicle/ISS docking
  - Sleep medication reported on 24% of misaligned nights and 11% of aligned nights

Flynn-Evans *et al., In preparation*, 2014

Consequences of Circadian Misalignment

	Aligned Mean (SD)	Misaligned Mean (SD)	p-value
Actigraphy Sleep Duration (h)	6.4 (1.2)	5.5 (1.4)	**<0.01**
Latency (m)	10.4 (15.1)	13.0 (24.9)	0.29
Number of Awakenings	1.7 (1.9)	1.8 (1.8)	0.36
Sleep Efficiency	89% (7%)	90% (7%)	0.18
Sleep Quality	66.8 (17.7)	60.2 (21.0)	**<0.01**
Alertness	57.9 (21.7)	53.5 (21.4)	0.14

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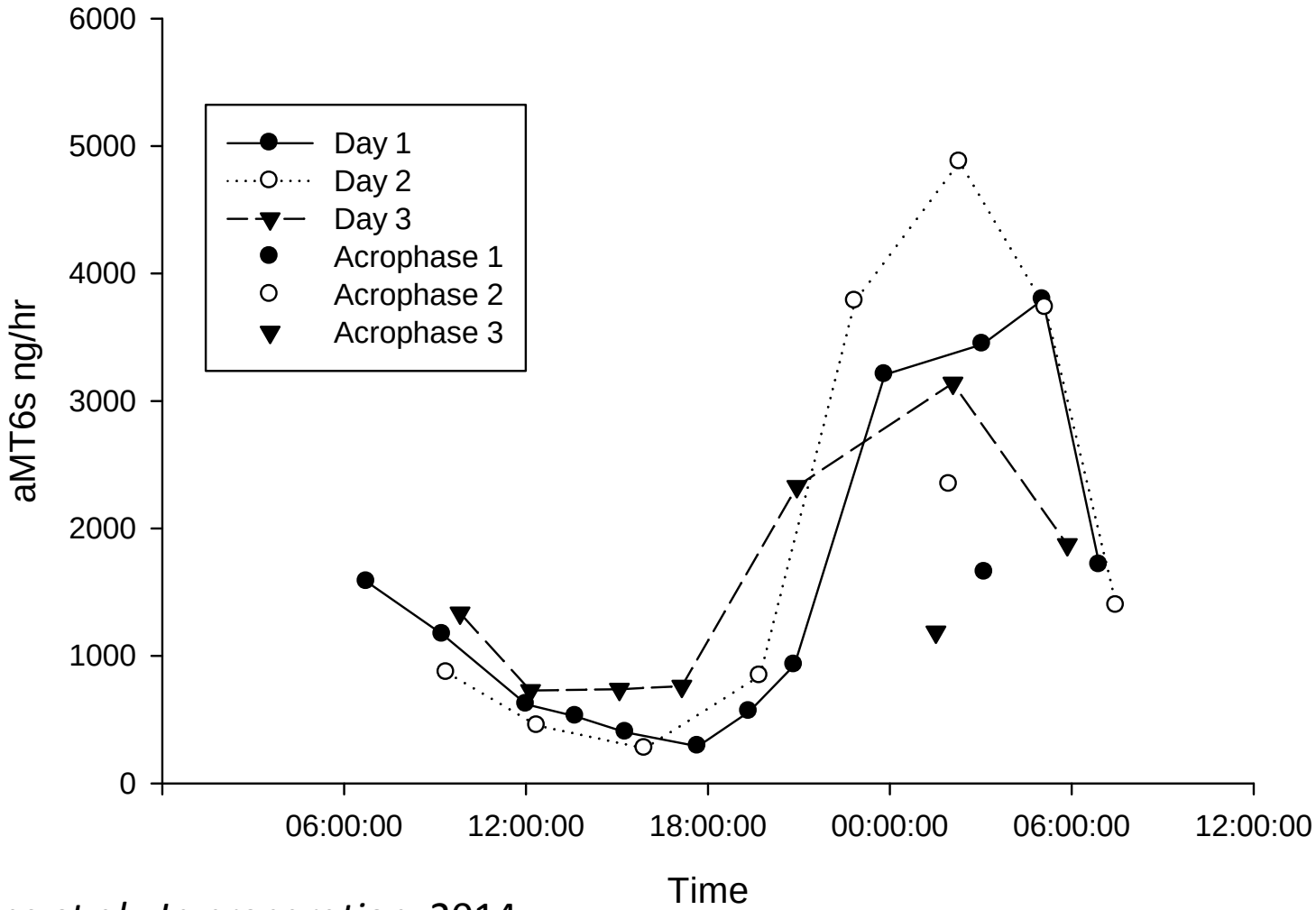
Circadian Phase Shift by Day of Simulation



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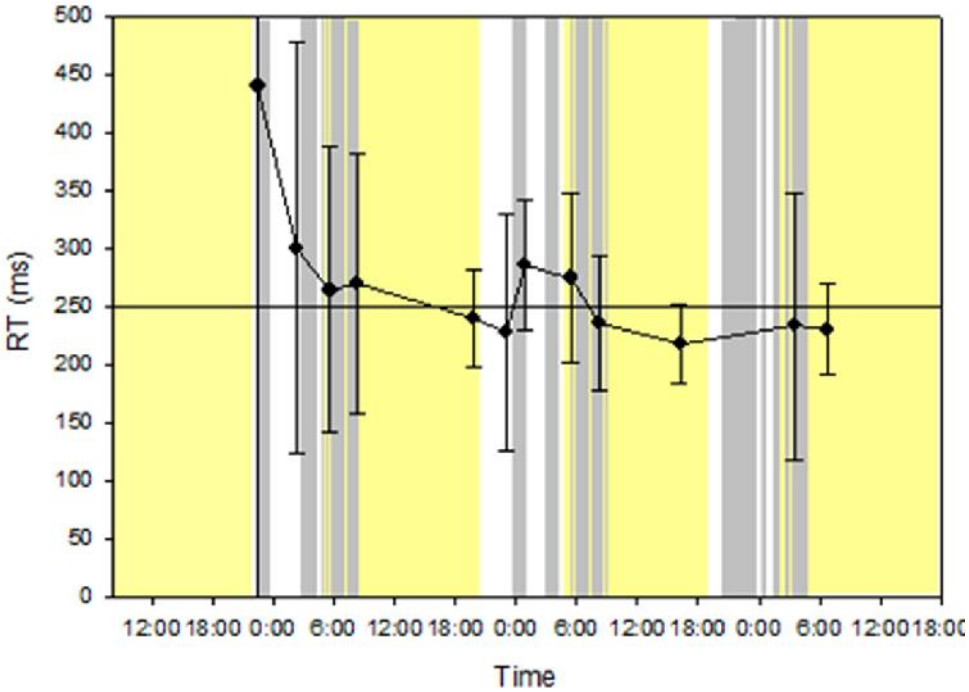
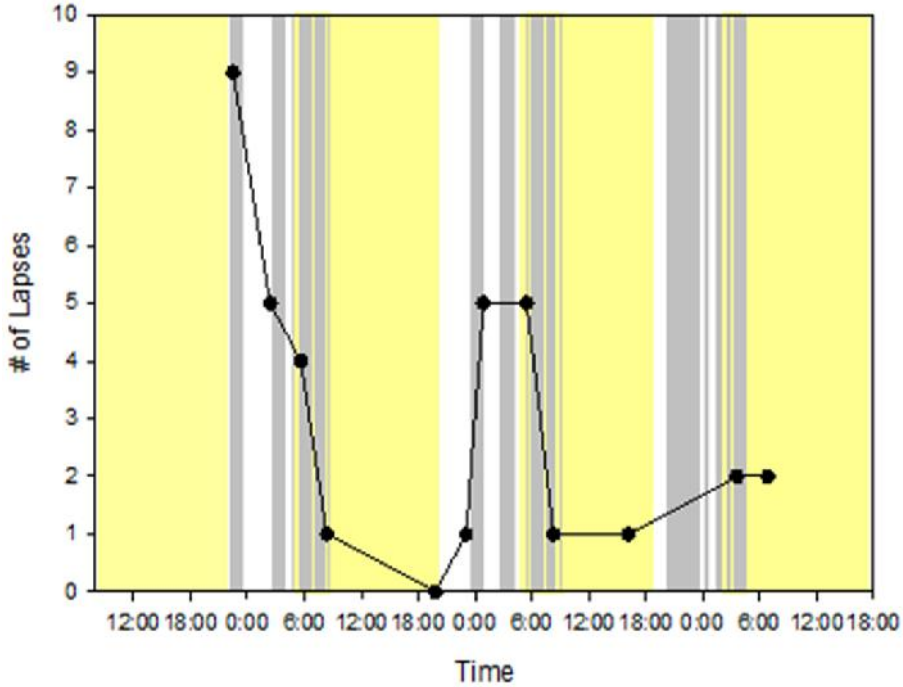
Performance Results





Flynn-Evans *et al., In preparation*, 2014

Short-Haul Airline Operations

Early Starts/Irregular Schedules

- Early morning starts are a circadian challenge
  - Circadian wake maintenance zone prevents early bedtime
- Irregular schedules prevent regular bed- and wake times
- Lead to chronic and acute sleep debt and circadian misalignment

Study Methods

- Systematic evaluation of schedule types
  - Baseline, early, evening, night schedules
  - Assessment during duty days and days off
- Outcomes
  - Hassle factors
  - PVT on iPod
  - Actigraphy
  - Sleep logs
  - Sleepiness scales, countermeasure logs
  - Urine collection for melatonin assessment
- Data Mining
  - Operational outcomes
  - Correlations with fatigue measures

n = 44 study
n = 13 urine collection

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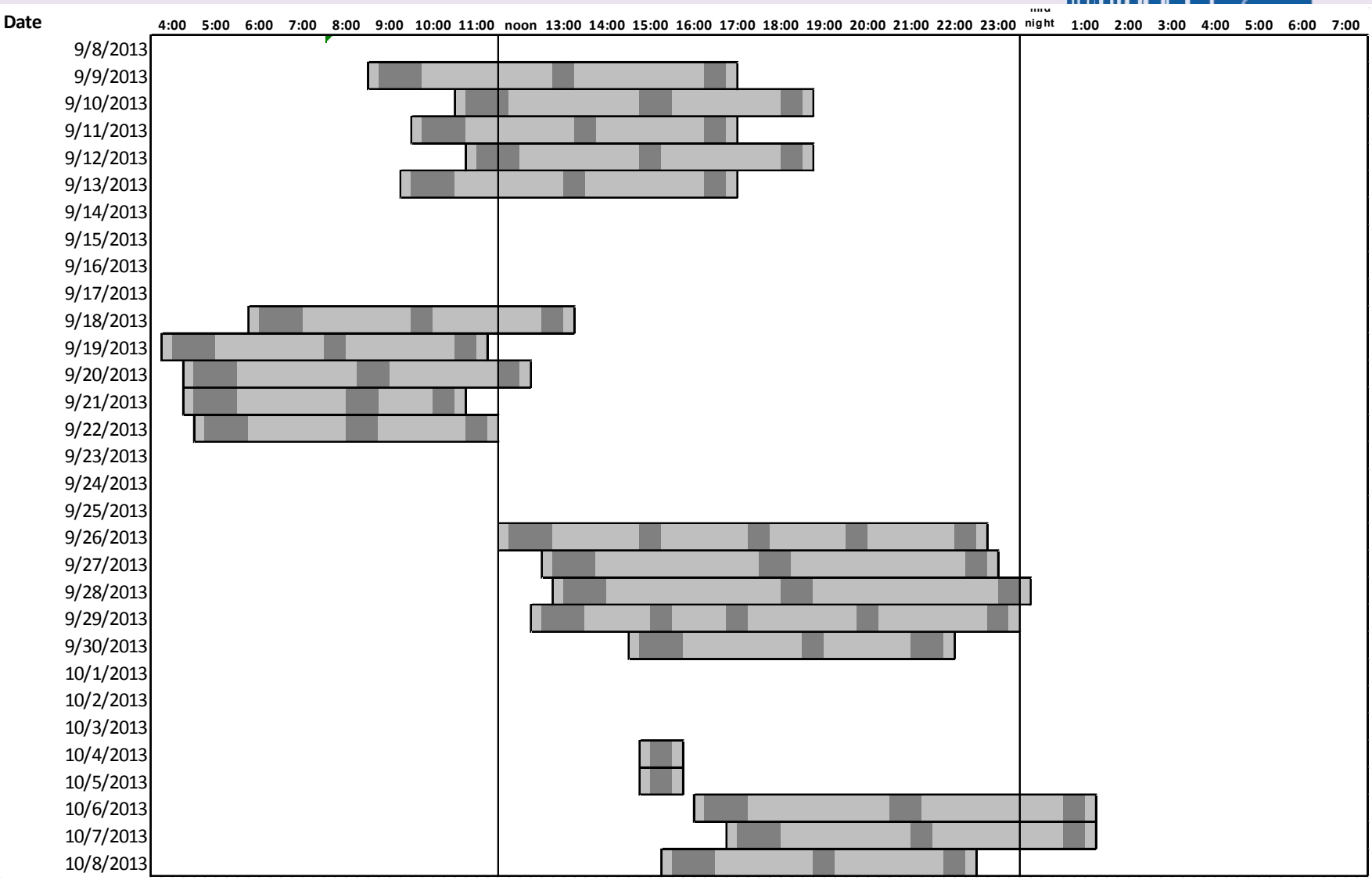

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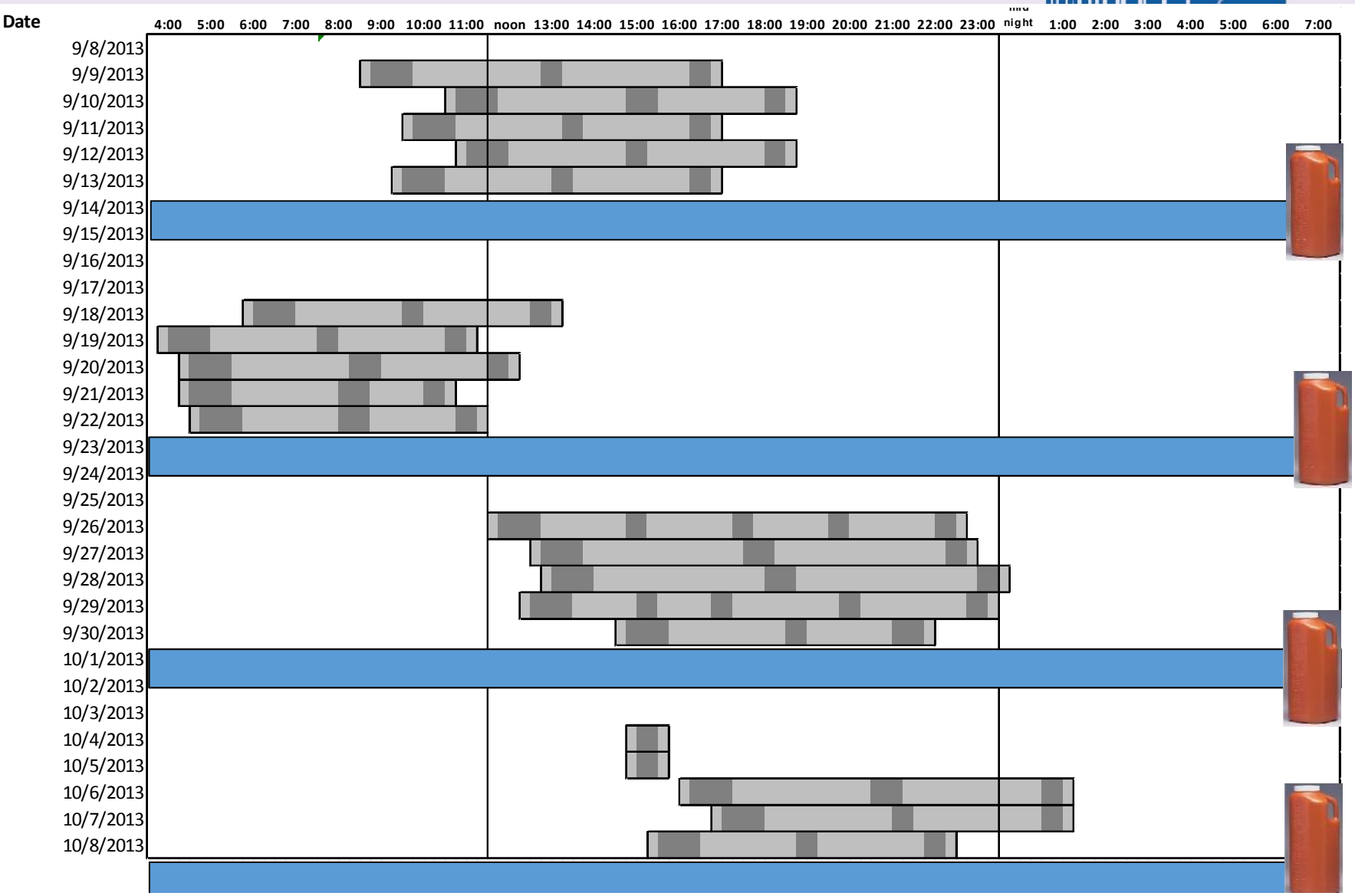
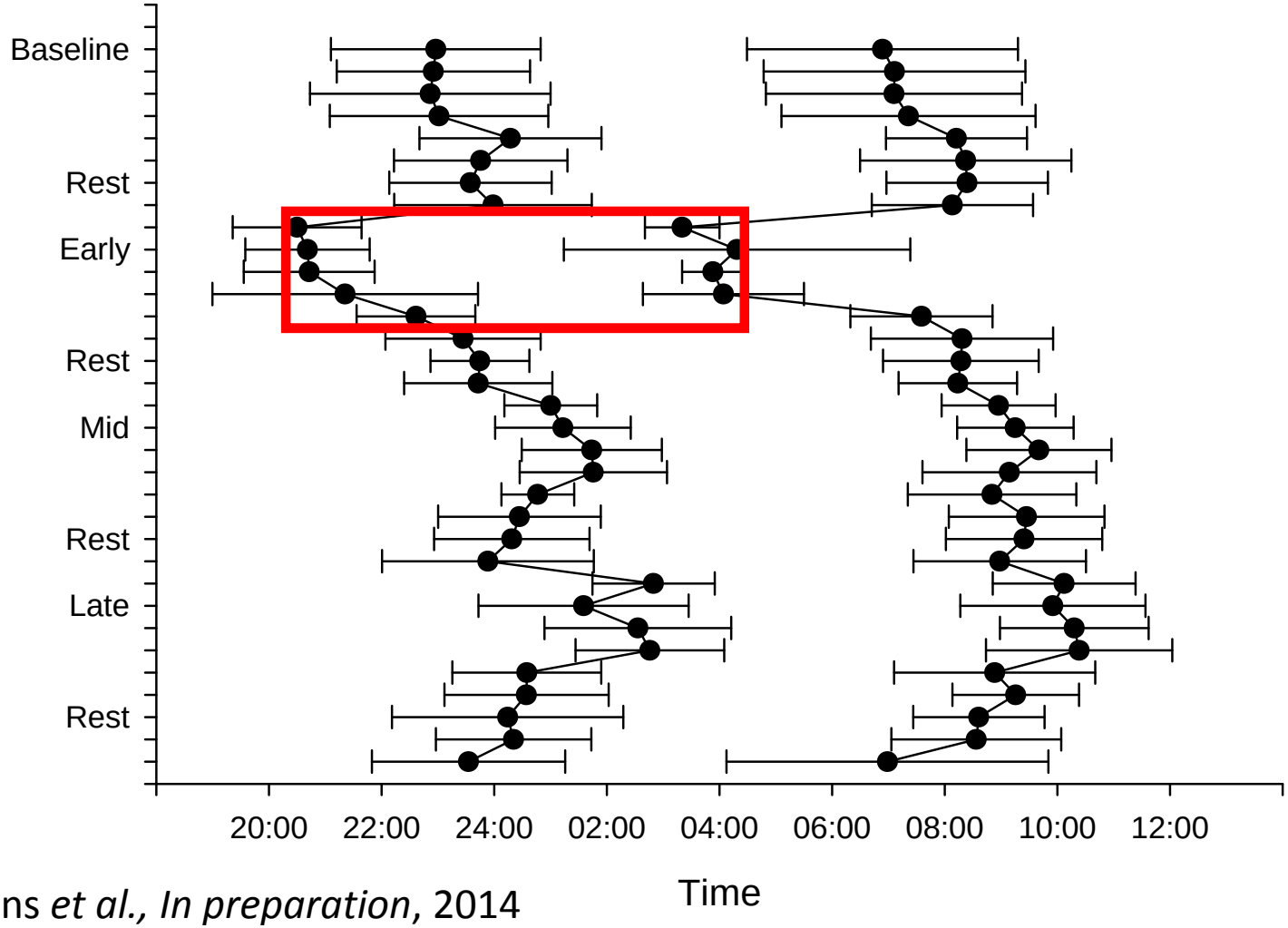


Bedtime and Wake Time by Schedule Type



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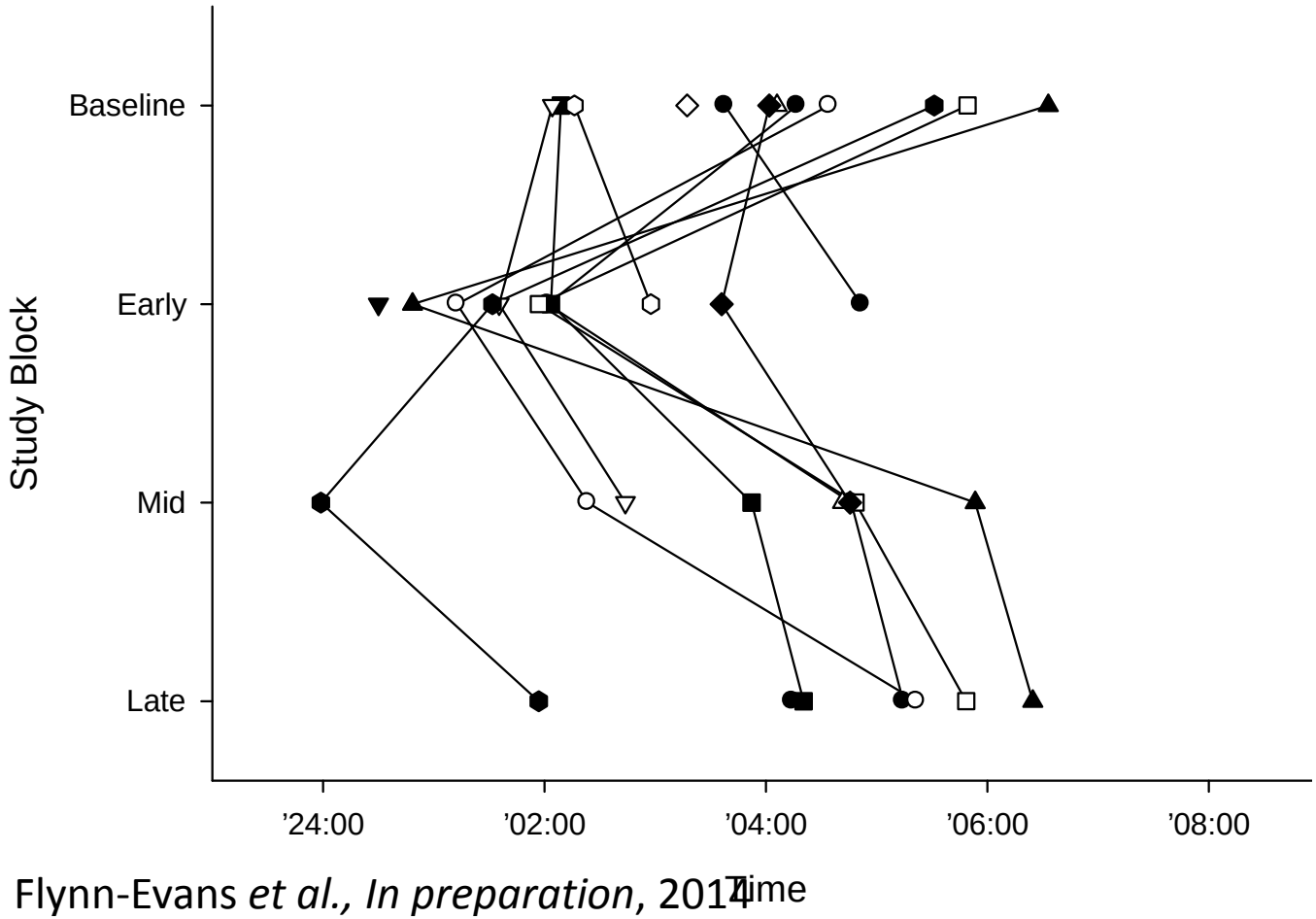
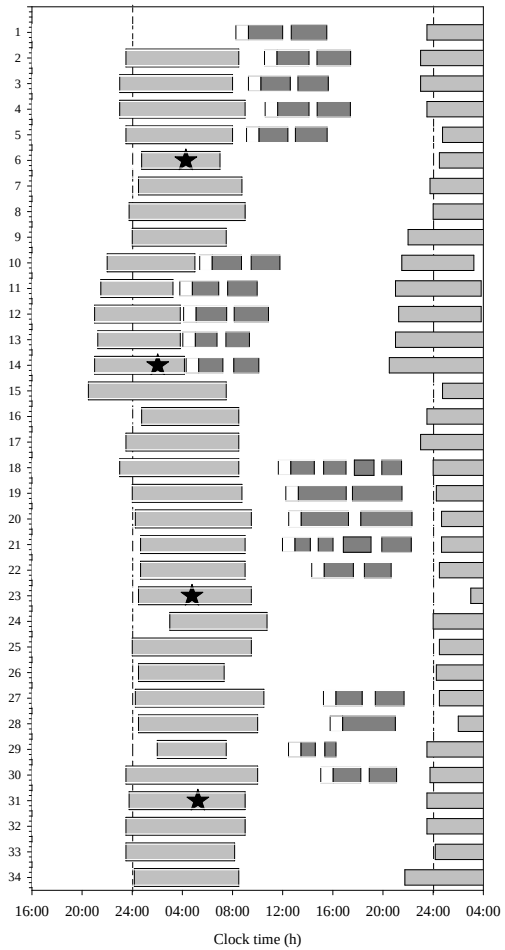
Circadian Phase Shifts by Schedule Type

Melatonin Acrophase by Individual





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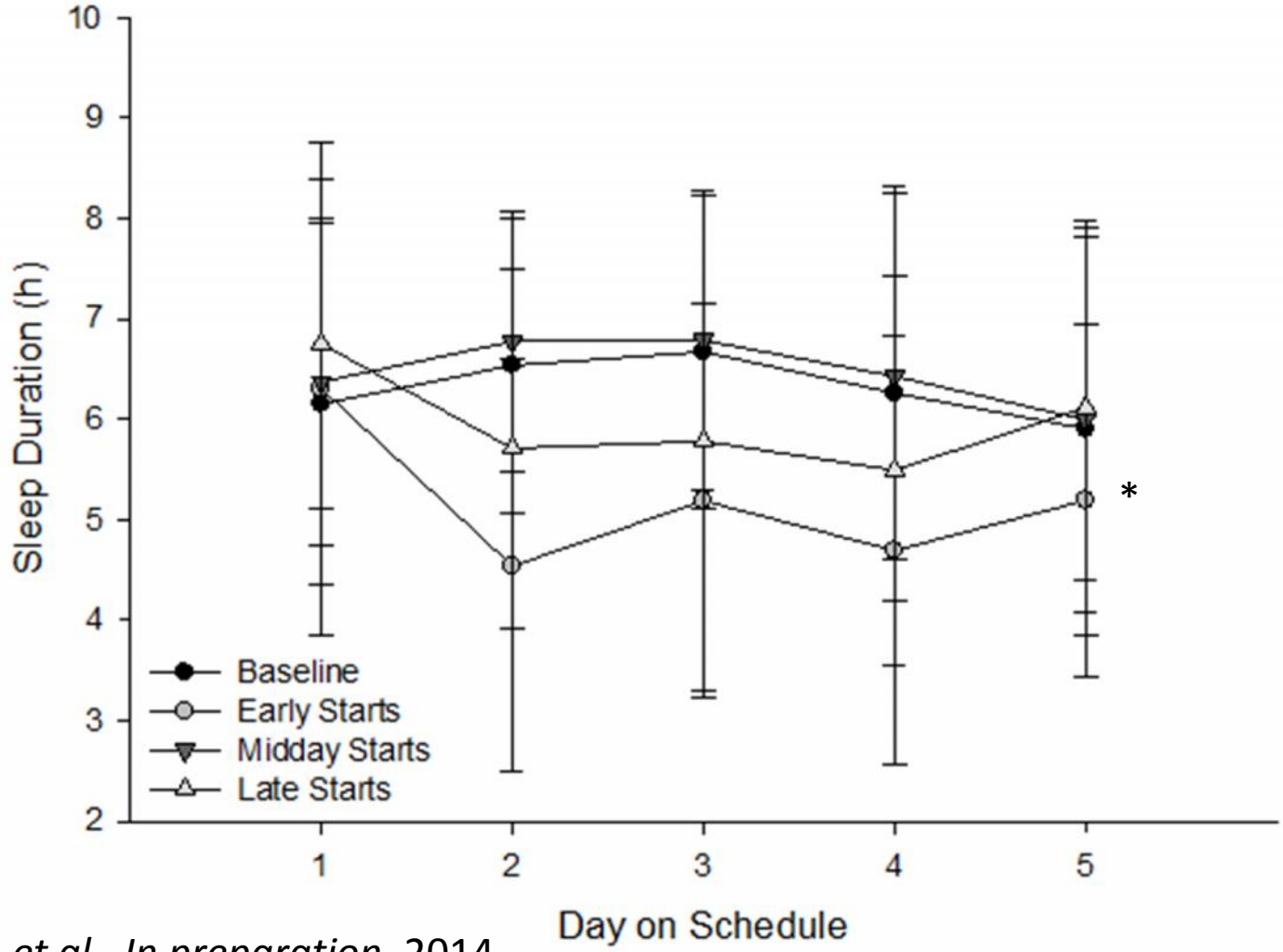
Sleep Duration Shorter on Early and Late Shifts



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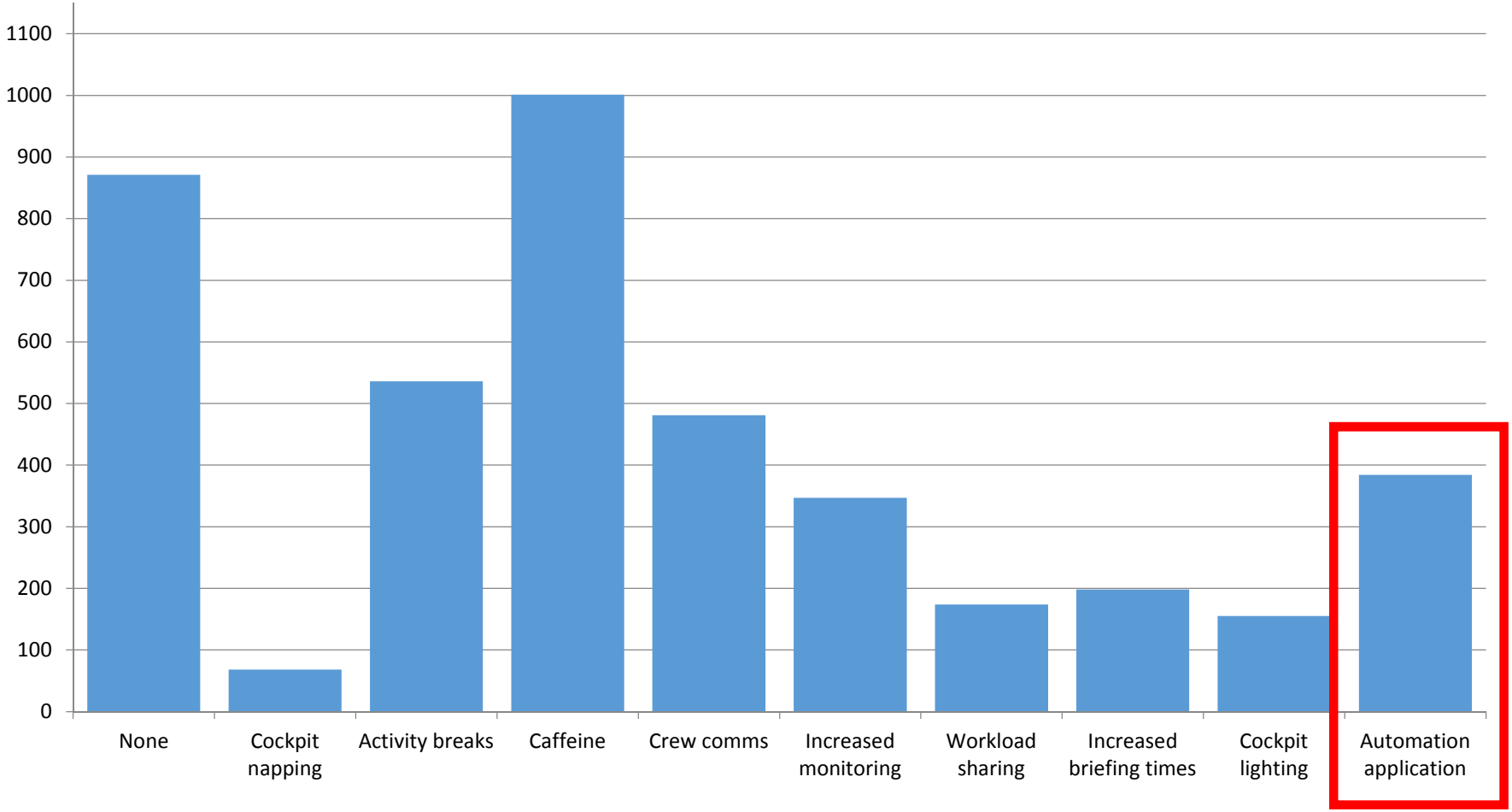
Countermeasures Used During Flight



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Key Practical Take Away Points

- Sleep loss remains a concern in spaceflight and aviation
- Circadian misalignment accounts for substantial sleep loss in many high stress environments
- Scheduling and light countermeasures available to facilitate increased sleep duration and performance enhancement
- Fatigue Risk Management Systems must provide better education about circadian misalignment and how to prepare operators for non-traditional shifts