Sleep in Space: The Space Shuttle, International Space Station and Beyond

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S122E008916

Environmental conditions are challenging

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FEATURE

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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.

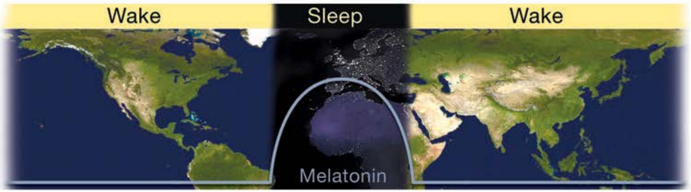
Neither could Buzz Aldrin. In the cramped lander, Buzz had the sweet spot, the floor. He stretched out as much as he could in his spacesuit and closed his eyes. Nothing happened. On a day like this, sleep was out of the question.

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 moonwalk, 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.

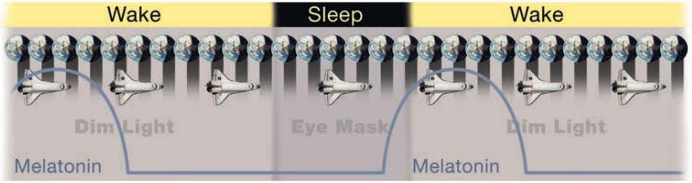
Earth Conditions

On a 24-hour external light/dark cycle, the body's circadian clock remains properly synchronized (e.g., hormones like melatonin are released at the appropriate time).

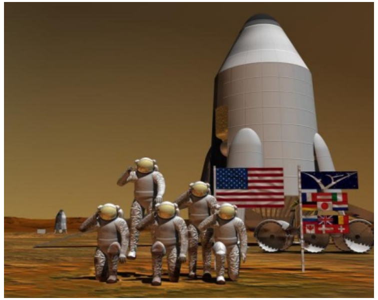


Space Conditions

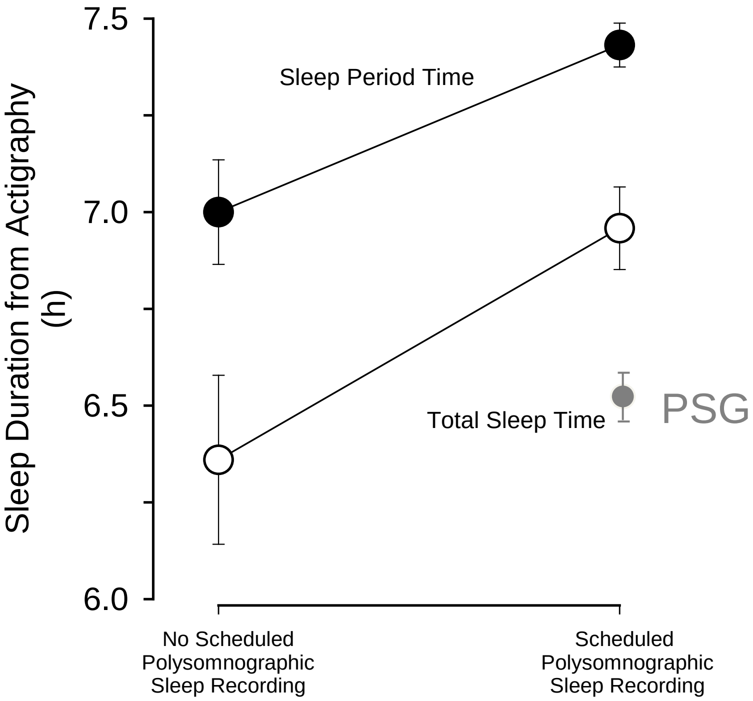
On the orbiter's 90-minute light/dark cycle, weak interior ambient light does not sufficiently cue the body's circadian clock, which may then become desynchronized (e.g., inappropriately timed hormone release).



Mars day length = 24.6 hours



Sleep recording on STS-90 and STS-95



Dijk D-J, Neri DF, Wyatt JK, Ronda JM, Riel E, Ritz-de Cecco A, Hughes RJ, Elliott AR, Prisk GK, West JB, Czeisler CA. Am J Physiol 2001; R1647-R1664.

Large-scale study of sleep in space

Systematic review

We searched PubMed on June 22, 2014, to identify previous studies of sleep outcomes during spaceflight. Search terms were "human," "astronaut," and "sleep". This search yielded 88 candidate manuscripts. We narrowed our search to original reports, written in English, that included sleep duration measured objectively (with actigraphy or polysomnography) during spaceflight, and that were published during the interval from October 4, 1957 (the day that Sputnik 1 launched) to June 22, 2014. In cases where more than one manuscript included data for the same cohort of astronauts, we included only one manuscript. Six studies met those criteria, with an average of four participants (range one to seven) per study and a cumulative total of 25 crew members studied during the 57-year interval.

Barger *et al.*, *Lancet Neurology*, 2014 reports on the most extensive study of sleep during spaceflight ever done, with more than half of all eligible crew members completing the study. 64 astronauts on 80 space shuttle missions (26 flights, 1063 in-flight days) and 21 astronauts on 13 ISS missions (3,248 in-flight days), with **ground-based data from all astronauts (4,014 days)** and more than **4,311 nights of sleep recording in space.**

Barger LK, Flynn-Evans EE, Kubey A, Walsh L, Ronda JM, Wang W, Wright KP, Czeisler CA. Prevalence of sleep deficiency and use of hypnotic drugs in astronauts before, during, and after spaceflight. Lancet Neurol 2014; 13: 904-912.

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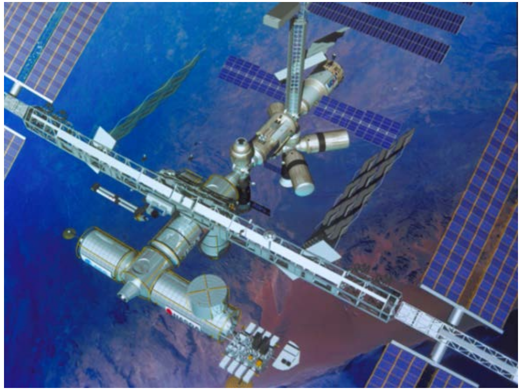
Crew Participation

	Mission	Completed study			Mission	Completed study
1	STS-104	1		*12*	STS-122	3
	STS-107	0		*13*	STS-123	3
	STS-108	0		*14*	STS-124	2
2	STS-109	1		*15*	STS-125	4
	STS-110	0		*16*	STS-126	6
3	STS-111	2		*17*	STS-119	2
4	STS-112	2		*18*	STS-127	2
5	STS-113	4		*19*	STS-128	4
6	STS-114	2		*20*	STS-129	5
7	STS-121	4		*21*	STS-130	3
8	STS-115	6		*22*	STS-131	3
9	STS-116	1		*23*	STS-132	4
	STS-117	0		*24*	STS-133	3
10	STS-118	4		*25*	STS-134	2
11	STS-120	6		*26*	STS-135	1
					Total	**80**



- 21 ISS crewmembers participated in the study
- Increments 14-24 (2006-2011)
- Generally ~3-6 month missions (mean = 155 $\pm$ 39 days)

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Protocol

Flight Sleep Log

<u>PREFLIGHT</u>:

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

<u>THROUGHOUT SPACEFLIGHT MISSION</u>

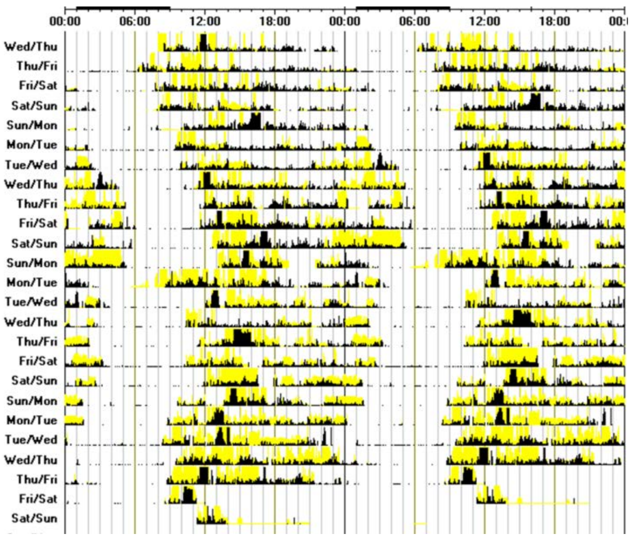
<u>POSTFLIGHT</u>:

- R+0 through R+7
  - Recovery sleep

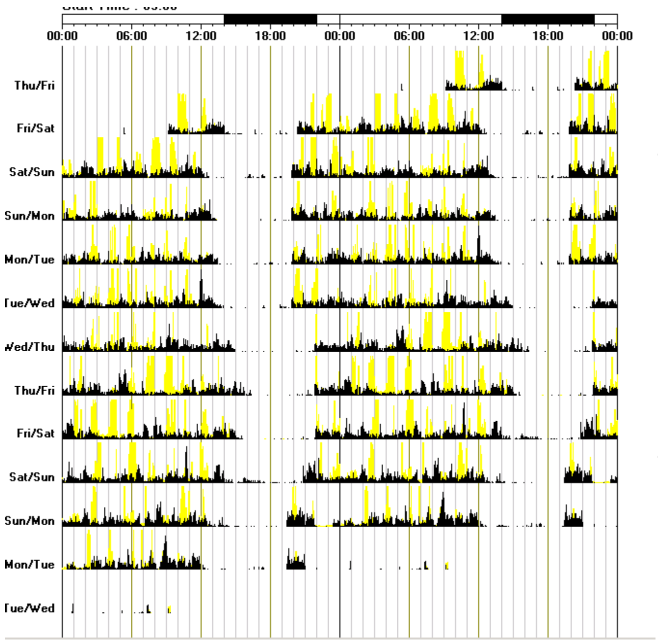
* No restriction on behavior during data collection periods

Actigraphy

L-11



Flight



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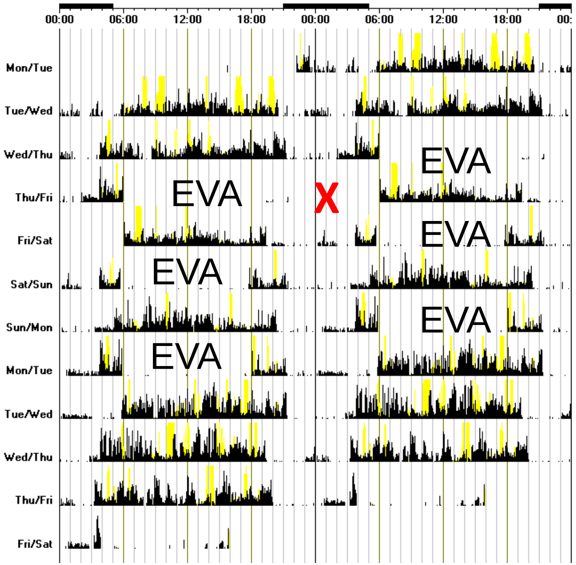

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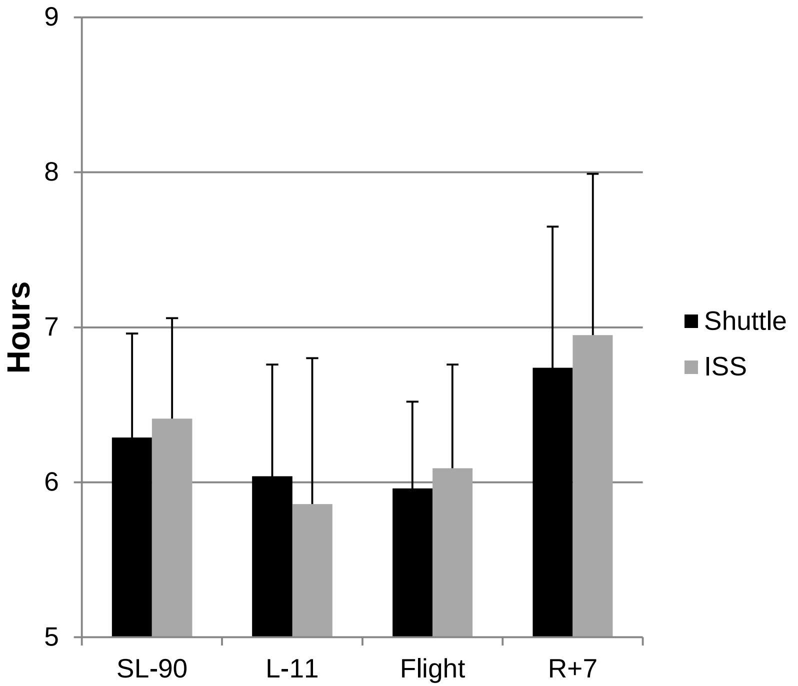
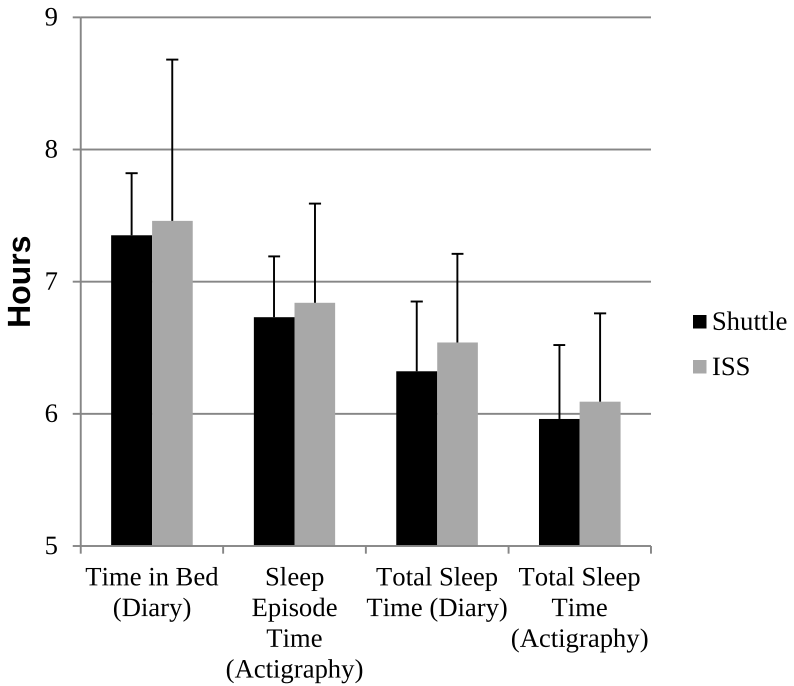
Sleep on shuttle and ISS missions





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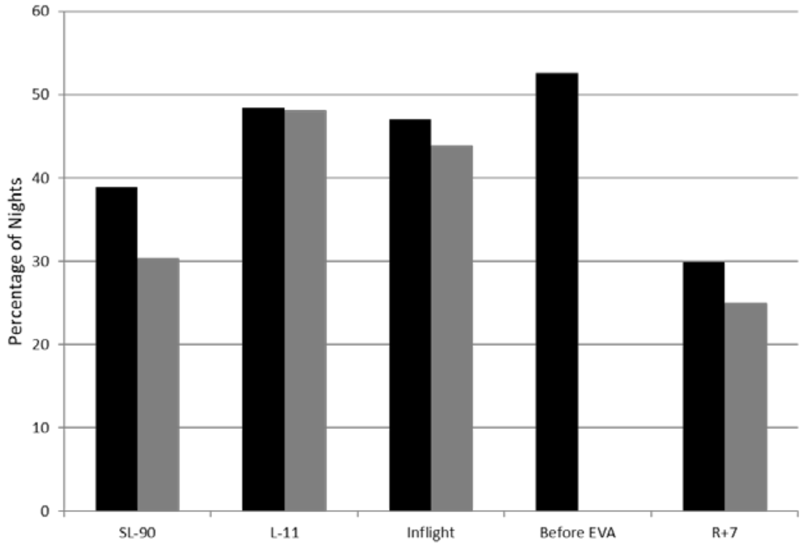

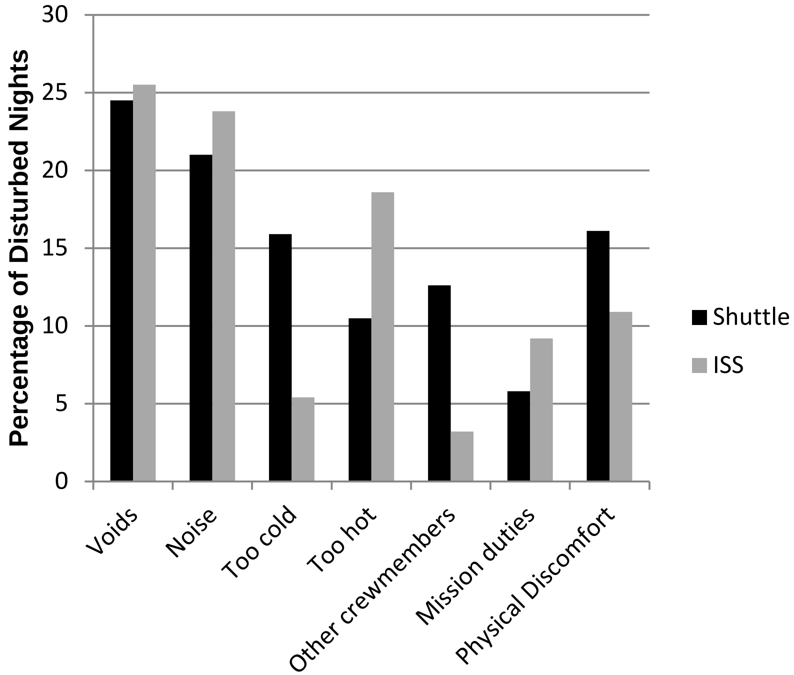

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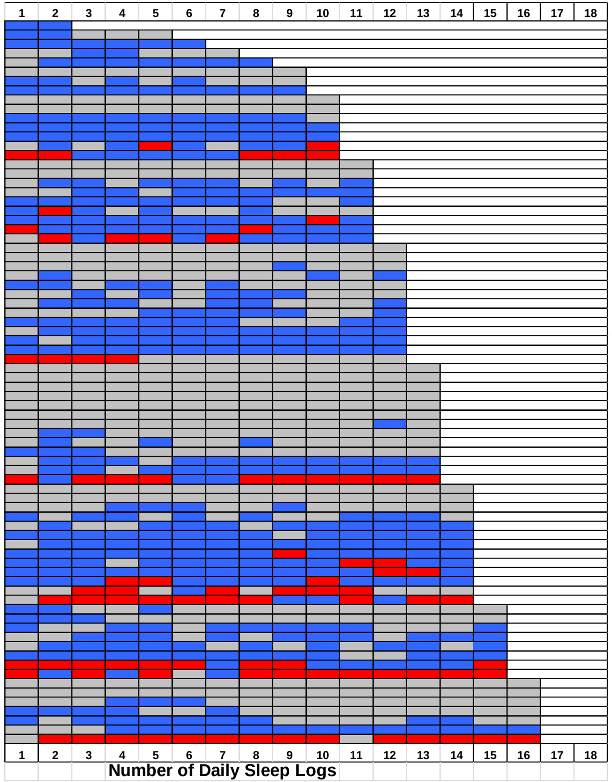
Use of Sleep Promoting Medications



	SL-90	L-11	**Flight**	R+7	Nights before EVA
Percentage of mission-crewmembers	27	72	**78**	25	70
Percentage of nights	5	33	**52**	8	60

- 2 doses of sleep medication were reported on 17% of the nights when medication was used
- Incidence of sleep medication use in space is 20 times greater than general population in U.S.

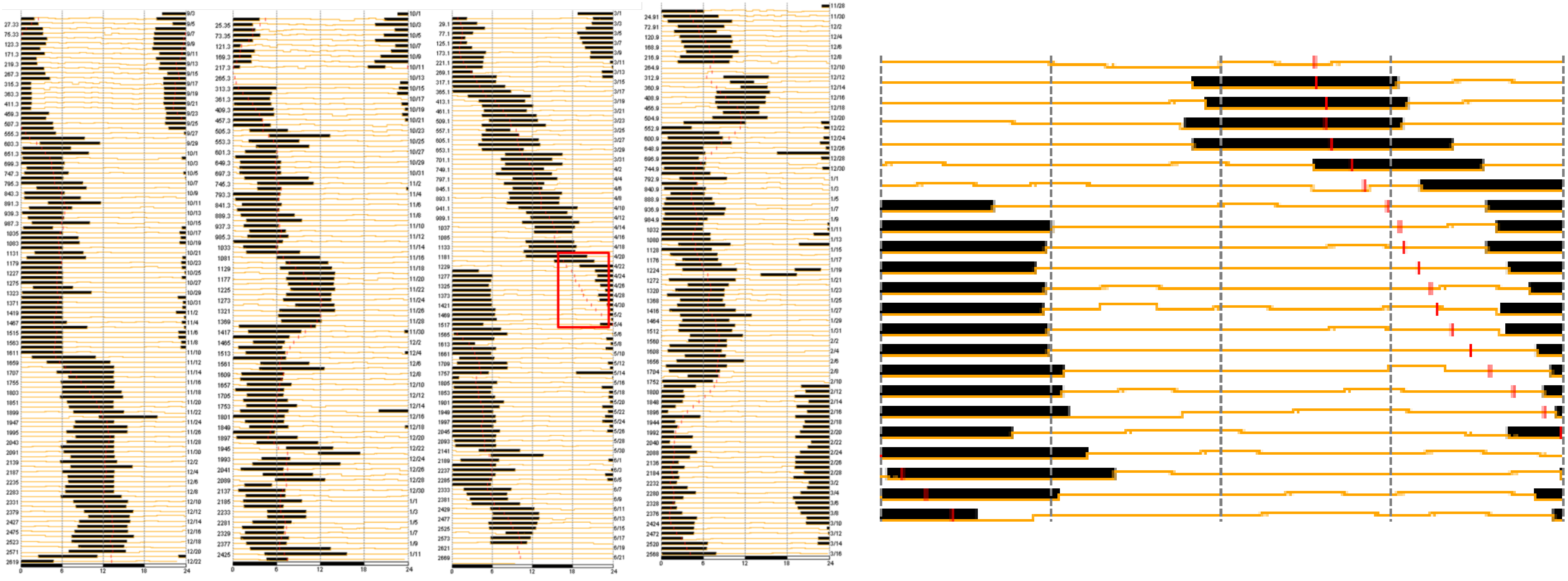
	Nights without sleep-promoting drugs		Nights with sleep-promoting drugs		Difference between nights with and without drugs (95% CI)		p value	
	Shuttle (n=252)	ISS (n=255)	Shuttle (n=355)	ISS (n=69)	Shuttle (N=49)	ISS (N=9)	For difference (shuttle)	For difference (ISS)
Total sleep time (actigraphy; h)	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 LK, Flynn-Evans EE, Kubey A, Walsh L, Ronda JM, Wang W, Wright KP, Czeisler CA. Prevalence of sleep deficiency and use of hypnotic drugs in astronauts before, during, and after spaceflight. Lancet Neurol 2014; 13: 904-912.

Frequent shifts in sleep-wake cycle on ISS missions



Flynn-Evans, EE, Barger, LK, Kubey, AA, Sullivan, JP and Czeisler, CA. Circadian misalignment affects sleep and medication use before and during spaceflight. Nature Micrograviry. 2016. Jan 7. doi:10.1038/npjmgrav.2015.19

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Effect of predicted circadian alignment on sleep outcomes

	Aligned Mean (SD)	Misaligned 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

- Sleep-promoting medication reported on 24% of misaligned nights and 11% of aligned nights
- Any medication reported on 63% of misaligned nights and 49% of aligned nights

Flynn-Evans, EE, Barger, LK, Kubey, AA, Sullivan, JP and Czeisler, CA. Circadian misalignment affects sleep and medication use before and during spaceflight. Nature Microgravity. 2016. Jan 7. doi:10.1038/npjmgrav.2015.19

Phoenix Mars Lander

- Launched: August 4, 2007
- Landed: May 25, 2008
- All scientists and engineers worked on a Mars sol schedule
- Switch to Earth time: August 11, 2008
- Feathering to remote operations at end of August, 2008
- Mission complete: September 30, 2008

Challenges of Martian Sol

- 24.65 hours Martian day presents a physiological challenge
  - ~ 39 additional minutes each day
- Mars sol equivalent to crossing 2 time zone every 3 days
- Laboratory simulation studies have shown the physiological challenges (increased sleep disturbances, decreased alertness and performance) and the benefits of lighting countermeasures

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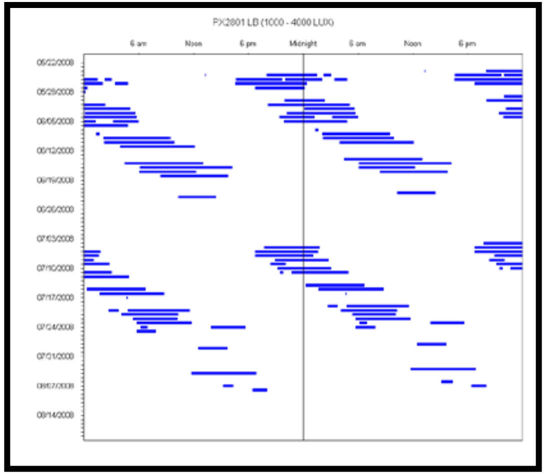
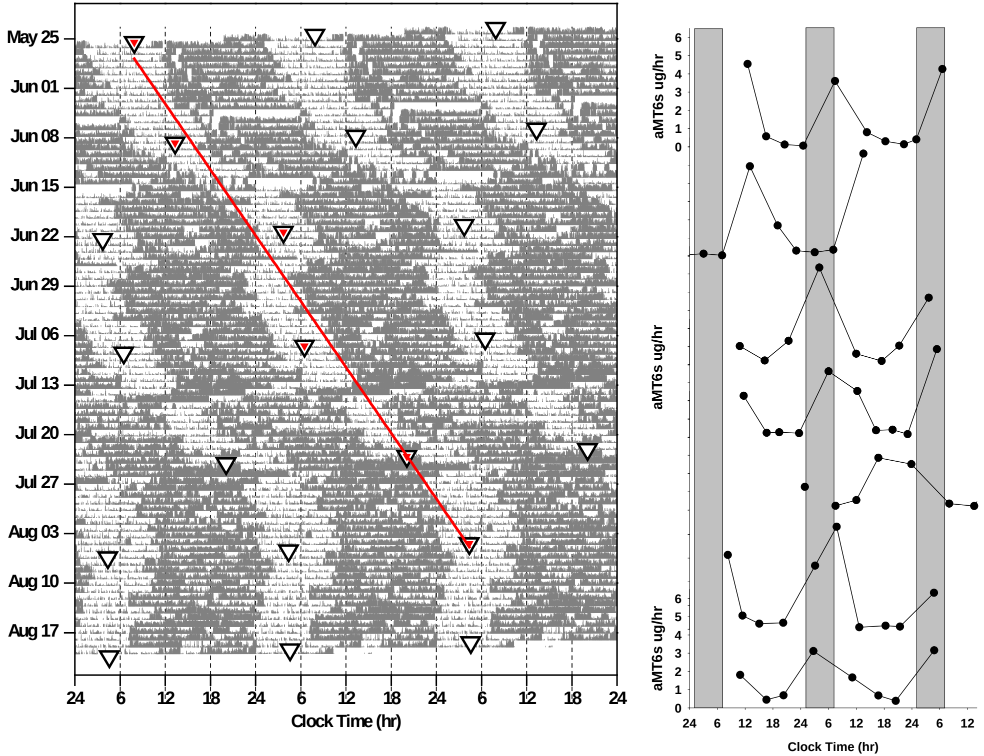
Blue-enriched light facilitated adjustment to 24.6 hour day





PX2801: 24.63±0.05 hours, r^2=0.97

Barger LK, Sullivan JP, Vincent, AS, Fiedler, ER, McKenna, LM, Flynn-Evans, EE, Gilliland, K, Sipes, WE, Smith, PH, Brainard, GC, Lockley SW. Learning To Live on a Martian Day: Fatigue Countermeasures during the Phoenix Mars Lander Mission. Sleep 2012; 35(10):1423-35.

Future Directions

- New lighting was recently installed on ISS and is currently being evaluated to see if it helps with circadian challenges.
- The monitoring and evaluation of sleep duration and timing should continue in future spaceflight missions as a medical requirement including baseline data collection prior to astronaut selection for flight to estimate more accurately individual baseline sleep duration.
- Randomized clinical trial of sleep-promoting medications in space (marginal benefits vs. associated risks)
- The development of other effective countermeasures to promote sleep inflight is essential, and may include scheduling modifications and behavioral strategies to ensure adequate sleep, which is essential for maintaining health, performance and safety.

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