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

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Environmental conditions are challenging

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

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.

Crew Participation

<table>
<thead>
<tr>
<th>Mission</th>
<th>Completed study</th>
<th>Mission</th>
<th>Completed study</th>
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<tbody>
<tr>
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<td>12 STS-122</td>
<td>3</td>
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<td>6</td>
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<tr>
<td>3 STS-111</td>
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<td>4 STS-112</td>
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<td>18 STS-127</td>
<td>2</td>
</tr>
<tr>
<td>5 STS-113</td>
<td>4</td>
<td>19 STS-128</td>
<td>4</td>
</tr>
<tr>
<td>6 STS-114</td>
<td>2</td>
<td>20 STS-129</td>
<td>5</td>
</tr>
<tr>
<td>7 STS-121</td>
<td>4</td>
<td>21 STS-130</td>
<td>3</td>
</tr>
<tr>
<td>8 STS-115</td>
<td>6</td>
<td>22 STS-131</td>
<td>3</td>
</tr>
<tr>
<td>9 STS-116</td>
<td>1</td>
<td>23 STS-132</td>
<td>4</td>
</tr>
<tr>
<td>10 STS-117</td>
<td>0</td>
<td>24 STS-133</td>
<td>3</td>
</tr>
<tr>
<td>11 STS-120</td>
<td>6</td>
<td>26 STS-135</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>80</td>
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</table>

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

Protocol

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
  – Recovery sleep

* No restriction on behavior during data collection periods
Sleep on shuttle and ISS missions

Sleep on shuttle and ISS missions

Use of Sleep Promoting Medications

- 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.

Frequent shifts in sleep-wake cycle on ISS missions

<table>
<thead>
<tr>
<th></th>
<th>Aligned</th>
<th>Misaligned</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actigraphy Sleep Duration (h)</td>
<td>6.4 (1.2)</td>
<td>5.4 (1.4)</td>
<td>&lt;0.01</td>
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<td>Latency (m)</td>
<td>10.3 (15.0)</td>
<td>13.2 (25.2)</td>
<td>0.26</td>
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<tr>
<td>Number of Awakenings</td>
<td>1.7 (1.9)</td>
<td>1.7 (1.7)</td>
<td>0.38</td>
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<tr>
<td>Sleep Efficiency</td>
<td>89% (7%)</td>
<td>90% (7%)</td>
<td>0.26</td>
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<tr>
<td>Sleep Quality</td>
<td>66.8 (17.7)</td>
<td>60.2 (21.1)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Alertness</td>
<td>57.9 (21.7)</td>
<td>53.5 (21.5)</td>
<td>0.13</td>
</tr>
</tbody>
</table>

- 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

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
Blue-enriched light facilitated adjustment to 24.6 hour day


PX2801: 24.63±0.05 hours, r²=0.97
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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