Human/System Integration Process

Research
How can we do better?

Requirements Development

Requirements Integration
Negotiating project buy-in

Design
Hands-on architectural involvement

Verification
Were requirements met?

Operations
Lessons learned!
Performance

Errors

Long term health effects

Short term health effects

Risk of Performance Errors due to Sleep Loss, Fatigue, Circadian Desynchronization, and Work Overload

Risk of Performance Errors due to Poor Team Cohesion and Performance, Inadequate Selection/Team Composition, Inadequate Training, and Poor Psychosocial Adaptation

Risk of Behavioral and Psychiatric Conditions
As Ops views Research...

... and, as Research views Ops

Donning his new canine decoder, Professor Schwartzman becomes the first human being on Earth to hear what barking dogs are actually saying.

“It’s fine to discover cures, but, remember, chronic conditions are our bread and butter.”
<table>
<thead>
<tr>
<th>Source</th>
<th>Average Hours of Sleep</th>
<th>Missions</th>
<th>Subjects (N)</th>
<th>Measurement Tool</th>
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</thead>
<tbody>
<tr>
<td>Dijk et al., 2002</td>
<td>6.5</td>
<td>STS-90, STS-95</td>
<td>5</td>
<td>PSG, Actigraphy</td>
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<td>Kelly et al., 2005</td>
<td>6.0</td>
<td>STS-89</td>
<td>4</td>
<td>Sleep Logs</td>
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<td>Monk et al., 1998</td>
<td>6.1</td>
<td>STS-78</td>
<td>4</td>
<td>Sleep Physiology</td>
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<td>Gundel et al., 1997</td>
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<td>Mir</td>
<td>4</td>
<td>Sleep Physiology</td>
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<td>Santy et al., 1988</td>
<td>6.0</td>
<td>STS Missions</td>
<td>58</td>
<td>Post-flight debrief</td>
</tr>
<tr>
<td>Frost et al., 1976</td>
<td>5.8</td>
<td>Skylab</td>
<td>3</td>
<td>Physiology</td>
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</table>
Ground studies have shown that minor sleep deprivation (no sleep in the past 18 hours) lead to impaired cognitive and motor performance, comparable to impairments seen in those with .05% - .1% blood alcohol levels (Williamson and Feyer, 2000; Dawson and Reid, 1997; Arnedt et al., 2001).

Individuals may not be aware of their performance deficits from inadequate recovery sleep. Laboratory and field studies have found this to be the case (Dinges et al. 1999; Van Dongen et al., 2003; Belenky et al. 2003; Dinges et al., 2005; as cited in Leveton and Dinges, 2006).
Evidence: Performance Decrements

Some astronauts need less sleep and/or may be more resistant to the effects of sleep loss on brain functions. Laboratory and field studies have found this to be the case for 10%-30% of people when sleep loss is mild to moderate (Van Dongen et al., 2004, 2005; LeProult et al., 2003; Caldwell et al., 2005)—evidence level 1.

Preliminary findings from Actiwatch Protocol / Sleep – Wake Flight Study indicate that individual vulnerabilities and different mission characteristics (e.g., noise, temperature) contribute to variability in data (Barger and Czeisler, preliminary unpublished data, 2008)

People can differ greatly in performance deficits from sleep loss, but not perceive it.
Evidence: Long-Term Health Outcomes

A wide range of serious long-term health consequences are associated with chronic, or cumulative, sleep loss:
• hypertension
• diabetes
• obesity
• heart attack
• stroke
• psychiatric disorders such as depression or severe anxiety.
Cultural Issues:

“To understand sleep – wake activity, let’s study Gyroscopes on the Station”
Research *Deliverables*

**Transition to Medical Operations for Medical Requirements**

The Transition Process:
- applies best practices for space exploration
- evaluates the effectiveness and operational *readiness* of human system health and performance-related research deliverables
- supports the Agency’s human spaceflight programs
Transition to Operations Steps

1. Description of the deliverable or product (detailed description, intended use, how it addresses a human system risk)
2. Data required to demonstrate efficacy, effectiveness, or utility of deliverable
3. Data required to demonstrate operational validation of the deliverable
4. Implementation plan describing specific use or application (e.g., protocol, regimen)
5. Analysis of mission resources required for implementation (e.g., crew time, power, mass, volume, etc.)

CRL 1-3: Hypothesis formulation, validation; CRL 4-5: Concept formulation, proof of feasibility;
CRL 6: Lab testing, efficacy; CRL 7: Integrated testing of cm in analog/simulated environment;
CRL 8: Validation in spaceflight to demonstrate efficacy and operational feasibility;
CRL 9: CM fully flight tested, ready for operational implementation
- Does sleep loss continue on long duration missions, or is there adaptation?
- How is performance affected?
- How can individual vulnerabilities to sleep loss best be determined?
- What are the best tools to monitor and assess decrements due to fatigue, sleep loss, and other spaceflight factors?
Gap: What are the best tools to monitor and assess decrements due to fatigue, sleep loss, and other spaceflight factors?

Psychomotor Vigilance Test
- extensively validated with pilots, physicians, shift workers

NEEMO Missions:
• Feasibility with astronauts
• Norms on astronauts
• Sensitivity to fatigue, etc.

Obtained normative data from NEEMO crewmembers

Developed 3-minute PVT Self Test interface feedback combined with performance algorithm

Evaluate PVT Self Test interface with astronauts who helped develop tests norms and with comparable individuals in analog environments

ISS Study

Transition to Ops
Gap: How can light be used in flight as a countermeasure?

Evidence shows that light serves as an effective countermeasure for circadian entrainment, alertness.
Gap: What are the best individual dosing requirements/protocols for Sleep and alertness medications during spaceflight?

(1) Determine best individual dosages

(2) Assess carry-over effects upon abrupt premature termination of sleep (to simulate an emergency situation)

(3) Transition the data and protocol as best practices for medical operations
BHP Research Deliverables
Transition to Medical Practices

a) Actigraphy Protocol
b) PVT Self Test
c) Blue Light Solid State Light Module (SSLM)
d) Individualized Sleep Medication Protocol