NASA-STD-3001 Technical Brief

Sleep Accommodations

OCHMO-TB-041
Rev B

Executive Summary

Astronauts must maintain a high level of cognitive performance during every phase of the mission. Top tier performance depends on the ability to acquire an adequate quantity of daily sleep and the appropriate sleep quality. Previous spaceflight experience has shown that astronauts commonly experience sleep deprivation. Additionally, due to the nature of spaceflight, circadian disturbances are present. Together, these two aspects lead to fatigue and errors while performing tasks. Evidence from short- and long-duration missions and other relevant environments suggests that environmental factors (e.g., noise, temperature, vibration, and light) inhibit sleep and impact well-being in space.
Thus, for crewmembers to achieve optimal sleep, they must be provided with a sleep environment that allows them to achieve quality sleep, free of external disruptions.

Relevant Technical Requirements

NASA-STD-3001 Volume 1, Rev C

[V1 3003] In-Mission Preventive Health Care
[V1 3004] In-Mission Medical Care
[V1 4011] Mission Cognitive State
[V1 4014] In-Mission Completion of Critical Tasks
[V1 5002] Astronaut Training
[V1 6001] Circadian Shifting Operations and Fatigue Management

NASA-STD-3001 Volume 2, Rev D

[V2 3006] Human-Centered Task Analysis
[V2 6013] Crew Performance Environmental Zone
[V2 6017] Atmospheric Control
[V2 6079] Crew Sleep Continuous Noise Limits
[V2 6080] Intermittent Noise Limits
[V2 6082] Annoyance Noise Limits for Crew Sleep
[V2 6092] Vibration Exposure Limits during Sleep
[V2 7038] Physiological Countermeasures Capability
[V2 7070] Sleep Accommodation
[V2 7071] Behavioral Health and Privacy
[V2 7073] Partial-g Sleeping
[V2 8001] Volume Allocation
[V2 8013] Intravehicular Translation Paths
[V2 8033] Restraints for Crew Tasks

Executive Summary (continued)

NASA astronaut Kjell Lindgren poses for a portrait inside a crew sleeping bag aboard the ISS. Photo: NASA

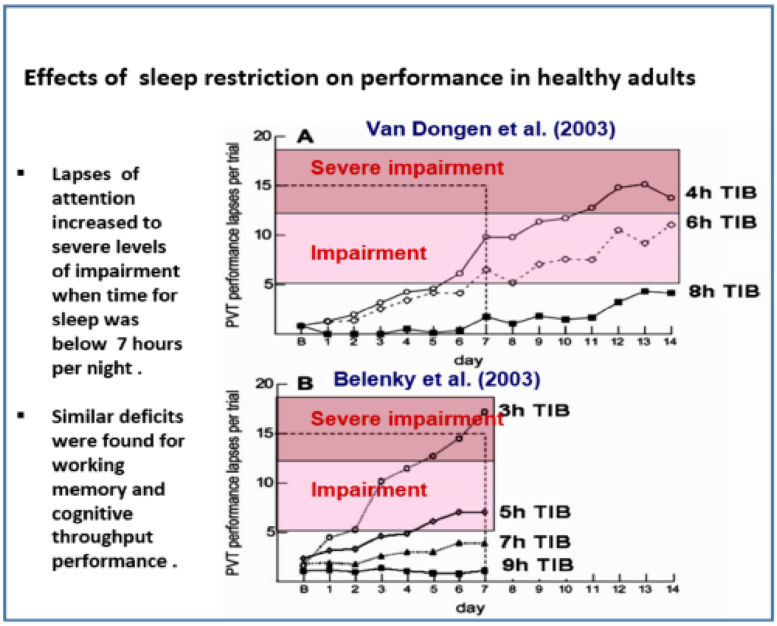
Relevant Technical Requirements

Volume 2, Rev D
[V2 8049] Window Light Blocking
[V2 8050] Window Accessory Replacement/Operation without Tools
[V2 8051] Illumination Levels
[V2 8055] Physiological Effects of Light (Circadian Entrainment)
[V2 8056] Lighting Controls
[V2 9057] Hearing Protection Provision
[V2 5007] Cognitive Workload
[V2 10200] Physical Workload

Houston We Have a Podcast:
For episode 58, Dr. Tom Williams discusses isolation and confinement. His focus is on habitability and behavioral health and performance risks to space flight, and he leads a research team that looks into isolation.

[Ep. 58: Hazard 2: Isolation | NASA]

Background



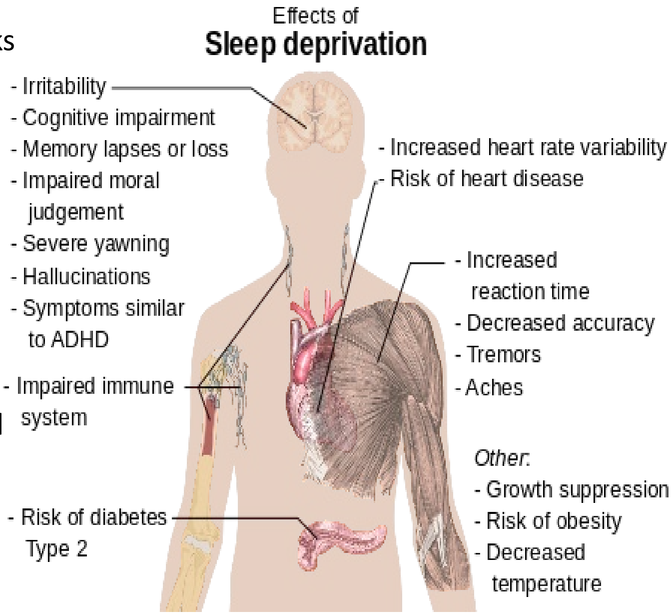
Dinges, 2006

Performance

- Studies on sleep and circadian cycle have reported that after seven days of six hours of sleep, a person's performance is equal to that of a person who has not slept for 24 to 36 consecutive hours.
- Lack of sleep slows mental processes and compromises reasoning ability and memory, with worrying consequences upon the crewmembers' return, the efficiency, and the safety of the mission (Monk, 1996).
- Some brain regions may "sleep" following insufficient sleep, leading to reductions in operational performance. During spaceflight, while performing daily tasks, brain regions could shut down for "local sleep" (Vyazovskiy, 2011).

Cognitive abilities

- Sleep loss and fatigue can cause errors in judgment and impairments to memory and cognition (Walker, 2004).
- The performance of critical tasks is impaired in an environment where there is limited outside help available. The interdependency of many on-board tasks means that the consequences of individual failure at carrying out one task component is multiplied and could potentially compromise the entire mission. In certain circumstances, these errors can produce huge economic losses or even loss of life (Reason, 2006).
- Poor sleep can also affect sustained attention. Sleep deprivation leads to reduced activation of attentional networks (in the frontal and parietal lobes) during a range of cognitive tasks (Lim and Dinges, 2010).
- Research on the effects of sleep deprivation has found that sleep-deprived subjects "*performed considerably worse on motor tasks, cognitive tasks, and measures of mood than non-sleep-deprived subjects*," with multiple days of partial sleep deprivation (i.e., chronic sleep loss) showing the most significant impact on cognitive performance (Pilcher & Huffcutt, 1996, as cited in Whitmire et al., 2008).



Background

Causes of sleep loss during spaceflight

In human spaceflight, sleep duration and sleep quality of astronauts are adversely affected by a combination of factors:

Sleep loss: ↓ Sleep quality, ↓ Sleep quantity

- Environmental conditions: Microgravity, pressure, elevated CO_2 levels, lighting, habitat layout, location of sleep quarters, lack of privacy, noise, temperature, and humidity.
- Individual vulnerabilities: Medication use, sleep hygiene.
- Mission conditions: Workload, slam shifting, work schedule, lack of sensory stimulation, exercise, sleep schedule, and confinements.

<u>Examples of issues reported by crewmembers</u>:

- **Gemini**: Sleep-work schedules were responsible for considerable sleep disruption and circadian misalignment during the Gemini missions due to the need for one member of a two-crew operation to be awake at all times.
- **Apollo 11:** Astronauts did not have hammocks and attempted to make themselves comfortable on the floor. Cited reasons they were unable to sleep include (1) the suits were uncomfortable, (2) the cabin was cold, (3) there was noise from a glycol pump in the Environmental Control System, and (4) sunlight was leaking into the cabin around the window shades and through the Alignment Optical Telescope.
- **Apollo 14:** The crew slept very little because of muscle soreness in the legs and lower back.
- **ISS**: Temperature on the ISS is between 18° and 27° Celsius and the humidity between 30 and 65%. The air must be cleared continuously to avoid carbon dioxide to stall around astronaut's faces.

Most common reported causes of sleep disturbance	Number (Percentage) of disturbed nights[a]				
	L-90	L-11	Inflight	R+7	p
Voids	451(64·3)	447 (79·3)	131 (24·5)	259(71·9)	<0·0001
Noise	124(17·7)	76(13·5)	112(21·0)	45(12·5)	0·0010
Too cold	10(1·4)	9(1·6)	85(15·9)	8(2·2)	<0·0001
Other crewmembers	0 (0)	0 (0)	67 (12·6)	0 (0)	<0·0001
Too hot	46 (6·6)	34 (6·0)	56 (10·5)	30 (8·3)	0·0228
Mission duties	10 (1·4)	19 (3·4)	31 (5·8)	3 (0·8)	<0·0001
Physical discomfort	56 (8·0)	29 (5·1)	86 (16·1)	29 (8·1)	<0·0001

"Every time that I got into it and closed my eyes I feel like falling. Now I have learned that I string out my sleeping bags like a hammock and make it as tight as I can and then I get in it and zip it up and use those Velcro® straps and make it as tight as I can. I need to feel like I am tied down to something touching something, or I feel like I am falling and it will wake me up" (NASA, 2001).

Reference Data

- According to the National Sleep Foundation and American Academy of Sleep Medicine, an average adult needs 7-9 hours of sleep for optimal daytime functioning. Consolidated sleep can only occur when timed at the correct circadian phase.
- Sleep is vital for keeping normal physical and mental health, cognition, and work performance for everyone, including astronauts.
- Numerous studies have been conducted to describe the nature of sleep in space and to quantify the frequency and magnitude of sleep loss. These studies have shown that astronauts sleep an average of about six hours while in space, irrespective of the spaceflight mission examined or methodology used to quantify sleep.
- This amount of sleep is less than the amount recommended by the National Sleep Foundation and the American Academy of Sleep Medicine to maintain satisfactory alertness, performance, and health. (NASA Human Research Program Evidence Report, NASA 2016).
- Studies have also reported that astronauts commonly experience circadian misalignment because of the absence of the 24-hour day-night cycle.

Source	Average Hours of Sleep (Ground)	Average Hours of Sleep (Spaceflight)	Missions	Subjects (N)	Measurement Tool	Category of Evidence
Barger et al., 2014	6.3	6.0	*STS-104, -109, -111, -112, -113, -114, -115, -116, -118, -120, -121, -122, -123, -124*	64	Actigraphy	II
Barger et al., 2014	6.4	6.1	*ISS*	21	Actigraphy	II
Dinges, et al., 2013	6.7	6.4	*ISS*	18	Sleep logs	III
Dijk et al., 2001	6.8	6.5	STS-90, -95	5	Polysomnography, actigraphy	II
Monk et al., 1998	6.5	6.1	STS-78	4	Polysomnography	II
Gundel et al., 1997	6.4	6.1	*Mir*	4	Polysomnography	II
Santy et al., 1988	n/a	6.0	Space shuttle	58	Post-flight debriefing	III
Frost et al., 1976	6.9	6.0	Skylab	3	Polysomnography	II

NASA Human Research Program Evidence Report, NASA 2016

Average Sleep deficit is approximately 0.3 hours (18 minutes) per day comparing inflight to ground (3 months prior to launch).

Reference Data

Sleep-Wake Actigraphy During Spaceflight

- Average nightly sleep duration for both shuttle and ISS is 6-6.5 hours.
- Sleep duration at R+7 increases to approximately 7 hours, indicative of a sleep debt.
- There is a higher use of sleep-promoting drugs inflight.
- There was no significant difference in total sleep time with and without sleep medications, although time to fall asleep was reduced with hypnotics (by 8.5 minutes).
- Reasons cited by ISS crewmembers for reduced sleep on orbit: voids, noise, temperature, physical discomfort, and mission conditions.

	2 weeks about 3 months before launch	11 days before launch	In-flight	7 days after return to Earth	p value	Night before EVA
Space Transportation System shuttle						
Time in bed (diary; h)	7·40 (0·59)	7·35 (0·51)	7·35 (0·47)	8·01 (0·78)	<0·0001	7·47 (0·60)
Sleep episode time (actigraphy; h)	7·27 (0·61)	7·00 (0·62)	6·73 (0·46)	7·90 (0·81)	<0·0001	6·61 (0·90)
Total sleep time (diary; h)	6·86 (0·57)	6·73 (0·47)	6·32 (0·53)	7·23 (0·71)	<0·0001	6·33 (0·84)
Total sleep time (actigraphy; h)	6·29 (0·67)	6·04 (0·72)	5·96 (0·56)	6·74 (0·91)	<0·0001	5·94 (0·96)
Sleep latency (diary; min)*	15·54 (8·82)	16·44 (9·29)	23·63 (14·75)	13·67 (8·98)	<0·0001	28·47 (27·62)
Sleep quality (diary)†	67·91 (13·37)	65·88 (13·35)	63·70 (13·35)	69·23 (13·13)	<0·0001	61·77 (18·01)
Alertness (diary)†	65·17 (15·51)	64·30 (14·56)	64·92 (13·51)	67·46 (12·83)	<0·0001	64·81 (16·29)
Proportion of crew members reporting use of sleep-promoting drugs (%)	21/79 (27%)	56/79 (71%)	61/78 (78%)	19/76 (25%)	<0·0001	23/33 (70%)
Proportion of nights on which sleep-promoting drug use was reported (%)	58/1155 (5%)	272/832 (33%)	500/963 (52%)	19/76 (8%)	<0·0001	50/83 (60%)
International Space Station						
Time in bed (diary; h)	7·37 (0·83)	7·14 (1·16)	7·46 (1·22)	8·34 (1·14)	<0·0001	..
Sleep episode time (actigraphy; h)	7·27 (0·60)	6·77 (0·99)	6·84 (0·75)	8·17 (0·88)	<0·0001	..
Total sleep time (diary; h)	6·77 (0·71)	6·33 (0·76)	6·54 (0·67)	7·17 (0·85)	<0·0001	..
Total sleep time (actigraphy; h)	6·41 (0·65)	5·86 (0·94)	6·09 (0·67)	6·95 (1·04)	<0·0001	..
Sleep latency (diary; min)*	12·99 (5·87)	14·41 (9·46)	13·74 (10·64)	15·29 (15·15)	0·8903	..
Sleep quality (diary)†	67·51 (14·02)	62·32 (15·64)	66·51 (13·43)	66·87 (11·13)	0·0084	..
Alertness (diary)†	61·68 (17·76)	55·98 (19·46)	57·69 (18·73)	61·40 (17·55)	0·0026	..

Data are mean (SD), based on raw data, or n/N (%); p values are from statistical models. *We excluded latency times of >240 min. †Ratings are from a 100 mm non-numeric visual analog scale. EVA=extra-vehicular activity.

Table 1: Sleep outcomes

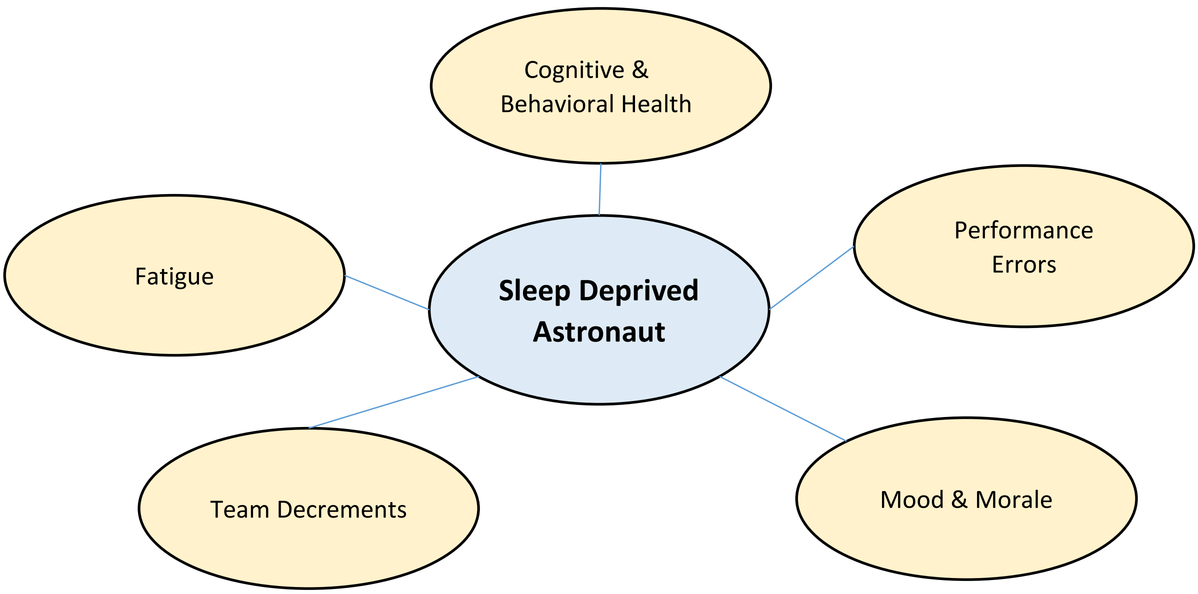
Reference:

Barger, L.K., et al. (2014). Prevalence of sleep deficiency and use of hypnotic drugs in astronauts before, during, and after spaceflight: an observational study. *Lancet Neurology, 13*(9): 904-912. https://doi.org/10.1016/s1474-4422(14)70122-x

Reference Data

Effects of sleep loss on crew health and performance

Sleep loss is associated with numerous negative short and long-term performance and medical consequences:



Behavioral

- Sleep loss can also be a behavioral stressor and lead to depressive symptoms, anxiety, and other adverse behaviors.
- Sleep deprivation has also been linked to behaviors that may compromise team interactions and performance. These include increased outward expression of hostility, a greater tendency to blame others, and less willingness to alleviate conflict by accepting blame (Kahn-Greenea, Lipizzia, Conrada, Kamimori, & Killgore, 2006).
- In simulated military operations after 36 hours of sleep deprivation, team members requested less information and engaged in less discussion of strategy regarding the movement of assets or coordination of team actions than when they were rested (Harville, Barnes, & Elliott, 2004).

Hazards of sleep loss can vary from *errors* to *crew loss and mission failure.*

Reference Data

Previous sleep deprivation-related accidents

Sleep debt is the cumulative effect of reduced sleep that can accumulate faster than one might expect. The only way to repay sleep debt is with good-quality sleep. Long-term sleep debt can turn into acute sleep deprivation, adversely affecting overall health, immune system functioning, ability to concentrate, and the ability to make informed decisions. Some of the most devastating disasters in recent history have a direct link to sleep deprivation:

Nuclear: the Chernobyl disaster

26th April 1986, Chernobyl, Russia (Ukraine)

Sleep deprivation, long hours, tight deadlines, and working at night are implicated as contributing factors.

Chernobyl disaster site

Oil and gas: the Exxon Valdez oil spill

24th March 1989, United States

The vessel moved out of its designated lane to avoid ice and then failed to return to their lane, resulting in an impact with the reef. Sleep deprivation and fatigue are speculated to be a contributing cause to the worker's inability to return the vessel to its correct lane before it struck the reef.

Transportation: Great Heck High-Speed Train Crash

28th February 2001, United Kingdom

A driver fell asleep while driving a Land Rover that was pulling a trailer on the M62. He was able to make it out of his vehicle just 60 seconds before a passenger train struck it and derailed. Shortly after, a second train traveling northbound plowed into the wreckage. The crash claimed ten lives.

Application

Design Considerations

Sleep is critical to crewmember health and performance, especially for missions that are longer and have greater autonomy. For crewmembers to achieve optimal sleep, they must be provided with a sleep environment that allows them to achieve quality sleep, free of external disruption. This includes:

- Appropriate sleep system: The type and volume depend on mission duration, mission scenario, and available volume.
    - Implementation can be done at different levels from sleep areas, beds, and larger private crew quarters containing waste and hygiene management (separated from sleep areas as much as possible). ***[V2 8001] Volume Allocation***
    - Bedding should be soft and easy to clean.
    - In general, short-duration missions (< 14 days) may require only temporary sleep areas.
    - Non-dedicated crew areas used for sleep during short-duration missions should be easy and fast to set up and takedown (e.g., sleeping bag).
    - Sleep preparation operations that require excessive time can result in reduced sleeping time, leading to sleep deprivation and decreased crew performance. Sleep areas should be easy to ingress and egress.
    - For long-duration missions (>30 days), crewmembers should have dedicated quarters that provide privacy, and crew-quarter design should incorporate features that contribute to feelings of comfort, privacy, and other aspects of behavioral health. ***[V2 7071] Behavioral Health and Privacy***

- Sufficient surface area and volume: For the largest crewmember, as well as the expected body postures and ranges of motion for sleeping (particularly the knees-to-chest posture to alleviate spaceflight-associated back pain); stowage of operational and personal equipment; donning and doffing clothing; and recreation and relaxation. (e.g., reading, using a computer and other personal items).

- Efficient schedule: Mission task analysis should plan for a reasonable rest-work schedule to allow enough time for sleep. ***[V1 6001] Circadian Shifting Operations and Fatigue Management; [V2 3006] Human-Centered Task Analysis***

- Provision of radiation protection: The radiation shielding requirements will vary because of exposure to different types and levels of radiation. Aboard the space station, hydrogen-rich shielding such as polyethylene is most frequently used in sleeping quarters to further minimize radiation exposure.

[V2 7070] Sleep Accommodation The system shall provide volume, restraint, accommodations, environmental control (e.g., vibration, lighting, noise, and temperature), and degree of privacy for sleep for each crewmember, to support overall crew health and performance. *From: NASA-STD-3001 Volume 2, Rev D*

Application

Design Considerations

Environmental control: Crewmembers need to have the ability to control the following sleep system aspects:

- Lighting: Exposure to light at inappropriate times leads to circadian misalignment, which causes sleep disruption. Short duration vehicles should, at a minimum, ensure that white light in sleeping areas have dimmable general illumination settings that minimize short-wavelength light to mitigate against inadvertently suppressing melatonin during the biological night. For vehicles supporting long duration missions (>30 days), lighting systems should provide white light composed of at least three different configurations of correlated color, temperature and intensity: one for general purpose illumination, one for pre-sleep, and another to facilitate alertness and schedule shifting. These settings should be implemented at specific times relative to the day-night cycle. **See OCHMO-TB-026 Lighting Design.**
- Ventilation: Adequate ventilation of the sleeping area is required to preclude unacceptable carbon dioxide levels and odors in head positions. Generally, ventilation flow should be from the head area down to the foot area. **See OCHMO-TB-002 ECLSS and OCHMO-TB-004 Carbon Dioxide.**
- Temperature: Given that there are broad individual differences in the optimal temperature for sleep, the sleep environment on space vehicles should be cool, but there should be sufficient insulation
- available for crewmembers to modify their environment to suit individual preferences. ***[V2 6013] Crew Performance Environmental Zone***
- Minimal vibration: Crewmembers could potentially free-float during sleep due to microgravity. However, some crewmembers prefer to be secured to the wall, necessitating minimization of vibration. Attachments should be available to secure the sleeping bag to the wall of the sleep chamber if desired (Flynn-Evans et al., 2016). ***[V2 6092] Vibration Exposure Limits during Sleep***
- Noise: For missions ≤30 days, acoustic levels during sleep are limited to NC-50 (NASA-STD-3001 Vol 2 Rev C [V2 6078] Continuous Noise Limits). Intermittent and impulse noises during sleep are controlled by the NASA-STD-3001 Vol 2 Rev C [V2 6082] Annoyance Noise Limits for Crew Sleep. Noise emanating from common areas has been shown to be disruptive to sleep. For a crewmember to relax, a quiet environment is to be provided during crew sleep. In missions >30 days, the NC-40 limit provides adequate auditory rest. **See** OCHMO-TB-035 Acoustics.

NASA astronaut Jack "2Fish" Fischer inhabits a personal sleep station inside the International Space Station. Photo: NASA

Back-Up

Major Changes Between Revisions

Rev A → Rev B

- Updated information to be consistent with NASA-STD-3001 Volume 1 Rev C and Volume 2 Rev D.

Original→ Rev A

- Updated information to be consistent with NASA-STD-3001 Volume 1 Rev B and Volume 2 Rev C.

View the current versions of NASA-STD-3001 Volume 1 & Volume 2 on the OCHMO Standards website

Referenced Technical Requirements

NASA-STD-3001 Volume 1 Revision C

[V1 3003] In-Mission Preventive Health Care All programs shall provide training, in-mission capabilities, and resources to monitor physiological and psychosocial well-being and enable delivery of in-mission preventive health care, based on epidemiological evidence-based probabilistic risk assessment (PRA) that takes into account the needs and limitations of each specific design reference mission (DRM), and parameters such as mission duration, expected return time to Earth, mission route and destination, expected radiation profile, concept of operations, and more. The term "in-mission" covers all phases of the mission, from launch, through landing on a planetary body and all surface activities entailed, up to landing back on Earth. In-mission preventive care includes, but is not limited to: (see NASA-STD-3001, Volume 1 Rev C for full standard).

[V1 3004] In-Mission Medical Care All programs shall provide training, in-mission medical capabilities, and resources to diagnose and treat potential medical conditions based on epidemiological evidence-based PRA, clinical practice guidelines and expertise, historical review, mission parameters, and vehicle-derived limitations. These analyses should consider the needs and limitations of each specific DRM and vehicles. The term "in-mission" covers all phases of the mission, from launch, through landing on a planetary body and all surface activities entailed, up to landing back on Earth. In-mission capabilities (including hardware and software), resources (including consumables), and training to enable in-mission medical care, are to include, but are not limited to: see NASA-STD-3001, Volume 1 Rev C for full standard).

[V1 4011] Mission Cognitive State Pre-mission, in-mission, and post-mission crew behavioral health and crewmember cognitive state shall be within clinically accepted values as judged by behavioral health evaluation.

[V1 4014] In-Mission Completion of Critical Tasks The planned number of hours for completion of critical tasks and events, workday, and planned sleep period shall have established limits to assure continued crew health and safety.

[V1 5002] Astronaut Training Beginning with the astronaut candidate year, general medical training, including but not limited to, first aid, cardiopulmonary resuscitation (CPR), altitude physiological training, carbon dioxide exposure training, familiarization with medical issues, procedures of space flight, psychological training, and supervised physical conditioning training shall be provided to the astronaut corps.

[V1 6001] Circadian Shifting Operations and Fatigue Management Crew schedule planning and operations shall be provided to include circadian entrainment, work/rest schedule assessment, task loading assessment, countermeasures, and special activities.

NASA-STD-3001 Volume 2 Revision D

[V2 3006] Human-Centered Task Analysis Each human spaceflight program or project shall perform a human-centered task analysis to support systems and operations design.

[V2 6013] Crew Performance Environmental Zone The system shall be capable of reaching atmospheric humidity and temperatures of nominally occupied habitable volumes within the zone provided in Figure 6.2-3—Crew Performance Environmental Zone, during all nominal operations, excluding suited operations, ascent, entry, landing, and post landing.

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Referenced Technical Requirements

NASA-STD-3001 Volume 2 Revision D

[V2 6017] Atmospheric Control The system shall allow for local and remote control of atmospheric pressure, humidity, temperature, ventilation, and ppO_2.

[V2 6079] Crew Sleep Continuous Noise Limits For missions greater than 30 days, SPLs of continuous noise shall be limited to the values given by the NC-40 curve (see Figure 6.6-1—NC Curves, and Table 6.6-3—Octave Band SPL Limits for Continuous Noise, dB re 20 µPa) in crew quarters and sleep areas. Hearing protection cannot be used to satisfy this requirement.

[V2 6080] Intermittent Noise Limits For hardware items that operate for eight hours or less (generating intermittent noise), the maximum noise emissions (not including impulse noise), measured 0.6 m from the loudest hardware surface, shall be determined according to Table 6.6-4—Intermittent Noise A-Weighted SPL and Corresponding Operational Duration Limits for any 24-hour period (measured at 0.6 m distance from the source). Hearing protection cannot be used to satisfy this requirement.

[V2 6082] Annoyance Noise Limits for Crew Sleep With the exception of communications and alarms, the system shall limit impulse and intermittent noise levels at the crewmember's head location to 10 dB above background noise levels during crew sleep periods. Hearing protection cannot be used to satisfy this requirement.

[V2 6092] Vibration Exposure Limits during Sleep The system shall limit vibration to the crew such that the acceleration between 1.0 and 80 Hz in each of the X, Y, and Z axes, weighted in accordance with ISO 20283-5, Mechanical Vibration—Measurement of Vibration on Ships; Part 5 - Guidelines for the Measurement, Evaluation and Reporting of Vibration with Regard to Habitability on Passenger and Merchant Ships, Annex A, is less than 0.01 g (0.1 m/s^2) RMS for each two-minute interval during the crew sleep period.

[V2 7038] Physiological Countermeasures Capability The system shall provide countermeasures to meet crew bone, muscle, sensorimotor, thermoregulation, and aerobic/cardiovascular requirements defined in NASA-STD-3001, Volume 1.

[V2 7070] Sleep Accommodation The system shall provide volume, restraint, accommodations, environmental control (e.g., vibration, lighting, noise, and temperature), and degree of privacy for sleep for each crewmember, to support overall crew health and performance.

[V2 7071] Behavioral Health and Privacy For long duration missions (>30 days), individual privacy facilities shall be provided.

[V2 7073] Partial-g Sleeping The system shall provide for horizontal sleep surface areas for partial-g and 1-g environments.

[V2 8001] Volume Allocation The system shall provide the defined habitable volume and layout to physically accommodate crew operations and living.

[V2 8013] Intravehicular Translation Paths The system shall provide intravehicular activity (IVA) translation paths that allow for safe and unencumbered movement of suited and unsuited crew and equipment.

[V2 8033] Restraints for Crew Tasks The system shall provide restraints for expected crew operations.

[V2 8049] Window Light Blocking Each system window shall provide a means to prevent external light from entering the crew compartment, such that the interior light level can be reduced to 2.0 lux at 0.5 m (20 in) from each window.

View the current versions of NASA-STD-3001 Volume 1 & Volume 2 on the OCHMO Standards website

Referenced Technical Requirements

NASA-STD-3001 Volume 2 Revision D

[V2 8050] Window Accessory Replacement/Operation without Tools System window accessories designed for routine use shall be operable by one crewmember and be removable or replaceable without the use of tools.

[V2 8051] Illumination Levels For interior architectures and exterior operations that do not include the presence of orbital sunlight, the system shall provide illumination levels to support the range of expected crew tasks, at minimum, per Table 8.7-1—Surface Illuminance Levels, that accommodate both human observers and remote camera systems.

[V2 8055] Physiological Effects of Light (Circadian Entrainment) The system shall provide the levels of light to support the physiological effects of light in accordance with Table 8.7-2—Physiological Lighting Specifications.

[V2 8056] Lighting Controls Lighting systems shall have on-off controls.

[V2 9057] Hearing Protection Provision Appropriate personal hearing protection shall be provided to the crew during all mission phases for contingency or personal preference.

[V2 5007] Cognitive Workload The system shall provide crew interfaces that result in Bedford Workload Scale ratings of 3 or less for nominal tasks and 6 or less for tasks performed under degraded system conditions.

[V2 10200] Physical Workload The system shall provide crew interfaces that result in a Borg-CR10 rating of perceived exertion (RPE) of 4 (somewhat strong) or less.

Reference List

1. Barger LK, et al. (2014). Prevalence of sleep deficiency and use of hypnotic drugs in astronauts before, during, and after spaceflight: an observational study. *Lancet Neurol, 13*, 904–912. https://ntrs.nasa.gov/citations/20190002008
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