NASA-STD-3001 Technical Brief

Mission Duration

OCHMO-TB-007
Rev A

Executive Summary

Mission duration is a key factor for many of the human system risks of spaceflight. Some risks are already known challenges and will be further exacerbated by increased mission duration. It is also one of the parameters that defines the applicable requirements to the engineering system. As the duration of a mission increases, the physical volume required to accommodate the personal needs of the crew and the mission tasks increases. Long-duration missions can also affect the crews' behavioral health due to confinement, stress, and isolation. The psychological needs of a long-duration mission drive additional volume and privacy requirements. Designing architecture for long-duration spaceflight missions requires consideration of additional factors that may not be as critical for a short duration mission. Success of a mission and the lives of the crew will depend on reliable systems that are optimal from the earliest phases of design.

Relevant Technical Requirements

NASA-STD-3001 Volume 1, Rev C

[V1 3001] Selection and Recertification
[V1 3002] Pre-Mission Preventive Health Care
[V1 3003] In-Mission Preventative Health Care
[V1 3004] In-Mission Medical Care
[V1 4014] Completion of Critical Tasks
[V1 4019] Pre-Mission Nutritional Status
[V1 4020] In-Mission Nutrient Intake
[V1 4022] Post-Mission Nutritional Assessment and Treatment
[V1 6001] Circadian Shifting Operations and Fatigue Management
[V1 6008] Crew Health Operations Concept Document

NASA-STD-3001 Volume 2, Rev D

[V2 3006] Human-Centered Task Analysis
[V2 4013] Muscle Effects
[V2 4015] Aerobic Capacity
[V2 4102] Functional Anthropometric Accommodation
[V2 4103] Body Mass, Volume, and Surface Area Data
[V2 4104] Crew Operational Loads
[V2 4105] Withstand Crew Loads
[V2 5007] Cognitive Workload
[V2 6004] Nominal Vehicle/Habitat Carbon Dioxide Levels
[V2 6026] Water Quality
[V2 6039] Water Dispensing Rate
[V2 6040] Water Dispensing Increments
[V2 6050] Atmosphere Contamination Limit

Executive Summary (continued)

NASA Astronaut Frank Rubio safely returned to Earth in September 2023 after spending 371 Days in Space. *Image: NASA/Bill Ingalls*

Related OCHMO Technical Briefs:

1. OCHMO-TB-017 Automated and Robotic Systems
2. OCHMO-TB-016 Behavioral Health and Performance
3. OCHMO-TB-032 Cognitive Workload
4. OCHMO-TB-002 Environmental Control & Life Support System (ECLSS)
5. OCHMO-TB-005 Usability, Workload, & Error
6. OCHMO-TB-033 Spaceflight Experience and Medical Care
7. OCHMO-TB- 025 Cabin Architecture
8. OCHMO-TB-013 Food and Nutrition
9. OCHMO-TB-012 Mortality Related to Human Spaceflight Technical Brief

Relevant Technical Requirements

NASA-STD-3001 Volume 2, Rev D

[V2 6059] Microbial Air Contamination
[V2 6079] Crew Sleep Continuous Noise Limits
[V2 6107] Nominal Vehicle/Habitat Atmospheric Ventilation
[V2 6108] Off-Nominal Vehicle/Habitat Atmospheric Ventilation
[V2 6109] Water Quantity
[V2 6110] Water Temperature
[V2 7001] Food Quality
[V2 7002] Food Acceptability
[V2 7003] Food Caloric Content
[V2 7004] EVA Food Caloric Content
[V2 7007] Food Microorganism Levels
[V2 7008] Food Preparation
[V2 7009] Food Preparation and Cleanup
[V2 7010] Food Contamination Control
[V2 7011] Food and Beverage Heating
[V2 7014] Food Spill Control
[V2 7015] Food System Cleaning and Sanitizing
[V2 7016] Personal Hygiene Capability
[V2 7020] Body Waste Management Capability
[V2 7023] Body Waste Management Provision
[V2 7041] Environmental Control
[V2 7043] Medical Capability
[V2 7052] Stowage Location
[V2 7070] Sleep Accommodations
[V2 7071] Behavioral Health and Privacy
[V2 7074] Clothing Quantity
[V2 7076] Clothing Safety and Comfort
[V2 7100] Food Nutrient Composition
[V2 8001] Volume Allocation
[V2 10200] Physical Workload

[Risk of Adverse Outcome Due to Inadequate Human Systems Integration Architecture]

Background

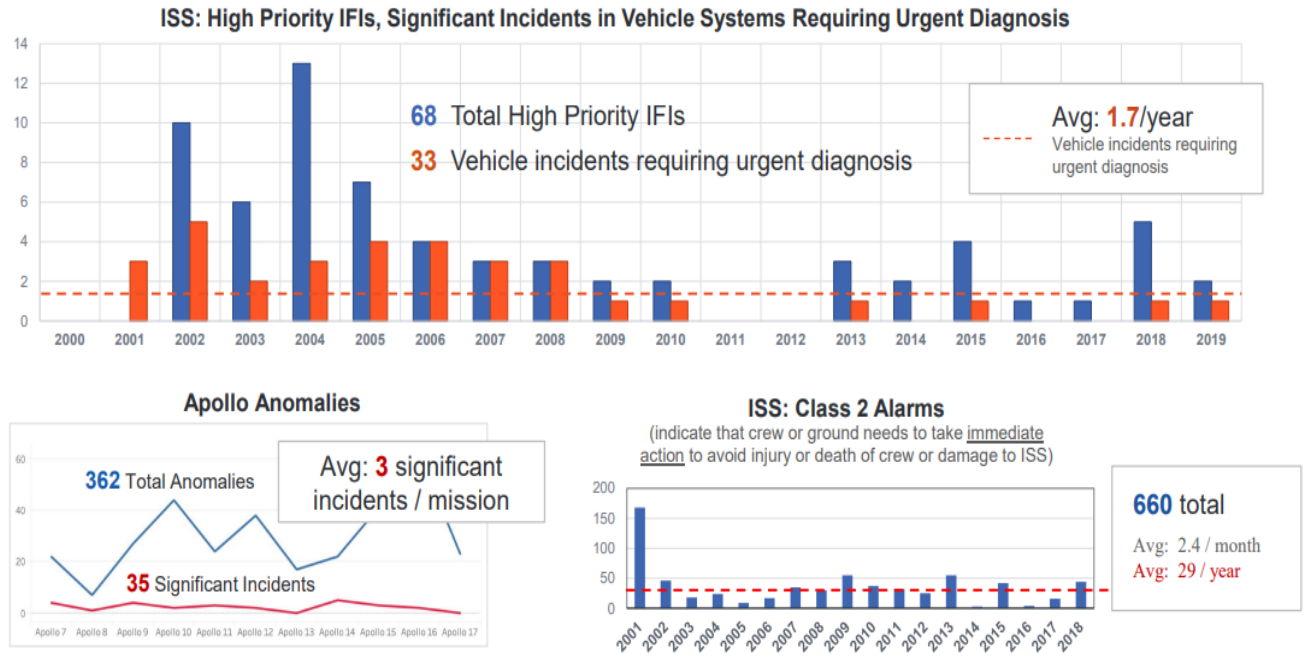
Effects of Communication Delays in Long-Duration Space Flight Missions

For the past 60 years, NASA's mission operations paradigm for human spaceflight has been one of near-complete real-time dependence on experts on the ground to control and manage the combined state of the mission, vehicle, and crew.

Current countermeasures include near real-time communication that allows a large team on the ground to manage the health of the crew and vehicle, in addition to resupplying as needed.

The crew will face numerous issues on longer-duration missions (i.e., Lunar and Mars missions) related to the coupling of humans and technology. Specifically, the communication delay of up to 40 minutes between the crew and ground support back on Earth.

The crew will have to perform more problem-solving and complex ops with reduced real-time support and existing onboard supplies. Communication delays will also lead to varied negative effects on teamwork and the multi-team system through the degraded quality of communication.



Anomaly Rates for Human Spaceflight, HSIA Risk CR 05/11/2023

HSIA Risk Statement: Given limited real-time ground support for execution of complex operations during future exploration missions, there is a possibility of adverse performance outcomes, most consequentially that crew are unable to adequately respond to unanticipated critical malfunctions or execute safety critical procedures.

Background

Mission duration definition

- Mission duration is one parameter that defines the requirements applicable to the engineering system. It is the total time the crew is away from the surface of Earth, measured from launch to landing or splashdown of the spacecraft. ***[NASA-STD-3001 V2-Definitions]***
- Traditionally, NASA has used 30 days as a cutoff between short and long-duration based on physiological changes from baseline on Earth. Mission duration refers to:
    1) short duration missions: less than or equal to 30 days, and
    2) long duration missions: greater than 30 days
- Designing architecture for long-duration spaceflight missions requires consideration of additional factors that may not be as critical for short-duration missions.
- When considering mission duration as a parameter to identify applicable requirements, we need to also consider the **mission type, trajectory, vehicle type, and distance from Earth, collectively known as Design Reference Missions (DRM).**
- Different DRM's have unique characteristics and present unique challenges. There is quite a difference between being on a 56-million km journey to Mars and orbiting Earth at 400 km altitude. Future exploration missions will extend human presence beyond low earth orbit (LEO). There are a variety of possible mission objectives, durations, and destinations.

Design Reference Missions (DRM)

DRM Categories	Mission Type and Duration	Gravity Environment	Radiation Environment	Vehicle/Habitat Design	Distance from Earth		EVA
					Evacuation	Communi-cation	Frequency
Low Earth Orbit	Short (<30 days)	Microgravity	LEO-Van Allen (<5-15 mGy)	Mid-sized volume, resupply	1 day or less	Real time	1-4 EVAs
	Long (30 days-1 year)	Microgravity	LEO-Van Allen (<5-150 mGy)	Mid-large optimized volume, resupply	1 day or less	Real time	1-10 EVAs
Lunar Orbital	Short (<30 days)	Microgravity	Deep Space-Van Allen (15-20 mGy)	Small volume, self-contained, limited resupply	3-11 days	Minor latency	Contingency EVA only or very few EVA
	Long (30 days-1 year)	Microgravity	Deep Space (175-220 mGy)	Mid-sized volume, self-contained, limited resupply	3-11 days	Minor latency	Contingency EVA only or very few EVA
Lunar Orbital + Surface	Short (<30 days)	Microgravity & 1/6g	Deep Space-Van Allen (15-20 mGy)	Small volume, resupply	3-11 days	Minor latency	5 EVAs, some back-to-back
	Long (30 days-1 year)	Microgravity & 1/6g	Deep Space (100-120 mGy)	Mid-large sized optimized volume, limited resupply	3-11 days	Minor latency	3-4 EVA per week, 20-24 EVA hours per week
Mars	Preparatory (<1 year)	Microgravity	Deep Space (175-220 mGy)	Midsized optimal volume, limited resupply, closed loop environment	Days-weeks	Controlled-Delayed	Contingency EVA only or very few EVA
	Mars Planetary* (730-1224 days)	Microgravity & 3/8g	Deep Space-Planetary (300-450 mGy)	Midsized optimal volume, no resupply, closed loop environment	Mission duration	No real time	

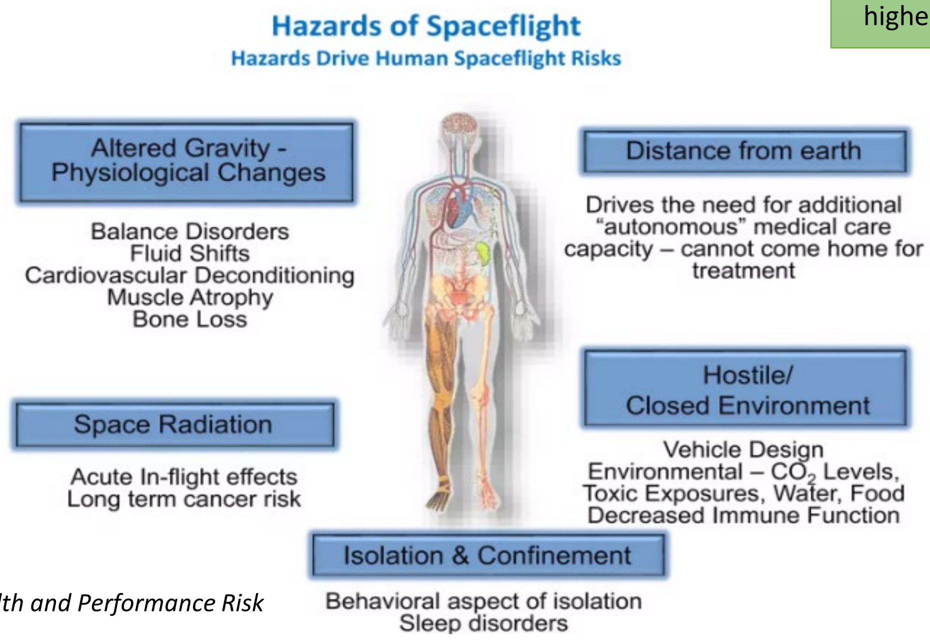
Based on memo-HEO-DM-1002 HEO Systems Engineering and Integration (SE&I) Decision Memo on Mars Mission Duration Guidance for Human Risk Assessment and Research Planning Purposes

Background

Full Mission Duration Applicability

- Missions may be comprised of consecutive segments that occur in different vehicles, occur in different locations in space with varying distances from Earth, and last for different durations.
- To protect human health and performance, in particular from exposures or conditions that have a cumulative component, each human spaceflight vehicle that is used to conduct one or more segments of a multi-segment/multi-vehicle mission shall follow Standards/Requirements pertaining to the entire duration of the multi-segment/multi-vehicle mission (from the launch of the crew through their landing back on Earth), even if their isolated segment would have allowed higher exposures or tailoring/relaxation of Standards/Requirements had their segment been executed as a stand-alone mission.
- For multi-segment or multi-vehicle missions, cumulative exposure over the entire duration of the mission needs to be considered. Exposure in one vehicle that is occupied for a segment of the full mission duration cannot be taken in isolation from the rest of the mission. It is not advisable for each vehicle to maintain its own short-duration exposure requirements and expect other vehicles or habitats in the mission to lower their exposure limits to compensate for a higher exposure level in another vehicle (e.g., Lunar dust exposure, radiation exposure PELs, volatile chemicals which are limited by Spacecraft Maximum Allowable Concentrations (SMACs), etc.).
- Similarly, a vehicle cannot expect other vehicles within the enterprise to compensate for the lack of countermeasures in that vehicle (e.g., lack of exercise capability, sub-optimal food provisioning, and food system infrastructure, habitable volume, etc.). **See NASA-STD-3001 Vols 1 & 2, Section 1.3.1 Full Mission Duration Applicability)**

SMACs are currently set for durations of 1 hr, 24 hrs, and 7, 30, 180, and 1000 days. If an Artemis mission is 90 days in total, then 180-day SMACs apply to all vehicles associated with that mission, even if they will house crew for only a small portion of the total mission duration. They also need to meet 1 hr, 24 hr, 7 and 30-day SMACs to protect against higher acute exposures.



Source: Human Health and Performance Risk Management

Reference Data

Physiological Timeline

≤3 days

- Fluid redistribution and temporary diuresis
- Genitourinary issues
- Metabolic capacity deficits

Changes associated with initial adaptation to space (e.g., transfer missions)

≤2 weeks

- Space Adaptation Syndrome (SAS)
- Back pain
- Sensorimotor and neurovestibular deconditioning

Concerns after initial adaptation to space occurs

>2 weeks

- Muscular and aerobic decrements
- Bone effects and renal stone risk
- Vision loss/changes

Concerns related to long spaceflight missions (e.g., ISS or lunar missions)

Vehicle/environmental features (including increased CO_2 and radiation exposure)
Head/nasal congestion
Fluid shifts and altered vascular motility

Psychological or Behavioral Timeline

≤3 days

- Sleep loss and circadian misalignment
- Adjustment reaction

≤2 weeks

- Acute stress
- Anxiety/panic
- Insomnia/sleep disturbance/circadian dysregulation
- Mood disturbance
- Cognitive disturbance, low morale
- Cumulative sleep loss and circadian misalignment
- Stress
- Adjustment reaction
- Interpersonal conflict (team, ground, family)

>2 weeks

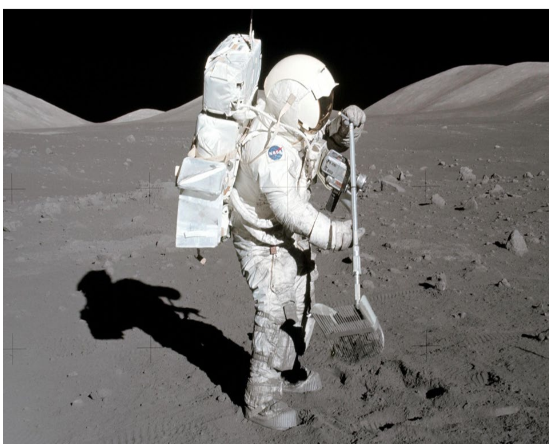
- Work overload
- Lack of meaningful work and/or monotony
- Apathy, low motivation
- Grief Reaction
- Depression
- Relationship problems (crew, family, mission support personnel)
- Adjustment, mood, anxiety, trauma-related, stress-related, and neurocognitive disorders
- Cumulative sleep loss and circadian misalignment

Reference OCHMO-TB-033 Spaceflight Experience and Medical Care Technical Brief for additional information

Reference Data

Mission Duration and Increased Exposure to Hazards

Low Earth Orbit (LEO)
- Near real-time communications (1-1.5 seconds)
- Reliance on Earth
- Evacuation capabilities
- Strong consumable and ORUs resupply



Lunar Missions
- Minor communication latencies
- Evacuation capabilities (3-11 days)
- Limited resupply
- Restrictions in onboard medical capability

Mars
- Extended communication latencies (0-40 minutes)
- No evacuation capability
- No consumable resupply
- Restrictions in onboard medical capability
- Limited ground medical support/autonomous Medical Care
- Task design/EVA operations and suit/vehicle design will impact medical conditions' severity

Increasing need for autonomy in medical response
Increasing risk of medical events

Application

This technical brief focuses on long-duration spaceflight considerations, specifically as they impact vehicle architecture and volume.

<u>Mission Duration and Habitability Requirements</u>

- All types of habitats for space exploration have some common requirements and other distinct requirements based on the environments in which they operate, mission duration, the number of crew, and mission goals. **"**Habitability requirements for space flights are driven by mission duration" (Woolford and Mount, 2006).

- During early space missions with tiny capsules (e.g., Mercury and Gemini), few activities required moving around, and most of the time, the astronaut was strapped to the seat. The design of the habitat was "seat-driven." This situation changed with the introduction of space stations and long-duration missions.

- To support performance in long-duration missions (months or years), higher habitability requirements is a prerequisite. Habitability is achieved by applying human factors in the design of living and working conditions.

NASA-STD-3001 Definitions [V2-Appendix C]

Habitability: The state of being fit for occupation or dwelling. Meeting occupant needs of health, safety, performance, and satisfaction.
Habitat: A type of spacecraft, not normally mobile, that has the conditions necessary to sustain the life of the crew and to allow the crew to perform their functions in an efficient manner.

SDM → LDM

SDM	LDM
• Air conditioning	• Interior design
• Food and water supply	• Zoning
• Illumination	• Privacy
• Noise level	• Hygiene
• Odors	• Work schedule
• Actuation forces	• Crew composition
• Vibrations	• Psychological care
• Medical care	• Communication
• Safety considerations	• Motivation

Experience shows that with increasing mission duration
the effects of isolation and confinement become predominant

Habitability aspects for short and long-duration missions (Messerschmid, 2008)
SDM = short-duration mission LDM = long-duration mission

Application

Habitable Volume

- Habitable volume is necessary for determining vehicle size in conceptual design, which impacts propulsion performance and habitability.

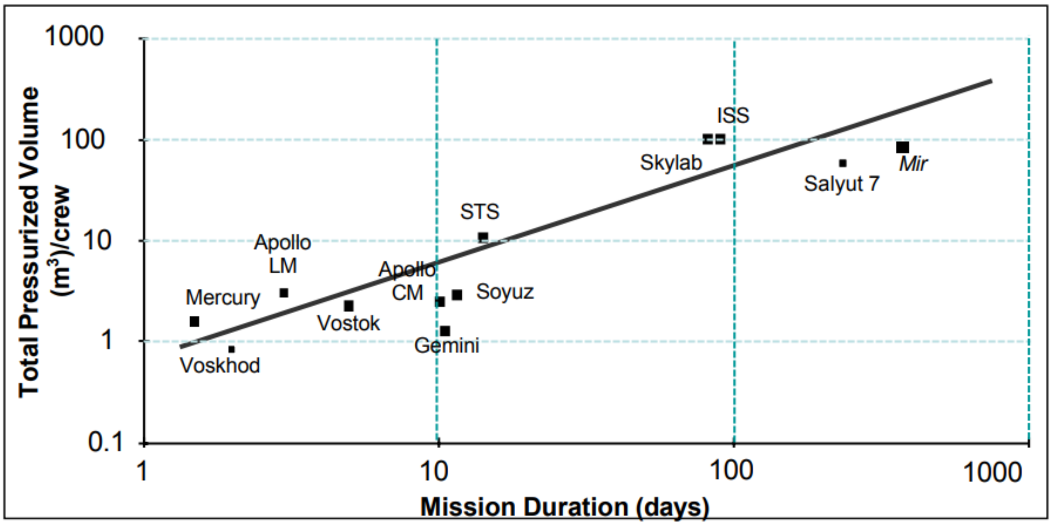
- The confinement, isolation, and stress that usually accompany a space mission tend to increase with mission duration. This creates a psychological need for more room. A sense of privacy and a need for personal space becomes more important over longer durations. The total required net habitable volume per crewmember and per total crew increases with duration.

- Increasing mission duration requires expansion in the physical volume to accommodate the physical characteristics of the entire user population, mission tasks, and personal needs. The total required net habitable volume (NHV) per crewmember, and per total crew, increases with duration, particularly if the mission cannot be logistically resupplied. ***[V2 Section 4] Physical Characteristics and Capabilities – Introduction, [V2 Appendix F]***

NASA-STD-3001 Definitions [V2-Appendix C]

Habitable Volume: The measure of space livable and functionally usable to crew within a pressurized volume after accounting for all installed hardware and systems.
Net Habitable Volume (NHV): The functional volume left available on a spacecraft after accounting for the loss of volume caused by deployed equipment, stowage, trash, and any other items that decrease the functional volume.
Non-Habitable Volume: is defined as the portion of Pressurized Volume taken up by fixed outfitting, equipment, stowage, and dedicated equipment work volumes.

- The task analysis method determines the volume required for the tasks to be performed during the mission and combines, co-locates, or overlaps them as necessary to determine the total volume required in the spacecraft. ***[V2 3006] Human-Centered Task Analysis***



Historical NASA spacecraft pressurized volume *Ref. HIDH*

Reference the NASA OCHMO-TB-025 Cabin Architecture Technical Brief for additional information.

Application

Volume Allocation

- The required volume is a function of the number of crew, the number of missions and contingency days, and the crew activities.

- Longer mission duration will increase functional volume needs for the accommodation of stowage, increased volume for exercise equipment including exercise performance, medical treatment facilities, and equipment; as well as crew sleep, recreation, and privacy for behavioral health. ***[V2 8001] Volume Allocation***

- The design and layout of functional volumes are guided by function and task analysis, as well as an iterative process of design and evaluation.

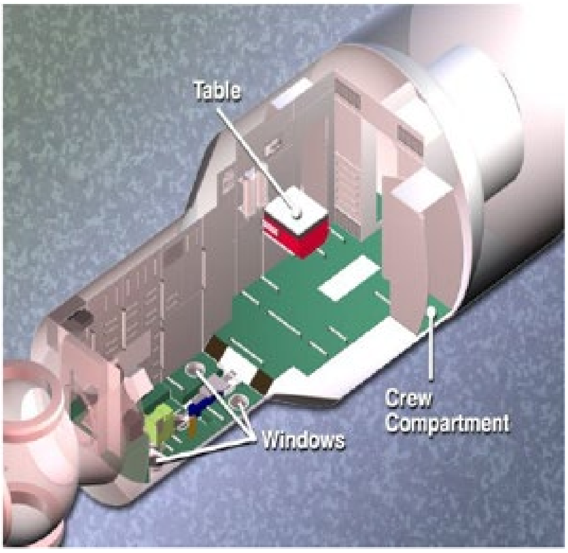


Illustration of the interior of ISS Zveda service module

Habitable Atmosphere

- The spacecraft's atmosphere must not be contaminated with substances that can harm the crew. Maintaining a habitable atmosphere in a spacecraft includes providing the proper atmospheric constituents in the proper quantities necessary to sustain life.

- NASA-STD-3001 provides technical requirements that address the key aspects of the human physiological system that must be accounted for through the use of an Environmental Control and Life Support System (ECLSS).

- Program-level requirements for atmospheric quality need to include considerations for factors such as vehicle architecture and mission duration. Long-duration missions may result in different requirements for subsystems such as an ECLSS, the placement of which may have an impact on the volume available to crewmembers.

Habitable atmosphere is the composition of the breathable environment within the Habitable Volume. ***[NASA-STD-3001 Definitions-V2-Appendix C]***

- Crewmembers may be more sensitive to CO_2 or other atmospheric pollutants during spaceflight than they are on Earth. Such issues are considered undesirable for shorter, near-Earth missions, but they cannot be accepted for long-duration exploration missions. ***NASA-STD-3001 Volume 2 6.2.8 Atmospheric Contamination; [V2 6004] Nominal Vehicle/Habitat Carbon Dioxide Levels; [V2 7041] Environmental Control; [V2 6107] Nominal Vehicle/Habitat Atmospheric Ventilation; and [V2 6108] Off-Nominal Vehicle/Habitat Atmospheric Ventilation.***

Reference the following Technical Briefs OCHMO-TB-025 Cabin Architecture, OCHMO-TB-002 ECLSS, OCHMO-TB 003 Habitable Atmosphere, and OCHMO-TB-004 CO2 for additional information

Application

Habitability Functions

NASA-STD-3001 provides design considerations for the daily functions of the crew inside the spacecraft, including dining, sleep, hygiene, waste management, and other activities to ensure a habitable environment.

Food & Nutrition

Key areas of concern for the health of the crew during long-duration spaceflight missions include loss of body mass (inadequate food intake), loss of bone and muscle, and depletion of body nutrient stores because of inadequate food supply and increased metabolism.

Short-duration missions

- During missions up to 3 days in length, the resources required to support certain types of foods, such as rehydratable and heated foods, may not be available because of mass and power constraints. Shelf-stable commercially available foods may be provided if they meet space food system requirements, including complete nutrition requirements.

Long-duration missions

- For missions longer than 3 days, the resources required to rehydrate and heat foods in various packaging sizes must be provided to support crew health throughout the mission.
- As mission length increases, more foods that meet requirements will need to be developed, as variety promotes healthy eating habits, crew appetite, and maintains crew health and performance.

Skylab food heating and serving tray with food, drinks, and utensils.

Crew receives food on ISS that they will not receive on an exploration mission. The crew on ISS receives fresh fruits and vegetables with almost every visiting vehicle, approximately once per month.

Source: HSRB Risk of Performance Decrement and Crew Illness Due to Inadequate Food and Nutrition, 2020

NASA-STD-3001 Volume 2

[V2 7001] Food Quality; [V2 7002]; Food Acceptability; [V2 7003] Food Caloric Content; [V2 7004] EVA Food Caloric Content; [V2 7007] Food Microorganism Levels; [V2 7008] Food Preparation; [V2 7009] Food Preparation and Cleanup; [V2 7010] Food Contamination Control; [V2 7011] Food and Beverage Heating; [V2 7012] Dining Accommodations; [V2 7014] Food Spill Control[V2 7015] Food System Cleaning and Sanitizing; [V2 7100] Food Nutrient Composition

Reference the OCHMO-TB-013 Food and Nutrition Technical Brief for additional information

Application

Food Packaging

- To maintain food quality throughout a mission, the type of packaging used depends on the mission duration and type of food.
- Several types of food and beverage packaging have been used in NASA space programs.
- The key consideration for extending food shelf life is preventing contact of the food with oxygen or water, which both cause oxidation and spoilage.


ISS Food System: Prepacked single servings which only require heating or water addition, or no further preparation prior to consumption.

Trash Disposal Planning

- For long-duration missions in LEO with visiting spacecrafts, plans for a return to Earth must be developed, including prioritization plans and stowage accommodations.
- For long-duration flights, sufficient stowage space must be made available, or if possible, a means to dispose of the trash in-flight should be provided. Disposal constraints must be kept in mind for the various types of trash.

Water Quality and Monitoring

- Microbially safe water is essential to prevent infection and mitigate risks to crew health and performance. ***[V2 6046] Water Quality Monitoring and [V2 6026] Potable Water Quality***

Short-duration missions

- Short missions with simple water systems or open-loop systems will not require extensive microbial sampling and analysis. However, as mission duration and system complexity increase, the risk of microbial contamination will increase.

Long-duration missions

- Long-duration water systems, such as those in a remote habitat, are more likely to suffer a contamination event. Periodic testing of the potable water should be considered to monitor water quality and allow timely action if necessary. Longer-duration missions may require autonomous monitoring or hardware that requires minimal consumables.

NASA-STD-3001 Volume 1
[V1 3003] In-Mission Preventive Health Care

NASA-STD-3001 Volume 2
[V2 3006] Human-Centered Task Analysis; [V2 6026] Potable Water Quality; [V2 6109] Water Quantity; [V2 6110] Water Temperature; [V2 6039] Water Dispensing Rate; [V2 6040] Water Dispensing Increments; [V2 6046] Water Quality Monitoring; [V2 6051] Water Contamination Control; [V2 7052] Stowage Location; [V2 8001] Volume Allocation
Reference the OCHMO-TB-027 Water Technical Brief for additional information

Application

Water Quantity

Missions of all lengths require the same daily water amount for the crew. As mission length increases, additional solutions such as urine reclamation or recycling may be considered to provide enough water to the crew during longer missions. ***[V2 6109] Water Quantity***

Clothing

- The change frequency depends on mission specifics; i.e., duration, stowage, laundry capabilities, etc. ***[V2 7076] Clothing Safety and Comfort and [V2 7074] Clothing Quantity***
- Crewmembers on shorter-duration missions may not be held to the same clothing constraints as those on long-duration missions.
- Long-duration missions may require clothing to be worn for extended periods of time and be constructed of antimicrobial fabrics that are extremely lightweight, whereas a shorter mission may accommodate more frequent clothing changes and a greater variety of fabric options.
- Implementation details of the mission will determine whether clothing needs impact vehicle volume and layout, but it must be considered during vehicle design.

Personal Hygiene

- Crewmembers on short-duration missions often perform only partial-body cleansing using disposable wipes and rinse-less shampoo.
- For longer-duration missions, both for cleanliness and crew comfort, reusable towels that can be soaked with water may be preferred. Whole-body cleansing during long-duration missions may be necessary to ensure cleanliness which may be difficult to accomplish with partial-body cleansing. ***[V2 7016] Personal Hygiene Capability***

Skylab Shower

Reference the OCHMO-TB-041 Waste Management Technical Brief for additional information

Body Waste Management

- Over long-duration missions, significant amounts of body waste will be generated. Saving this waste to package and return to Earth or burn up in orbit will no longer be an option and alternative solutions must be developed. ***[V2 7020] Body Waste Management Capability and [V2 7023] Body Waste Management Provision***

Application

Exercise

- Increased mission duration may lead to changes in exercise protocols and exercise equipment which may, in turn, impact volume allocations and scheduling decisions related to the activity. ***[V2 7038] Physiological Countermeasures Capability***

- Countermeasures, such as exercise, have been recommended or required to prevent bone density loss, muscle strength loss, and aerobic capacity decrements, especially during long-duration missions such as planetary and deep-space exploration. As missions increase in duration, this prevention is necessary to avoid injuries and crew performance reduction.

Monitoring and Treatment of Crew Health

- The current spaceflight medical scenario relies heavily on telemedicine and ground clinical support. The medical system on ISS is extensive, and all astronauts receive basic medical training prior to missions.

- The medical system design requirements need to reflect anticipated crew performance and physical characteristic changes due to exposure over the course of the mission.

- Long-duration missions will require a "crew medical officer" to handle routine medical check-ups and issues of emergent care that might arise while out of contact with ground resources. We are also moving towards having equal medical training for all crewmembers on Artemis missions.

- Medical systems should be optimized to provide the best available care, and rigorous crew selection should prevent major conditions from occurring.

- A challenge for missions beyond LEO is to minimize the impact of potential delays between transmission and receipt of expert medical advice.

- Other challenges include potential medical misdiagnosis incidents, the need for assistance during clinical procedures, the risk of toxic or ineffective medications, and the handling of the remains in case of a deceased crew member.

Lunar DRMs presume:

- Restrictions in onboard medical capacity
- Increased risk with increased duration of surface stay and more frequent/numerous EVA

Mars DRMs presume:

- Restrictions in onboard medical capability
- Limited ground medical support
- Autonomous Medical Care
- Task design/EVA operations and suit/vehicle design will impact medical conditions' severity

NASA-STD-3001 Volume 1

[V1 3001] Selection and Recertification; [V2 3002] Pre-Mission Preventive Health Care; [V1 3003] In-Mission Preventive Health Care; [V1 3004] In-Mission Medical Care; [V1 6008] Crew Health Operations Concept Document

NASA-STD-3001 Volume 2

[V2 7043] Medical Capability

Reference the following technical briefs OCHMO-TB-31 Exercise Overview, OCHMO-TB-033 Spaceflight Experience and Medical Care, OCHMO-TB-034 Crew Selection & Recertification, and OCHMO-TB-012 Mortality Related to Human Spaceflight for more information.

Application

Behavioral Health

- Long-duration missions can affect the crews' behavioral health due to confinement, stress, and isolation. The psychological needs of a long-duration mission may drive additional requirements.
- Privacy becomes more important for crewmembers as mission durations become longer. The psychological needs of a long-duration mission may drive additional space and privacy requirements.
- Certain personal activities such as sleeping, personal hygiene, waste management, and personnel interactions require some degree of privacy.
- Private areas where these activities occur should not be placed in passageways or highly congested activity centers. Additional degrees of isolation may be highly desirable, particularly in mixed-gender crews. As mission duration increases, the need for separation and privacy grows. Individual privacy facilities shall be provided for long-duration missions (>30 days). ***[V2 7071] Behavioral Health and Privacy***
- Crew also needs common areas to gather, eat, and plan their work. ***[V2 7084] Recreational Capabilities***

One of the two crew quarters located in the Zvezda module

Sleep Accommodations

- The sleep accommodation requirements depend primarily on the gravity environment and the mission duration. The selected sleep system type and volume depend on mission duration, mission scenario (e.g., microgravity vs. partial gravity), and available volume. Implementation can be done at different levels, from sleep areas, beds, individual crew quarters, shared crew quarters, and larger private crew quarters containing waste and hygiene management.
- Short-duration missions, such as LEO or lunar transit, may require only temporary sleep areas. The non-dedicated crew areas used for sleep during short-duration missions should be easy and fast to set up and take down (e.g., sleeping bag). Sleep preparation operations that require excessive time can reduce sleeping time, resulting in decreased crew performance. It should be easy to ingress and egress all sleep areas. Even temporary sleep accommodations should provide sound and light attenuation, comfortable temperature and airflow, and a degree of privacy.
- Missions greater than 30 days in duration should have dedicated crew quarters that provide privacy. Crew-quarter design should incorporate features that contribute to feelings of security, comfort, privacy, personality, relaxation, and other aspects of behavioral health. ***[V1 4014] Completion of Critical Tasks; [V1 6001] Circadian Shifting Operations and Fatigue Management; [V2 6079] Crew Sleep Continuous Noise Limits; [V2 7070] Sleep Accommodations, and [V2 7071] Behavioral Health and Privacy.***

Reference the OCHMO-TB-016 Behavioral Health Technical Brief and the OCHMO-TB-041 Sleep Accommodations Technical Brief for additional information

Application

Workload

- Long-duration missions will have a different performance profile than missions of short durations. Astronauts may experience long periods of low workload or outright boredom, punctuated with bursts of high workload due to emergency or off-nominal conditions.

- Maintaining a ready engagement among crewmembers during extended periods of inactivity is essential to effective performance during periods of sudden critical activity. ***[V1 4014] Completion of Critical Tasks, [V2 5007] Cognitive Workload, and [V2 10200] Physical Workload***

- Additionally, it is important to manage increases in workload during long-duration missions to facilitate crew morale, since crew cohesion tends to decrease as length of stay increases.

Team Cohesion and Collaboration

- Team conflict is a risk factor for long-duration space missions because of its potential impact on team member satisfaction, team cohesion, and performance. ***[V1 3001] Selection and Recertification***

- Team issues are likely to occur on every long-duration mission. Consideration of team composition and performance factors will be especially important for longer-duration missions.

Eating dinner on *Skylab I* (1973)
Source: NASA

Eating dinner on the ISS (2015)
Source: NASA

Reference the NASA OCHMO-TB-032 Cognitive Workload for additional information

Application

Maintainability

ISS040 (2014)-Reid Wiseman Performs Routine In-flight Maintenance

- Crew maintenance of the spacecraft will present unprecedented challenges in planetary exploration, primarily due to the significantly greater distances and durations required for such missions. HSIA requirements must be levied at the onset of the design and development cycle for increasingly Earth-independent missions.
- For Low Earth Orbit Missions, NASA has been able to shift maintainability requirements from the design phase to operations because ground support can be increased throughout the mission.
- This will not be possible to the same extent with extended lunar surface operations where vehicles and equipment will reside on the Moon. The same will be valid for Mars, compounded by long communication latencies that will not allow the ground to provide real-time guidance and oversight for preventive and corrective maintenance tasks.
- In addition, environmental factors associated with surface operations, including dust, thermal extremes, day-to-night transitions, static electricity, dormancy, etc., will increase maintainability challenges.
- NASA-STD-3001 provides guidance in designing equipment and systems to facilitate maintenance and ensure proper maintainability to support crew in routine operations and conditions requiring critical repairs.

NASA-STD-3001 Volume 2

[V2 9111] Maintenance Concept of Operations; [V2 9112] Availability of Critical Systems; [V2 9113] Damage Prevention, [V2 9114] In-Mission Maintenance, [V2 9036] Design for Maintenance; [V2 9037] Commercial Off-the-Shelf (COTS) Equipment Maintenance; [V2 9038] In-Mission Tool Set; [V2 9115] Maintenance Tools Usability

Reference the OCHMO-TB-036 Design for Maintainability for additional information.

Back-Up

Major Changes Between Revisions

Original → Rev A

- Updated information and standards to be consistent with NASA-STD-3001 Volume 1 Rev C and Volume 2 Rev D.
- Added considerations for communication delays and maintainability
- Additional content added for clarity and guidance throughout

Referenced Technical Requirements

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

NASA-STD-3001 Volume 1 Revision C

[V1 3001] Selection and Recertification Crewmembers shall be medically and psychologically selected and annually recertified following the guidance in OCHMO-STD-100.1A, NASA Astronaut Medical Standards Selection and Annual Recertification.

[V1 3002] Pre-Mission Preventive Health Care Pre-mission preventive strategies shall be used to reduce in-mission and long-term health medical risks, including, but not limited to: (see NASA-STD-3001, Volume 1 Rev C for full technical requirement).

[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), individual crewmember needs, clinical practice guidelines, flight surgeon expertise, historical review, mission parameters, and vehicle-derived limitations. These analyses consider the needs and limitations of each specific vehicle and design reference mission (DRM) with particular attention to parameters such as mission duration, expected return time to Earth, mission route and destination, expected radiation profile, concept of operations, and more. In-mission preventive care includes, but is not limited to: (see NASA-STD-3001, Volume 1 Rev C for full technical requirement).

[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, individual crewmember needs, clinical practice guidelines, flight surgeon expertise, historical review, mission parameters, and vehicle-derived limitations. These analyses consider the needs and limitations of each specific vehicle and design reference mission (DRM) with particular attention to parameters such as mission duration, expected return time to Earth, mission route and destination, expected radiation profile, concept of operations, and more. In-mission capabilities (including hardware and software), resources (including consumables), and training to enable in-mission medical care, and behavioral care, are to include, but are not limited to: (see NASA-STD-3001, Volume 1 Rev C for full technical requirement).

[V1 4014] 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 4019] Pre-Mission Nutritional Status Pre-mission nutritional status shall be assessed, and any deficiencies mitigated before launch.

[V1 4020] In-Mission Nutrient Intake Programs shall provide each crewmember with 100% of their calculated nutrient and energy requirements, based on an individual's age, sex, body mass (kg), height (m), and appropriate activity factor.

[V1 4022] Post-Mission Nutritional Assessment and Treatment Post-mission nutritional assessment and treatment shall be aimed at returning to baseline.

[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.

Referenced Technical Requirements

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

NASA-STD-3001 Volume 1 Revision C

[V1 6008] Crew Health Operations Concept Document The medical and health care operations concept should include, as a minimum, the operational concepts of crew selection; pre-flight medical intervention standards; inflight medical and health care standards; private medial conferences; periodic health and fitness evaluation; behavioral health support for the crew, ground personnel, and crew families; definitive care facilities; vehicle/habitat crew performance system; medical survival kits; post- flight standards; post-flight medical evaluations; and landing/launch EMS support. For past programs, this information has been documented in a Crew Health Operations Concept (CHOC) document.

NASA-STD-3001 Volume 2 Revision D

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

[V2 4013] Muscle Effects The effects of muscle endurance and fatigue shall be factored into system design.

[V2 4015] Aerobic Capacity The system shall be operable by crewmembers with the aerobic capacity as defined in NASA-STD-3001, Volume 1.

[V2 4102] Functional Anthropometric Accommodation The system shall ensure the range of potential crewmembers can fit, reach, view, and operate the human systems interfaces by accommodating crewmembers with the anthropometric dimensions and ranges of motion as defined in data sets in Appendix E, Physical Characteristics and Capabilities, Sections E.2 and E.3.

[**V2 4103] Body Mass, Volume, and Surface Area Data** The system shall accommodate the body characteristic data for mass, volume, and surface area as defined in Appendix E, Physical Characteristics and Capabilities, Sections E.4, E.5, and E.6.

[V2 4104] Crew Operational Loads The system shall be operable by crew during all phases of flight, including prelaunch, ascent, orbit, entry, and postlanding, with the lowest anticipated strength as defined in E, Physical Characteristics and Capabilities, Section E.7.

[V2 4105] Withstand Crew Loads The system shall withstand forces imparted by the crew during all phases of flight, including but not limited to prelaunch, ascent, orbit, entry, and postlanding, as defined in Appendix E, Physical Characteristics and Capabilities, Section E.7 without sustaining damage.

[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 off-nominal tasks.

[V2 6004] Nominal Vehicle/Habitat Carbon Dioxide Levels The system shall limit the average one-hour CO_2 partial pressure ($ppCO_2$) in the habitable volume to no more than 3 mmHg.

[V2 6026] Water Quality At the point of crew consumption or contact, the system shall provide potable water that is safe for human use, including drinking, food rehydration, personal hygiene, and medical needs and is aesthetically acceptable.

[V2 6039] Water Dispensing Rate Water shall be dispensed at a rate that is compatible with the food system.

[V2 6040] Water Dispensing Increments To prevent overflow, water shall be dispensable in specified increments that are compatible with the food preparation instructions and time demands of the allotted meal schedule.

Referenced Technical Requirements

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

NASA-STD-3001 Volume 2 Revision D

[V2 6050] Atmosphere Contamination Limit The system shall limit gaseous pollutant accumulation in the habitable atmosphere below individual chemical concentration limits specified in JSC-20584, Spacecraft Maximum Allowable Concentrations for Airborne Contaminants (SMACs).

[V2 6059] Microbial Air Contamination The system shall provide air in the habitable atmosphere that is microbiologically safe for human health and performance

[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 6107] Nominal Vehicle /Habitat Atmospheric Ventilation The system shall maintain a ventilation rate within the internal atmosphere that is sufficient to provide circulation that prevents CO_2 and thermal pockets from forming, except during suited operations, toxic cabin events, or when the crew is not inhabiting the vehicle.

[V2 6108] Off-Nominal Vehicle/Habitat Atmospheric Ventilation The system shall control for ppO_2, $ppCO_2$, and relative humidity during off-nominal operations, such as temporary maintenance activities in areas not in the normal habitable volume.

[V2 6109] Water Quantity The system shall provide a minimum water quantity as specified in Table 6.3-1—Water Quantities and Temperatures, for the expected needs of each mission, which are considered mutually independent.

[V2 6110] Water Temperature The system shall provide the appropriate water temperature as specified in Table 6.3-1—Water Quantities and Temperatures, for the expected needs of each mission and task.

[V2 7001] Food Quality The food system shall provide the capability to maintain food safety and nutrition during all phases of the mission.

[V2 7002] Food Acceptability The system shall provide food that is acceptable to the crew for the duration of the mission.

[V2 7003] Food Caloric Content The system shall provide each crewmember with an average of 12,698 kJ (3,035 kcal) per day, else an average energy requirement value is determined using Table 7.1-1—EER Equations and applying an activity factor appropriate to the mission gravity and planned level of physical activity.

[V2 7004] EVA Food Caloric Content For crewmembers performing EVA operations, the food system shall provide an additional 837 kJ (200 kcal) per EVA hour above nominal metabolic intake as defined by [V2 7003] Food Caloric Content, of this NASA Technical Standard.

[V2 7007] Food Microorganism Levels Microorganism levels in the food and production area shall not exceed those specified in Table 7.1-3—Food Microorganism Levels.

[V2 7008] Food Preparation The system shall provide the capability for the preparation, consumption, and stowage of food.

[V2 7009] Food Preparation and Cleanup The food system shall allow the crew to unstow supplies, prepare meals, and clean up for all crewmembers within the allotted meal schedule.

[V2 7010] Food Contamination Control The food storage, preparation, and consumption areas shall be designed and located to protect against cross-contamination between food and the environment.

Referenced Technical Requirements

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

NASA-STD-3001 Volume 2 Revision D

[V2 7011] Food and Beverage Heating The system shall provide the capability to heat food and beverages to a temperature appropriate for the given item.

[V2 7014] Food Spill Control The system shall provide the ability to contain and remove food particles and spills.

[V2 7015] Food System Cleaning and Sanitizing The system shall provide methods for cleaning and sanitizing food facilities, equipment, and work areas.

[V2 7016] Personal Hygiene Capability Personal hygiene items shall be provided for each crew member, along with corresponding system capabilities for oral hygiene, personal grooming, and body cleansing.

[V2 7020] Body Waste Management Capability The system shall provide the capability for collection, containment, and disposal of body waste for both males and females.

[V2 7023] Body Waste Management Provision Body waste management supplies shall be provided for each crewmember and be located within reach of crewmembers using the waste body management system.

[V2 7041] Environmental Control The system environmental control shall accommodate the increased O_2 consumption and additional output of heat, CO2, perspiration droplets, odor, and particulates generated by the crew in an exercise area.

[V2 7043] Medical Capability A medical system shall be provided to the crew to meet the medical requirements of NASA-STD-3001, Volume 1.

[V2 7052] Stowage Location All relocatable items, e.g., food, EVA suits, and spare parts, shall have a dedicated stowage location.

[V2 7070] Sleep Accommodations 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 crew health and performance.

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

[V2 7074] Clothing Quantity Clean, durable clothing shall be provided in quantities sufficient to meet crew needs.

[V2 7076] Clothing Safety and Comfort Clothing shall be comfortable in fit and composition, for the environment, e.g., temperature and humidity, in which it will be worn.

[V2 7100] Food Nutrient Composition The system shall provide a food system with a diet including the nutrient composition that is indicated in the Dietary Reference Intake (DRI) values as recommended by the National Institutes of Health, with the exception of those adjusted for spaceflight as noted in Table 7.1-2—Nutrient Guidelines for Spaceflight.

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

[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.

All referenced tables and figures are available in NASA-STD-3001 Volume 2 Revision D.

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