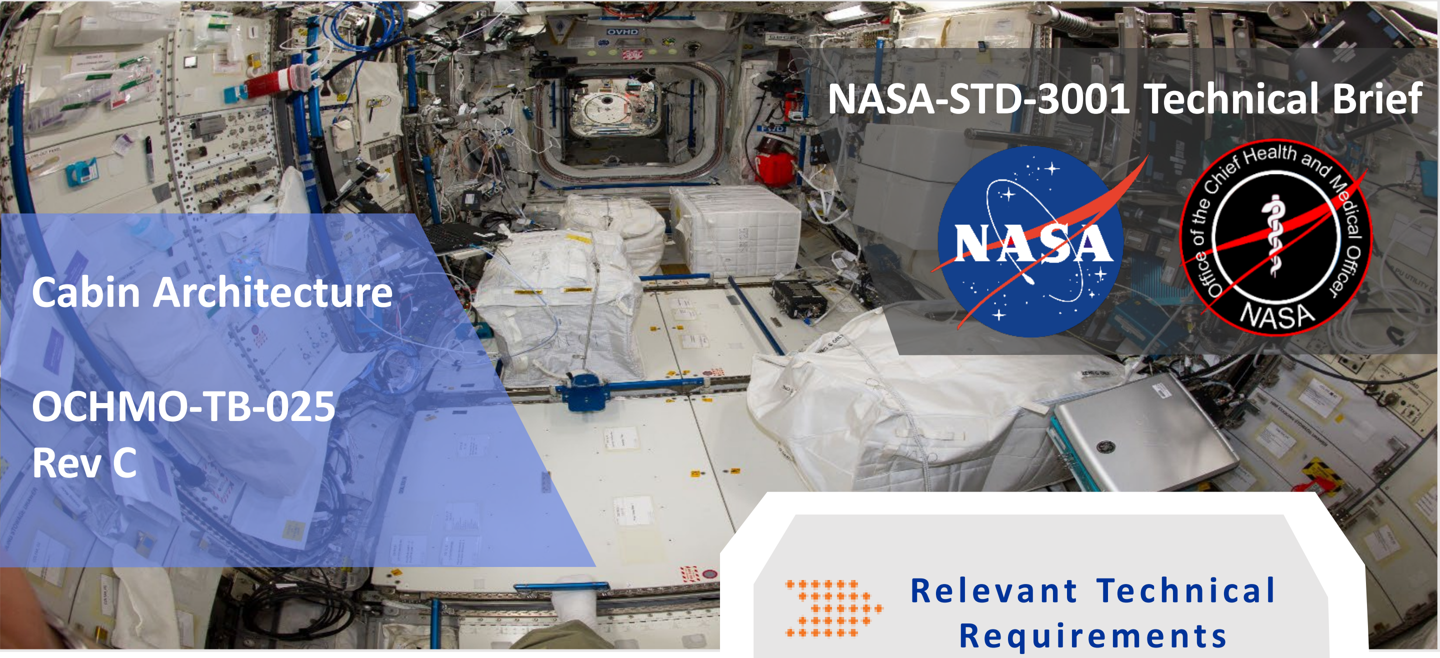


NASA-STD-3001 Technical Brief

Cabin Architecture

OCHMO-TB-025
Rev C

Executive Summary

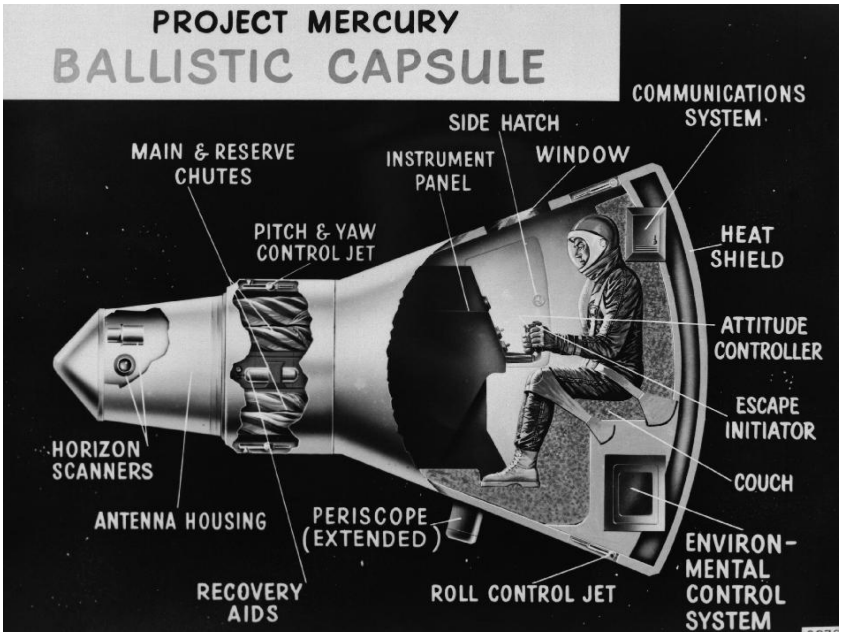
A cabin space intended for human use must keep the occupant(s) alive, support all the physical systems and cargo that a mission requires, and accommodate the activities the crew must perform. These necessities must be balanced against volume and mass limits imposed by the capabilities of the vehicle itself. Technical requirements in NASA-STD-3001 Volume 2 aim to ensure the crew cabin contains all necessary features to maximize crew efficiency, human performance, and mission success.

Relevant Technical Requirements

NASA-STD-3001 Volume 1, Rev C
[V1 3004] In-Mission Medical Care

NASA-STD-3001 Volume 2, Rev D
[V2 7021] Body Waste Management System Location
[V2 7038] Physiological Countermeasures Capability
[V2 7050] Stowage Provisions
[V2 7051] Personal Stowage
[V2 7052] Stowage Location
[V2 7053] Stowage Interference
[V2 7054] Stowage Restraints
[V2 7055] Priority of Stowage Accessibility
[V2 7056] Stowage Operation without Tools
[V2 7057] Stowage Access while Suited
[V2 7058] Identification System
[V2 7064] Trash Accommodation
[V2 7065] Trash Volume Allocation
[V2 7066] Trash Stowage Interference
[V2 7069] Labeling of Hazardous Waste
[V2 7070] Sleep Accommodation
[V2 8001] Volume Allocation
[V2 8005] Functional Arrangement
[V2 8006] Interference
[V2 8007] Spatial and Interface Orientation
[V2 8010] Location Identifiers
[V2 8011] Location Aids
[V2 8013] Intravehicular Translation Paths
[V2 8014] Escape Translation Paths
[V2 8020] Crew Ingress/Egress Translation Path - Ground
[V2 11005] EVA Translation Path Hazard Avoidance

Background



The Mercury capsule was cramped
The capsule contained all essential systems for flight, communications, and keeping the crewmember alive. With regards to volume accommodations for crew activities, there was enough room for an astronaut to sit and operate the command console, but little else. The crew space had only 2.8 cubic meters of habitable volume, the smallest of any American crewed space vehicle.

International Space Station (ISS) crew complaints about inconvenient stowage system
"…Stowage is one area that deserves some attention, because ground doesn't really understand the problems of gathering equipment from multiple locations and tying it down for use at a work site. Walls are already cluttered, and it's hard to organize a location nearby. Most items are buried deep in bags, sometimes three or four deep. Inside a locker, there is a CTB, inside of which is a kit, which has a Ziploc with a tool inside. This can really add to the cost of doing business…"


The Leonardo Permanent Multipurpose Module (PMM), installed in March 2011, is used for storage on the ISS.

Risks
If a crew cabin space is inadequately designed, laid out, or furnished, the crew will either have difficulty performing tasks or will be unable to perform them at all. Additionally, crew discomfort can cause and aggravate reduced effectiveness. In extreme cases, improper design can endanger the crew or cause damage to the vehicle. For example, if an emergency egress path is blocked by storage containers, the crew would have difficulty escaping the vehicle.

Reference Data

Stowage
The system must provide space to store everything the crew and mission needs. Items must be stored in a dedicated, accessible location that does not interfere with other crew tasks.

Trash
The system must have a trash management system to deal with waste produced during the mission. Special care must be taken to ensure containment of trash and its odor.

Body Waste & Hygiene
The system must provide space for crewmembers to perform hygiene tasks and means to safely dispose of body waste.

Crew Task Volume
Any crewed vehicle must have enough physical space for a specified number of crew to perform all necessary tasks for the duration of the mission.

Spatial Configuration
The spatial configuration of the cabin must facilitate crew operations in a logical manner.

Spatial Orientation
In a microgravity environment, the crew lacks a common "up-and-down." The system must establish a consistent orientation of interfaces and spaces.

Translation Paths
The system must facilitate the easy and safe movement of crew and equipment through, in, and out of the vehicle.

One of two crew quarters located in the *Zvezda* module

Eating dinner on *Skylab I* (1973)

Eating dinner on the *ISS* (2015)

Application

The crux of the challenge when designing a crewed cabin space is *striking the balance* between everything that the crew and mission needs, and the volume and mass limits dictated by the capabilities of the vehicle. The crew cannot get all the comforts or space they want, but engineers cannot simply design a 'windowless box' with no regard to crew needs.

Things to consider:

What systems does the vehicle require (power, thermal, ECLSS, etc.)

- Each of these systems take up mass and volume
- They must not interfere with other cabin elements
- They must be accessible for maintenance

Consumables (food, water, air, etc.)[1,2]

- Longer missions require more consumables
- Food must be stored separately and hygienically

Cargo (tools, clothes, EVA suits, etc.)

- Different missions will require different cargo, which will need to be stored and accessible

Crew (number, size, age, etc.)

- More crew will require more resources
- Crew of differing size, age, etc. will use more or less resources

Crew tasks and activities (eating, sleeping donning/doffing suits, etc.)

- Every task requires a certain amount of space
- Certain tasks should be in separate spaces (e.g., eating/waste management and hygiene)

Mission parameters (duration, destination, etc.)[3]

- Longer and farther missions will require more resources

ISS Astronaut using Advanced Resistive Exercise Device (ARED)

1. OCHMO-TB-013 Food and Nutrition Technical Brief
2. OCHMO-TB-027 Water Technical Brief
3. OCHMO-TB-007 Mission Duration Technical Brief

Skylab sleep chamber (1973)

ISS sleep chamber (2012)

Application

Relevant Technical Requirements from NASA-STD-3001

[V1 3004] In-Mission Medical Care; [V2 7050] Stowage Provisions; [V2 7051] Personal Stowage; [V2 7052] Stowage Location; [V2 7053] Stowage Interference; [V2 7054] Stowage Restraints; [V2 7055] Priority of Stowage Accessibility; [V2 7056] Stowage Operation without Tools; [V2 7057] Stowage Access while Suited; [V2 7058] Identification System

ISS food storage boxes with restraints

Factors to consider for storage include:

- Volume of relocatable items
- Type of items that will be stowed and where they should be stored. Examples are:
  - Personal items – clothing, personal hygiene items, personal items
  - Workstation – Writing equipment, camera equipment, emergency equipment
  - Consumable hygiene – tissues, soap, wipes
  - Galley – Food and food prep, utensils, wipes, housekeeping supplies
  - Recreation – Games, reading materials, audio-visual equipment
  - Meeting areas – Writing materials, presentation aids
- Medical treatment area – medical equipment, pharmaceuticals, dispensary supplies[1,2]
- Exercise facility – exercise equipment
- Body waste management system – wipes, urine collection devices[3]
- Trash management system – wet and dry trash receptacles, trash bags
- The gravity environment resupply and return over the vehicle or habitat life cycle
- Flexibility for different potential scenarios
- The potential usage of nonstandard storage locations
- The balance between centralized and distributed systems
- Operability
- Accessibility
- Interference
- Labeling
- Compliance with the overall inventory management system

Restraints holding storage containers

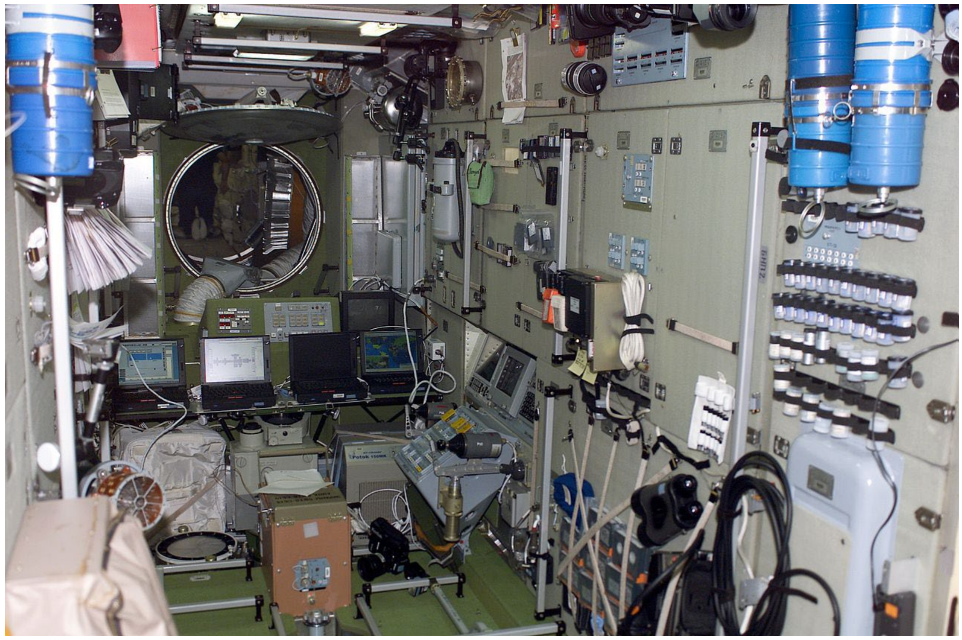
1. OCHMO-TB-033 Medical Care Technical Brief
2. OCHMO-TB-006 Pharmaceutical Technical Brief
3. OCHMO-TB-042 Waste Management Technical Brief

Application

Relevant Technical Requirements from NASA-STD-3001
[V2 8007] Spatial and Interface Orientation; [V2 8010] Location Identifiers; [V2 8011] Location Aids

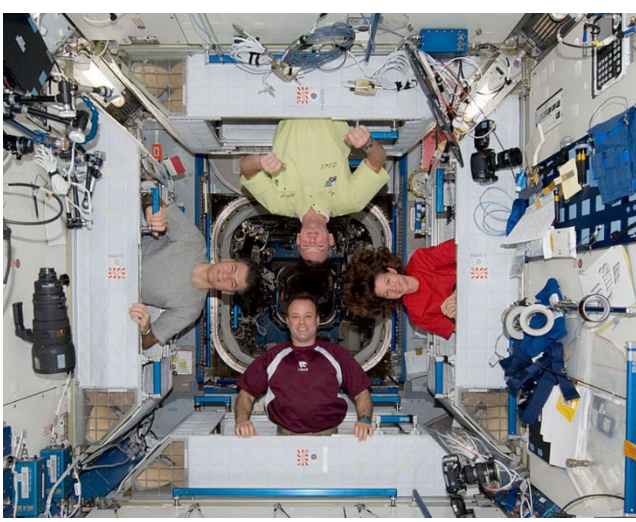
Proper orientation defining is important where there is no natural "down" from gravity.

Location aids with a defined coding system support navigation between vehicle modules. This includes designing the system with navigation in mind, such that the location of modules and stations does not contribute to confusion.



ISS Zvezda Module. Note how the color switches from dark to light to signify down and up, respectively (mimicking grass and sky), and how the computers, lighting, etc. support the design.

It may be the case that individual stations such as laboratories or sleeping stations are placed along the designated floor and ceiling. In this case, they should also conform to a frame of reference, though the frame may be separate from that of the vehicle at large.



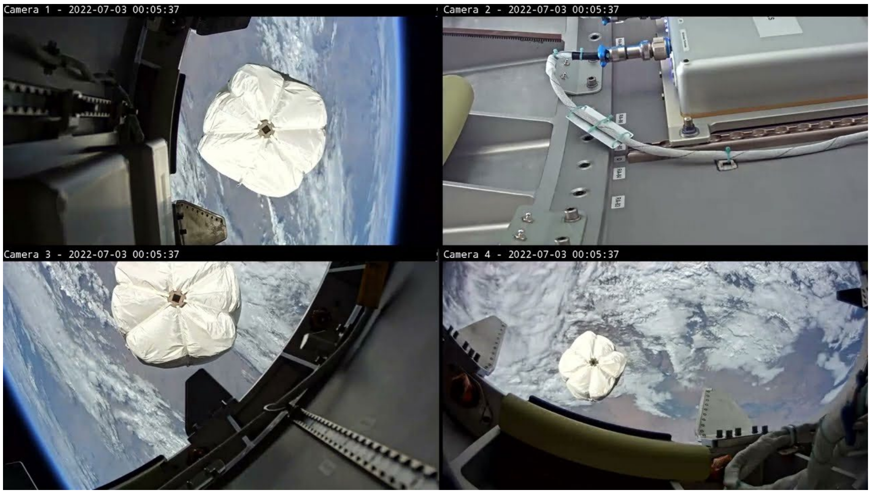
ISS sleeping stations external orientations

ISS sleeping station internal orientation

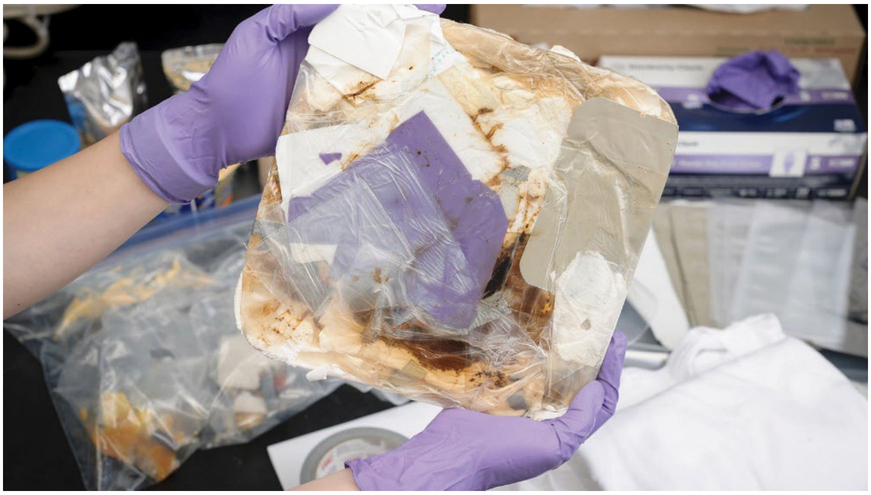
Application

Relevant Technical Requirements from NASA-STD-3001
[V2 7021] Body Waste Management System Location; [V2 7064] Trash Accommodation; [V2 7065] Trash Volume Allocation; [V2 7066] Trash Stowage Interference

Designing and designating locations for the body waste management system and trash has separate considerations than most stowage. These include the psychological effects of grooming and bathing, privacy, odor control, personal hygiene items, and cleaning capability. Body waste system may be connected to the water system for reclamation. Having several trash system receptacles throughout the vehicle will increase ease of access, but may require additional planning for stowage locations. Trash might either be stowed for the duration of the mission or ejected.



Trash being ejected from the ISS



Trash melted into a tile using a heat melt compactor

Trash may contain water and desirable gases that need to be recovered to minimize the need for mid-mission resupplies and storage capabilities.

One potential method for efficient storage of trash is to melt and compact it. This could be useful for long-duration and surface missions where ejecting trash is not a feasible option. For maximum efficiency, this would want to be mixed with a process for reclaiming desirable gases and water from the trash.

Application

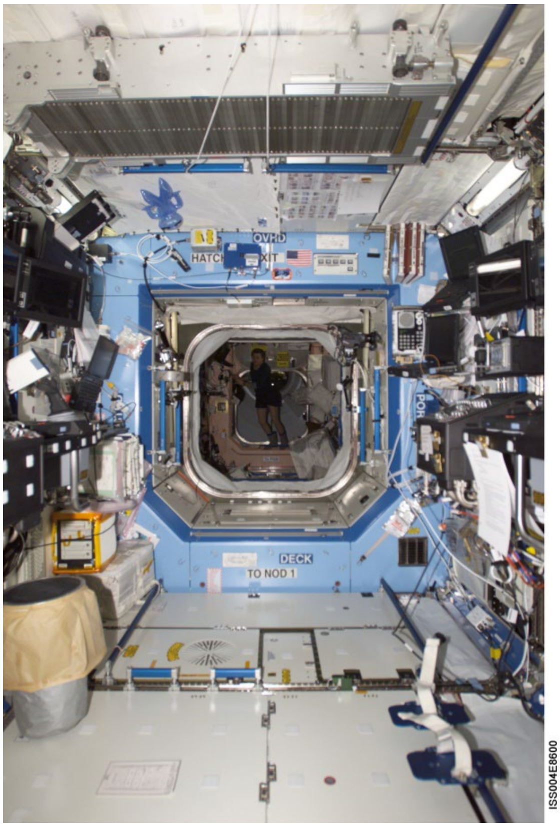
Relevant Technical Requirement from NASA-STD-3001
[V2 7069] Labeling of Hazardous Waste

Waste Category	Hazardous Waste Definitions	Hazardous Waste Considerations
Batteries	All types of batteries (e.g., Ni-Cad, Alkaline).	Damaged batteries may be dangerous if the terminals are not taped/isolated.
Biological/ Biomedical	Any solid or liquid that may present a threat of infection to humans, including non-liquid tissue, body parts, blood, blood products, body fluids, and laboratory wastes that contain human disease-causing agents. Also to include used absorbent material saturated with blood, blood products, body fluids, excretions, or secretions contaminated with visible blood or blood products that have dried.	Contained within a bag and a secondary container.
Sharps	Payload- and crew-generated needles, syringes, or any intact or broken objects that are capable of puncturing, lacerating, or otherwise penetrating the skin (e.g., glass, scalpels, hard broken plastic, syringes, etc.).	Store within sealable containers that will not puncture or leak.
Chemical Hazard	Any waste in solid, liquid, or semi-solid form that is contaminated with a chemical substance that requires special handling during disposal.	Chemicals are to be individually contained and separated based on their properties.
Radioactive	Solid, liquid, or gaseous materials that are radioactive or become radioactive and for which there is no further use.	The Kennedy Space Center Radiation Protection Officer and Johnson Space Center Radiation Health Office provide requirements based on radioactivity.

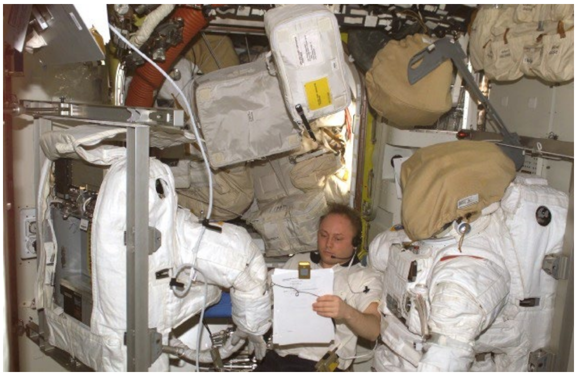
Application

Relevant Technical Requirements from NASA-STD-3001

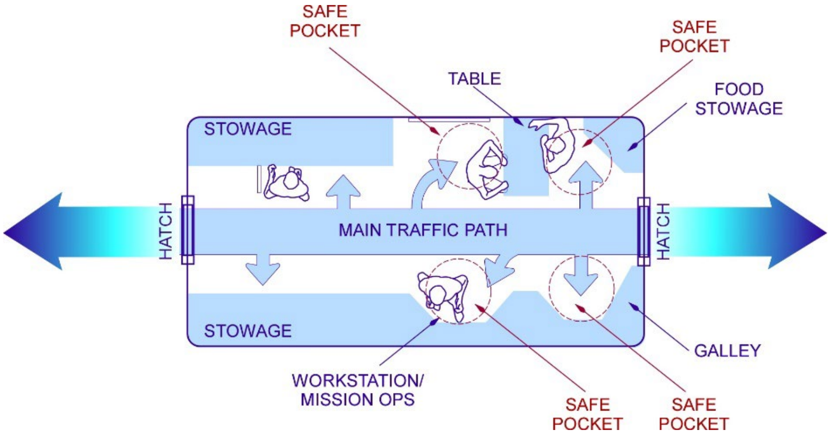
[V2 7038] Physiological Countermeasures Capability; [V2 8001] Volume Allocation; [V2 7070] Sleep Accommodation; [V2 8005] Functional Arrangement; [V2 8006] Interference; [V2 8013] Intravehicular Translation Paths; [V2 8014] Escape Translation Paths; [V2 8020] Crew Ingress/Egress Translation Path – Ground; [V2 11005] EVA Translation Path Hazard Avoidance



Optimal translation path with minimal rack front stowage from the ISS US Lab.



Sub-optimal stowage from the ISS Airlock Module.



Cabin design to avoid blocking translation paths

Stowage arrangements need to coincide with other architectural factors such as translation paths and mission tasks. As part of this, preplanning in system architecture with dedicated stowage volumes are necessary.

Appropriate system architecture can largely be determined through task analysis and previous experience. Task analysis looks at human anthropometry for all potentially necessary ranges of motion including factors such as suits, objects to carry, and tool usage. This method has limitations in that not all mission tasks or activities may be known at the beginning of development. It may instead require activities that are certain to take place, such as sleeping , eating, hygiene, system control, and extra-vehicular activity to derive a set of volume drivers that can estimate overall system volume and architecture. The experience-based method takes previous missions and derives necessary volume based on the number of crewmembers. This method does not account for different mission tasks like the task analysis method does and has limited information for extended surface missions.

Back-Up

Major Changes Between Revisions

Rev B → Rev C

- Updated information to reflect the revisions to language throughout both volumes of NASA-STD-3001.
- Updated/added website links due to new NASA website launch

Rev A → Rev B

- Added additional information and application notes on specific technical requirements.

Original → Rev A

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

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 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).

NASA-STD-3001 Volume 2 Revision D

[V2 7021] Body Waste Management System Location The body waste management system shall be isolated from the food preparation and consumption areas for aesthetic and hygienic purposes.

[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 7050] Stowage Provisions The system shall provide for the stowage of hardware and supplies, to include location, restraint, and protection for these items.

[V2 7051] Personal Stowage The system shall provide a stowage location for personal items and clothing.

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

[V2 7053] Stowage Interference The system shall provide defined stowage locations that do not interfere with crew operations.

[V2 7054] Stowage Restraints The system shall provide the capability to restrain hardware, supplies, and crew personal items that are removed or deployed for use as defined by crew task analysis.

[V2 7055] Priority of Stowage Accessibility Stowage items shall be accessible in accordance with their use, with the easiest accessibility for mission-critical and most frequently used items.

[V2 7056] Stowage Operation without Tools Stowage containers and restraints shall be operable without the use of tools.

[V2 7057] Stowage Access while Suited The stowage system shall be accessible by a suited crewmember.

[V2 7058] Identification System The stowage identification system shall be compatible with the inventory management system.

[V2 7064] Trash Accommodation The system shall provide a trash management system to contain, mitigate odors, prevent release, and dispose of all expected trash.

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 7065] Trash Volume Allocation Trash stowage volumes shall be allocated for each mission.

[V2 7066] Trash Stowage Interference The system shall provide defined trash stowage that does not interfere with crew operations.

[V2 7069] Labeling of Hazardous Waste The hazard response level (HRL) of all liquids, particles, gases, and gels shall be labeled on the outermost containment barrier in location(s) visible to crew.

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

[V2 8005] Functional Arrangement Habitability functions shall be located based on the use of common equipment, interferences, and the sequence and compatibility of operations.

[V2 8006] Interference The system shall separate functional areas whose functions would detrimentally interfere with each other.

[V2 8007] Spatial and Interface Orientation The system shall have consistent spatial and interface orientations relative to a defined vertical orientation.

[V2 8010] Location Identifiers A standard location coding system shall be provided to uniquely identify each predefined location within the system.

[V2 8011] Location Aids The system shall provide aids to assist crewmembers in locating items or places within the system and orienting themselves in relation to those items or places.

[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 8014] Emergency Escape Paths The system shall provide unimpeded and visible emergency escape routes commensurate with the hazard analyses and response concepts.

[V2 8020] Assisted Ingress and Egress Translation Path The system shall provide translation paths that accommodate the ingress and egress of a crewmember assisted by another crewmember.

[V2 11005] EVA Translation Path Hazard Avoidance EVA translation paths shall be free from hazards.

Reference List

1. Human Integration Design Handbook (HIDH). (2014). NASA/SP-2010-3407/REV1. https://www.nasa.gov/sites/default/files/atoms/files/human_integration_design_handbook_revision_1.pdf
2. Stuster, J. (2010). Behavioral Issues Associated with Long-Duration Space Expeditions: Review and Analysis of Astronaut Journals Experiment 01-E104 (Journals): Final Report. *NASA/TM-2010-216130*. https://lsda.jsc.nasa.gov/lsda_data/dataset_inv_data/ILSRA_2001_104__1740256372_.pdf_Expedition_8_ILSRA-2001-104_2011_31_010100.pdf