NASA-STD-3001 Technical Brief

Vehicle Hatches

OCHMO-TB-028
Rev B

Executive Summary

Hatch: An opening with an operable, sealable cover that ensures the isolation of adjoining environments and allows passage of people and cargo/equipment from one environment to the other. A hatch is composed of two components: a hatchway (the opening itself) and a hatch cover (the piece that closes the hatchway). A pressure hatch is one in which the atmosphere on one side of the hatch can be different from that on the opposite side of the hatch when the hatch cover is closed.

Relevant Technical Requirements

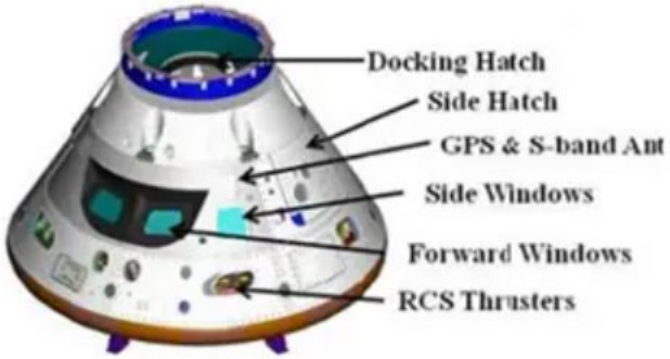
NASA-STD-3001 Volume 2, Rev D

[V2 4102] Functional Anthropometric Accommodation
[V2 4104] Crew Operational Loads
[V2 4105] Withstand Crew Loads
[V2 6012] Crew Health Environmental Limits
[V2 6020] Atmospheric Data Recording
[V2 8014] Emergency Escape Paths
[V2 8022] Hatches and Door Operation Without Tools
[V2 8023] Unlatching Hatches
[V2 8024] Hatch and Door Operating Times
[V2 8025] Hatch and Door Operating Force
[V2 8027] Hatchway Size and Shape
[V2 8028] Pressure Equalization across the Hatch
[V2 8029] Visibility across the Hatch
[V2 8030] Hatch, Hatch Cover and Door Interference
[V2 8031] Hatch Closure and Latching Status Indication
[V2 8032] Hatch Pressure Indication
[V2 8040] Mobility Aid for Assisted Ingress and Egress
[V2 8041] Unassisted Ingress, Egress, and Escape Mobility Aids
[V2 8043] Window Provisioning
[V2 8045] Window Optical Properties
[V2 8053] Emergency Lighting
[V2 12006] Volume Accommodation

Background

Capsule Hatch Types

Orion Capsule



Side hatches are used for vehicle ingress, egress in nominal/land landings, and egress for water landings in low sea state

Side Hatch

Astronaut training for water egress

Side hatch access for crew ingress from Launch Pad White Room

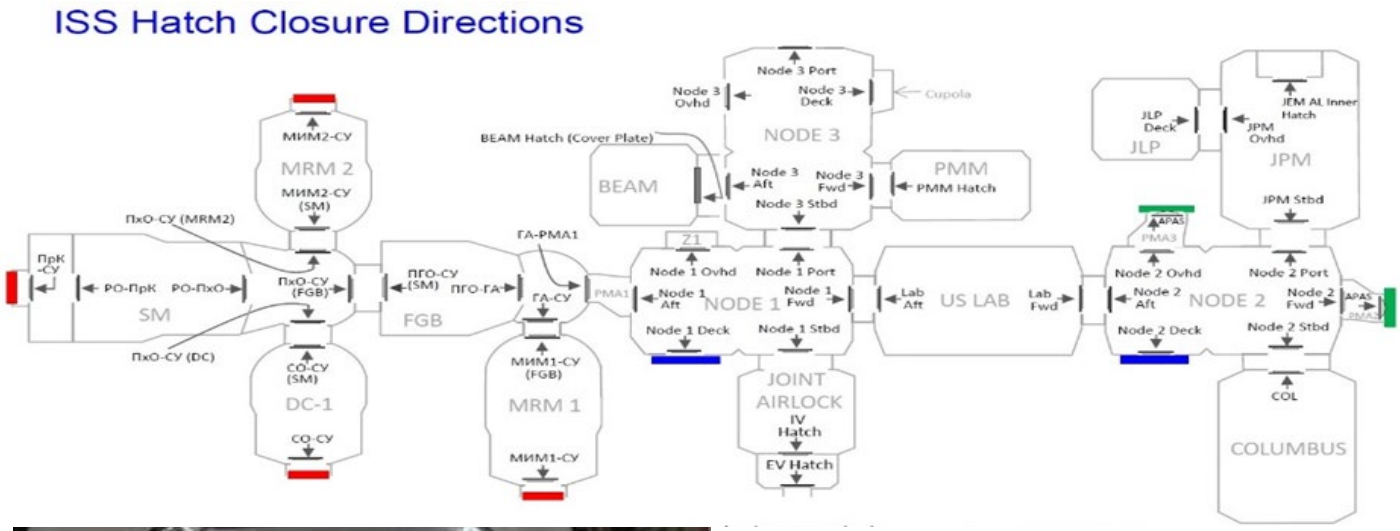
Boeing Starliner/Atlas V Launch Complex

Overhead (Docking) Hatch

Overhead hatch is used to transfer into vehicle post-docking (e.g., Gateway), or as alternate egress path post-landing such as water landing with high sea states

Background

ISS Hatch Placement



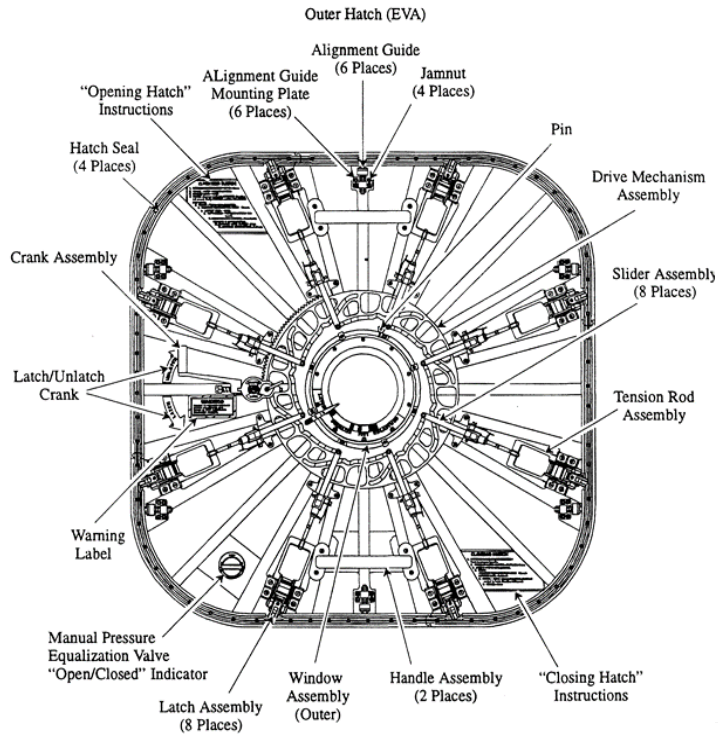
View through Lab forward Node 2 (N2) aft hatches looking forward. Note N2 forward hatch and PMA-2 visible in center of image.

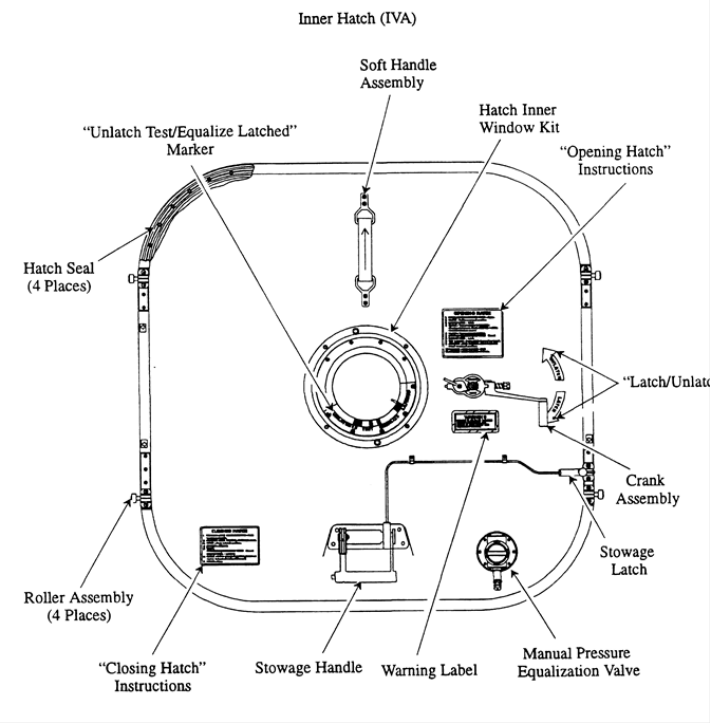
1. United States Orbital Segment (USOS) Common Berthing Mechanism (CBM) hatch connects all USOS modules.
2. Androgynous Peripheral Attach System (APAS) hatch connects Pressurized Mating adapter (PMA) to USOS or Russian module and are also used for US Commercial Vehicles.
3. The Vestibule refers to the volume between hatches where two modules (or a module and a vehicle or two vehicles) are connected. The vestibule must be pressurized prior to crew members opening the hatches.

Node longitudinal hatch (USOS type). Radial hatches visible around circumference.

SpaceX Dragon docked to PMA. Crew translates through Dragon overhead hatch and PMA APAS hatch into ISS.

Background





ISS Hatch Specifications associated with NASA-STD-3001 Volume 2, Revision D

[V2 8024] Hatch Cover and Door Operating Times For nominal operations, hatches and doors shall be operable by a single crewmember in no more than 60 seconds, from both sides of the hatch.

[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 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 8025] Hatch Cover and Door Operating Force The forces required to operate each crew interface for the hatch covers and doors shall be within the crewmember strength defined by requirement [V2 4104] Crew Operational Loads for the worst-case pressure differential and anticipated encumbering equipment and clothing.

[V2 8022] Hatches, Hatch Covers, and Door Operation without Tools Hatches, hatch covers, and doors shall be operable on either side by a single crewmember without the use of tools in expected gravity conditions, orientations, suit configurations, and operational configurations.

[V2 8023] Unlatching Hatch Covers Hatch shall require two distinct and sequential operations to unlatch.

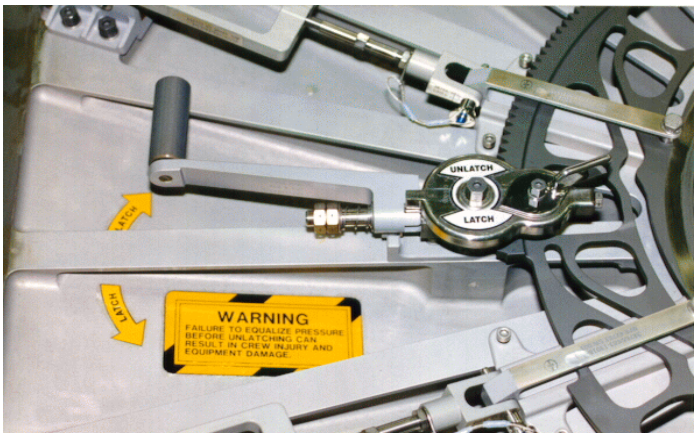
[V2 8029] Visibility across the Hatch The system shall provide a window for direct, non-electronic visual observation of the environment on the opposite side of the hatch.

[V2 8028] Pressure Equalization across the Hatch Each side of each hatch shall have manual pressure equalization capability with its opposite side, achievable from that side of the pressure hatch by a suited or unsuited crewmember.

Background

ISS Hatch Opening Procedure

ISS Hatch Opening



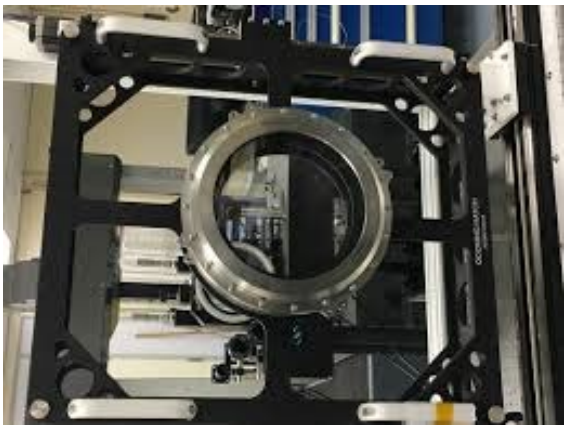
ISS Hatch Assembly

- Prior to opening a hatch, crew views through window to ensure no hazardous conditions are present.
- The crew must equalize pressure by opening the Manual Pressure Equalization Valve (MPEV).
- **[V2 8028] Pressure Equalization across the Hatch** Each side of each hatch shall have manual pressure equalization capability with its opposite side, achievable from that side of the pressure hatch by a suited or unsuited crewmember. **NASA-STD-3001 Volume 2 Revision D**
- The Crank Assembly actuates the latch drive mechanism which seats and unseats the hatch on the bulkhead and pre-loads hatch seals.
- **[V2 8032]** Pressure hatches shall indicate, viewable from both sides of the hatch, pressure differential across the hatch. **NASA-STD-3001 Volume 2 Revision D**
- Once pressure is confirmed the crank handle is pulled upright and put in engaged position.
- The crew opens hatch by turning crank counterclockwise on the IVA side or clockwise on the EVA side of hatch.
- **[V2 4105] Withstand Crew Loads** Strength data developed in accordance with section 4.1, Physical Data Sets, in NASA-STD-3001, Volume 2 shall be applied to the design of all elements of the system, hardware, and equipment with which the crew interfaces to ensure that crew tasks can be efficiently and effectively performed without injury to the crew and that hardware can be used by all crewmembers within the upper and lower ranges of anticipated strength without sustaining damage. **NASA-STD-3001 Volume 2 Revision D**
- The crew selects unlatch on hatch crank handle and turns crank to release latch from bulkhead.
- The crank is moved to the stowed position prior to opening the hatch in order to avoid potential mechanical interference as the hatch is opened.
- The hatch is physically opened, and the hatch door is moved to stowed position.

Background

Hatch Windows

Astronaut James Dutton looking through ISS hatch window



Orion Hatch Window Testing

The hatch window is designed to:

- Provide the crew with a view through the hatch and ability to see conditions present on the other side of the hatch.
- Protect crew from harmful ultraviolet and infrared radiation, environmental degradation, and debris hits.
- **[V2 8029] Visibility across the Hatch** The hatch window assembly is required to provide the crew with direct, non-electronic visual observation of the environment on the opposite side of the hatch. **NASA-STD-3001 Volume 2 Revision D**
- Hatch window composition varies with different vehicles. All hatch windows must address needs of strength (being able to withstand pressure and vacuum environments), thermal environments, and debris protection while providing optical properties sufficient for crew viewing and high-resolution imagery if needed.
- ISS hatch windows consist of two pressure panes of glass which meet all hatch window requirements but have increased risk of structural and degradation issues as well as increased weight and cost when compared to some newer window alternatives.
- The Orion hatch windows are designed with multiple panes consisting of glass and acrylic which provide strength and clarity of view, while avoiding degradation and structure issues of entirely glass windows. The acrylic panes also decrease weight and associated costs.
- **[V2 8045] Window Optical Properties** System windows shall have optical properties commensurate with their tasking in accordance with 66320 Optical Property Requirements for Glasses, Ceramics, and plastics in Spacecraft Window Systems. **NASA-STD-3001 Volume 2 Revision D**

Hatch Window Reference Documents:

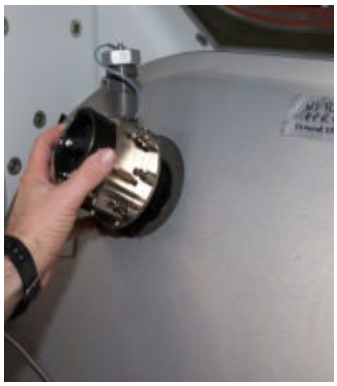
- JSC 65828 Rev. B, change 1 Structural Design Requirements And Factors of Safety For Spaceflight Hardware.
- JSC 66320 Optical Property Requirements For Glasses, Ceramics, and Plastics in Spacecraft Window Systems.
- NASA-STD-5018, Strength Design and Verification Criteria for Glass, Ceramics and Windows in Human Space Flight Applications.

Background

Pressure Equalization Valves

Positive Pressure Equalization Valve (PPEV)

- The PPEV is designed to regulate pressure during launch and limit the pressure differential across a module during transit to orbit.
- The PPEV drives the hatch closed while the Negative Pressure Relief Valve (NPRV) protects against overpressure that can push the hatch open.
- The PPEV is located inside the module and allows cabin air to exit in the event of over pressurization.
- When the pressure drops back to the acceptable level then the PPEV closes, maintaining the contents of the environment. The PPEV also allows sampling of the module atmosphere prior to change out.
- The PPEV will be mounted to the hatch until the module is mated, at which time a manual pressure equalization valve will replace it.
- **[V2 8028] Pressure Equalization across the Hatch** Each side of each hatch shall have manual pressure equalization capability with its opposite side, achievable from that side of the pressure hatch by a suited or unsuited crewmember. **NASA-STD-3001 Volume 2 Revision D**



Manual Pressure Equalization Valve

Manual Pressure Equalization Valve

Positive Pressure Equalization Valve

Manual Pressure Equalization Valve (MPEV)

- Allows air from either side of the hatch to mix with air on the other side, thus equalizing the pressure on both sides. This ensures that the hatch can be safely opened.
- Allows manual sampling of the air on the other side of the hatch to ensure that it is pure enough for human occupancy, especially after a contingency contamination scenario.
- Assists with monitoring and proper depress of the vestibule area.
- **[V2 8032] Hatch Pressure Indication** Pressure hatches shall indicate, viewable from both sides of the hatch, pressure differential across the hatch. **NASA-STD-3001 Volume 2 Revision D**

Operational Note – When the hatch is closed against a vacuum for a length of time, the space between the seal beads can bleed down to the vacuum. This can make it more difficult for the crew to open the hatch after opening the MPEV, as the MPEV on ISS does not vent the interstitial cavity between beads. The Orion hatch MPEV was modified to vent this volume when the MPEV is opened.

Application

Hatch Mishaps

Mercury Liberty Bell 7 (07/21/1961)
Gus Grissom

Navy helicopter was able to rescue Gus Grissom but unable to lift the Liberty 7 capsule due to excessive water weight.

- The Mercury Liberty Bell 7 flew the second crewed suborbital flight.
- It was designed with a new explosive hatch release that would allow an astronaut to exit the spacecraft quickly in the event of an emergency.
- Emergency personnel could also trigger the explosive hatch from outside the spacecraft by pulling on an external lanyard.
- The flight went smoothly, but after splashdown the hatch blew prematurely and caused the capsule to take on water, endangering the commander's life.
- Gus Grissom was able to safely exit the vehicle, but the recovery helicopters were unable to lift the vehicle due to excessive weight of the additional water and it was lost.
- The incident resulted in a change of procedures which required the firing safety pin to remain in place until after the helicopter hook was attached and tension applied to the recovery cable.
- The capsule was salvaged through a Discovery Channel recovery project in 1999.

Liberty Bell recovered in 1999

[V2 8023] Unlatching Hatch Covers Hatch shall require two distinct and sequential operations to unlatch.
From: NASA-STD-3001 Volume 2, Rev D

Application

Hatch Mishaps

Apollo 1 (01/27/1967)
Roger Chaffee, Ed White, & Gus Grissom

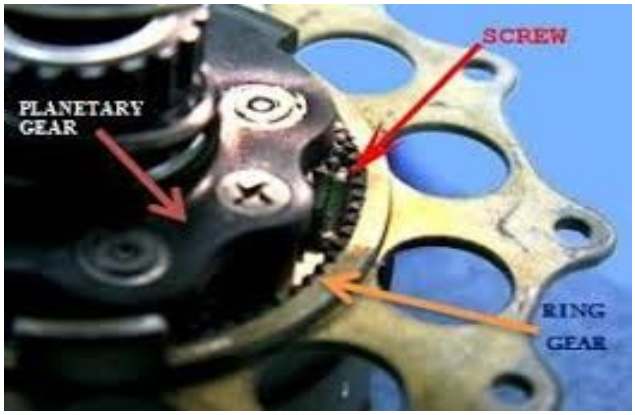
- A spark, believed to be caused by an electrical short, combined with the 100% oxygen environment at elevated pressure, created a fire which spread rapidly.
- This increased pressure upon the hatch caused it to seal tightly and prevented it from being opened from the inside of the vehicle.
- The hatch could not be easily opened from the exterior by emergency personnel and did not have a pyrotechnic automatic opening system.
- Rescue personnel were equipped with gas masks designed for protection against toxic vapors. They had no heat-protective garments and were unable to assist crew. The crew was unable to escape the vehicle and perished in the fire.
- Cause of death of the Apollo 1 Crew was determined to be asphyxia from inhalation of toxic gases due to the fire. Contributory cause of death was thermal burns.

[V2 6003] O^2 Partial Pressure Range for Crew Exposure; [V2 8014] Emergency Escape Paths; [V2 8015] Assisted Ingress and Egress Translation Path; [V2 8022] Hatches, Hatch Covers, and Door Operation without Tools; [V2 8024] Hatch Cover and Door Operating Times; [V2 8028] Pressure Equalization across the Hatch; [V2 9027] Protection; [V2 9028] Isolation of Crew from Spacecraft Equipment
From: NASA-STD-3001 Volume 2, Rev D

Application

Hatch Mishaps

STS-80 Columbia (11/19/1996)
Kenneth Cockrell, Kent Rominger, Story Musgrave, Thomas Jones, & Tamara Jernigan



- During the STS-80 mission, two planned extravehicular (EVA) spacewalks were cancelled when astronauts were unable to open the outer airlock hatch.
- Investigation found that a small screw had come loose from the internal assembly and lodged in the planetary gears of the hatch actuator.
- Investigative findings determined additional contributing factors:
  - *One of the fasteners had backed out and was lodged between a planetary gear and the ring gear within the actuator gearbox.*
  - *A second fastener was partially backed out and loose.*
  - *The design requirements called for a locking threaded insert, but the incorrect non-locking type had been used.*
- Mishap resulted in loss of EVA and associated objectives, including evaluation of tools to be used for ISS construction and maintenance.

Back-Up

Major Changes Between Revisions

Rev A → Rev B

- 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

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 2 Revision D

[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 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 6012] Crew Health Environmental Limits The system shall maintain levels of cabin humidity and temperature within the boundaries of the Operating Limits as shown in Figure 6.2-2—Crew Health Environmental Limits, to protect for crew health during pressurized operations when crew occupies the cabin, excluding suited operations, ascent, entry, landing, and post landing.

[V2 6020] Atmospheric Data Recording For each isolatable, habitable compartment, the system shall automatically record pressure, humidity, temperature, ppO_2, and $ppCO_2$ data continuously.

[V2 8014] Emergency Escape Paths The system shall provide unimpeded and visible emergency escape routes commensurate with the hazard analyses and response concepts.

[V2 8022] Hatches and Door Operation Without Tools Hatches and doors shall be operable on either side by a single crewmember without the use of tools in expected gravity conditions, orientations, suit configurations, and operational configurations.

[V2 8023] Unlatching Hatches Hatches shall require two distinct and sequential operations to unlatch.

[V2 8024] Hatch and Door Operating Times For nominal operations, hatches and doors shall be operable by a single crewmember in no more than 60 seconds, from both sides of the hatch.

[V2 8025] Hatch and Door Operating Force The forces required to operate each crew interface for the hatches and doors shall be within the crewmember strength defined by requirement [V2 4104] Crew Operational Loads for the worst-case pressure differential and anticipated encumbering equipment and clothing.

[V2 8027] Hatchway Size and Shape Hatchways and doorways shall be sized and shaped to accommodate all planned translations, including unrestricted passage of a suited crewmember and crewmembers carrying cargo or equipment.

[V2 8028] Pressure Equalization across the Hatch Each side of each hatch shall have manual pressure equalization capability with its opposite side, achievable from that side of the pressure hatch by a suited or unsuited crewmember.

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 8029] Visibility across the Hatch The system shall provide a window for direct, non-electronic visual observation of the environment on the opposite side of the hatch.

[V2 8030] Hatch, Hatch Cover and Door Interference When opened, hatches, hatch covers and doors shall allow for unrestricted flow of traffic.

[V2 8031] Hatch Closure and Latching Status Indication Pressure hatches shall indicate closure and latching status on both sides of the hatch.

[V2 8032] Hatch Pressure Indication Pressure hatches shall indicate, viewable from both sides of the hatch, pressure differential across the hatch.

[V2 8040] Mobility Aid for Assisted Ingress and Egress Mobility aids shall be provided for the assisted ingress and egress of suited or unsuited crewmembers.

[V2 8041] Unassisted Ingress, Egress, and Escape Mobility Aids Mobility aids shall be provided for ingress, egress, and escape of crewmembers without assistance from other crew or ground personnel.

[V2 8043] Window Provisioning The system shall provide windows with unobstructed fields of view for expected crew operations.

[V2 8045] Window Optical Properties System windows shall have optical properties commensurate with crew task needs.

[V2 8053] Emergency Lighting The system shall provide emergency lighting for crew egress and/or operational recovery in the event of a general power failure.

[V2 12006] Volume Accommodation The system shall provide the volume necessary for the ground support personnel to perform all ground processing tasks using the required tools and equipment.

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