NASA-STD-3001 Technical Brief

Mishaps During Entry, Descent, and Landing

OCHMO-TB-039
Rev B

Executive Summary

Re-entry into the Earth's atmosphere, descent, and subsequent landing are a few of the stages in spaceflight that are life-threatening due to the myriad of processes and vehicle reliabilities that must occur in order for the crew to land safely and unharmed. The crew and vehicle are subjected to the vacuum of space, extreme heat, high speeds, g-forces, and vibrations. Historically, astronauts have sustained minor injuries, but loss of life has occurred, as well as near-misses. It is imperative that these lessons learned be considered in vehicle design and protecting the crew within.

Soyuz 1: Vladimir Komarov

Relevant Technical Requirements

NASA-STD-3001 Volume 1, Rev C

- [V1 3004] In-Mission Medical Care
- [V1 3012] Terrestrial Launch/Landing Medical Support
- [V1 5009] Physiological Exposure Mission Training

NASA-STD-3001 Volume 2, Rev D

- [V2 3006] Human-Centered Task Analysis
- [V2 3102] Human Error Analysis
- [V2 6011] Post Landing Relative Humidity (RH)
- [V2 6025] Contamination Monitoring and Alerting
- [V2 6048] Toxic Hazard Level Four
- [V2 6064] Sustained Translational Acceleration Limits
- [V2 6065] Rotational Velocity
- [V2 6066] Sustained Rotational Acceleration Due to Cross-Coupled Rotation
- [V2 6067] Transient Rotational Acceleration
- [V2 6069] Acceleration Injury Prevention
- [V2 6081] Alarm Maximum Sound Level Limit
- [V2 6107] Nominal Vehicle/Habitat Atmospheric Ventilation
- [V2 7043] Medical Capability
- [V2 7055] Priority of Stowage Accessibility
- [V2 8023] Unlatching Hatches
- [V2 8033] Restraints for Crew Tasks
- [V2 9053] Protective Equipment
- [V2 9055] Equipment Automation of Rescue Aids
- [V2 10165] Automation and Robotics Override and Shut-Down Capabilities
- [V2 10002] Design-Induced Error
- [V2 10084] Communication Capability
- [V2 11001] Suited Donning and Doffing
- [V2 11024] Ability to Work in Suits
- [V2 11032] LEA Suited Decompression Sickness Prevention Capability
- [V2 11100] Pressure Suits for Protection from Cabin Depressurization

Background

Soyuz 11 – June 30, 1971

During separation of the orbital and service modules from the descent module, the pyrotechnic system did not operate as intended. All of the pyrotechnics fired simultaneously rather than the designed sequential firing mode, which was believed to be due to the excessive vibration loads on the vehicle. This caused a pressure equalization seal to open in the descent module at a higher-than-designed altitude, resulting in the rapid depressurization of the crew module. The rapid depress led to loss of consciousness of the crew despite attempts by one of the crew to block the leakage of air from the vehicle. The spacecraft otherwise made a nominal automatic touchdown with no known anomalies at the time of the recovery team. The lives of Georgi Dobrovolski, Vladislav Volkov, and Viktor Patsayev were lost due to the vacuum experienced.

Contributing factors:

- Absence of an open-valve warning system
- Absence of an emergency valve-choking system
- No structural shock testing performed for a worst-case scenario
- Crew were not wearing pressurized suits for re-entry

See OCHMO-TB-38 Decompression & LEA Suit Mishaps

Soyuz 11: (L-R) Georgi Dobrovolski, Viktor Patsayev and Vladislav Volkov

Relevant Technical Requirements
[V1 3004] In-Mission Medical Care, [V1 5009] Physiological Exposure Mission Training
[V2 9055] Equipment Automation of Rescue Aids, [V2 11032] LEA Suited Decompression Sickness Prevention Capability, [V2 11100] Pressure Suits for Protection from Cabin Depressurization
From: NASA-STD-3001 Volume 1, Rev C & NASA-STD-3001 Volume 2, Rev D

Soyuz TMA-11 (15S) – April 19, 2008

During entry, the Soyuz instrumentation and propulsion module (IPM) failed to properly separate from the descent module (DM). This resulted in a ballistic entry, higher g-loads during descent, and the spacecraft landing more than 400 km short of the intended target. The abnormal entry attitude (hatch-forward) during early descent caused excessive heating on the hatch and back shell of the descent module. The recovery team's arrival at the landing site was delayed by approximately 45 minutes due to the off-target landing. Yi So-yeon was later hospitalized because of injuries sustained during entry and landing. The South Korean Science Ministry stated that the astronaut had a minor injury to her neck muscles and had bruised her spinal column.

Contributing factor:

- A Russian investigation into the cause of the DM/IPM separation system failure concluded that one of the five pyrotechnically actuated locks, which attach the Soyuz instrumentation and propulsion module to the descent module, failed to release at the proper time.

Relevant Technical Requirements
[V1 3012] Terrestrial Launch/Landing Medical Support, [V1 5009] Physiological Exposure Mission Training
[V2 6064] Sustained Translational Acceleration Limits, [V2 6069] Acceleration Injury Prevention, [V2 8033] Crew Restraint Provision
From: NASA-STD-3001 Volume 1, Rev C & NASA-STD-3001 Volume 2, Rev D

Background

STS-107 – February 1, 2003

Damage to the Thermal Protection System from a debris strike on ascent resulted in the loss of crew and vehicle on entry.

At 81.7 seconds Mission Elapsed Time a piece of foam insulation from the External Tank (ET) left bipod ramp separated from the ET and struck the orbiter left wing leading edge in the vicinity of the lower half of reinforced carbon-carbon (RCC) panel #8, causing a breach in the RCC. During re-entry this breach allowed super-heated air to penetrate through the leading-edge insulation and progressively melt the aluminum structure of the left wing, resulting in a weakening of the structure until increasing aerodynamic forces caused loss of control, failure of the wing, and break-up of the orbiter. This breakup occurred in a flight regime in which, given the design of the orbiter, there was no possibility for the crew to survive.

Contributing factors:

- Depressurization of the crew module, which started at or shortly after orbiter breakup. Existing crew equipment protects for this type of lethal event, but inadequate time existed to configure the equipment for the environment encountered. The crew would have only had about 40 seconds to don gloves and helmets.
- The combination of the lack of upper body restraint and a helmet that, by design, does not internally conform to the head while exposed to cyclical motion resulted in lethal mechanical injuries for some of the unconscious or deceased crew members. If the harnesses had been locked or the crew had been conscious and able to brace, the injuries likely would not have been lethal.
- Separation from the crew module and the seats with associated forces, material interactions, and thermal consequences. This event is the least understood due to limitations in current knowledge of mechanisms at this Mach number and altitude. Although the seat restraints played a significant role in the lethal-level mechanical injuries, there is currently no full range of equipment to protect for this event. This event was not survivable by any means currently known to the investigative team.
- Exposure to near vacuum, aerodynamic accelerations, and cold temperatures. Current crew survival equipment is not certified to protect the crew above 100,000 feet, although it may potentially be capable of protecting the crew.

Relevant Technical Requirements
[V1 3004] In-Mission Medical Care, [V1 5009] Physiological Exposure Mission Training
[V2 3006] Human-Centered Task Analysis, [V2 3102] Human Error Analysis, [V2 6064] Sustained Translational Acceleration Limits, [V2 6065] Rotational Velocity, [V2 6066] Sustained Rotational Acceleration Due to Cross-Coupled Rotation, [V2 6067] Transient Rotational Acceleration, [V2 6069] Acceleration Injury Prevention, [V2 8033] Crew Restraint Provision, [V2 11024] Ability to Work in Suits, [V2 11032] LEA Suited Decompression Sickness Prevention Capability, [V2 11100] Pressure Suits for Protection from Cabin Depressurization
From: NASA-STD-3001 Volume 1, Rev C & NASA-STD-3001 Volume 2, Rev D

STS-107: Rear (L-R) David Brown, Laurel Clark, Michael Anderson, Ilan Ramon; Front (L-R) Rick Husband, Kalpana Chawla, William McCool

See OCHMO-TB-38 Decompression & LEA Suit Mishaps

Background

Apollo ASTP – July 24, 1975

As the spacecraft descended, the commander, who was reading the checklist, failed to tell the command module pilot to move the Earth Landing System auto/manual switch to auto. The crew saw that the spacecraft was well below the deployment altitude and proceeded to manually deploy the chutes. Drogue chutes were deployed manually at 18,550 feet instead of 23,500 feet as the automatic system would have done. At 10,000 feet the commander realized that Earth Lander System (ELS) was not in AUTO and quickly switched ELS Logic and AUTO, deploying the main parachutes at 7,150 feet and disabling the Reaction Control System (RCS) instead of 10,500 feet. The RCS was not disabled manually (RCS command switch turned to “off”) at this time. It was disabled manually at 16,000 feet instead of when the checklist indicated at 24,000 feet, which was due to the alarm noise levels leading to the inability to communicate properly to initiate the command. The cabin pressure relief valve opened automatically at 24,500 feet.

During a 30-second period of high thruster activity after drogue parachute deployment, a mixture of air and propellant combustion products followed by a mixture of air and nitrogen tetroxide oxidizer (N_2O_4) vapors were sucked into the cabin. One of the positive roll thrusters is located only two feet away from the steam vent that pulls in outside air when the cabin relief valve is open. This exposed the crew to a high level of N_2O_4 since emergency oxygen masks were not available until landing. The pilot passed out, but the commander quickly put the oxygen mask on him and he was revived. The exposure resulted in a two-week hospital stay for the crew after landing.

Contributing factors:

- Failure to follow a time-critical procedure in a tightly coupled system
- The noise from an alarm caused communication difficulties between the crew and it could not be confirmed if the switch was thrown
- Nitrogen tetroxide (N_2O_4) flooded the cabin when the cabin pressure relief opened, which was due to the closure of the propellant isolation valves from crew not activating the ELS at the correct altitude – cabin pressure relief valve was located two feet from the positive RCS roll thrusters

Rescue team with ASTP Apollo command module during recovery

Relevant Technical Requirements

[V1 5009] Physiological Exposure Mission Training

[V2 3006] Human-Centered Task Analysis, [V2 3102] Human Error Analysis, [V2 6081] Alarm Maximum Sound Level Limit, [V2 6025] Contamination Monitoring and Alerting, [V2 6048] Toxic Hazard Level Four, [V2 7055] Priority of Stowage Accessibility, [V2 9053] Protective Equipment, [V2 9055] Equipment Automation of Rescue Aids, [V2 10002] Design-Induced Error, [V2 10165] Automation and Robotics Override and Shut-Down Capabilities

From: NASA-STD-3001 Volume 1, Rev C & NASA-STD-3001 Volume 2, Rev D

Background

Mercury MR-4 – July 21, 1961

After landing , the spacecraft hatch pyrotechnic charges prematurely fired. The crewmember was able to escape from the emergency situation, but because of waves flooding the capsule, the capsule sunk and the crew member was nearly drowned. The crewmember was rescued after three to four minutes in the water.

Contributing factors:

- Hatch opened prematurely without command, which led to the flooding of the cabin prior to the arrival of rescue crew
- Water ingress through open valve in suit and neck dam

Virgil "Gus" Grissom during recovery following the capsule sinking

Relevant Technical Requirements

[V2 8023] Unlatching Hatches, [V2 11001] Suited Donning and Doffing

From: NASA-STD-3001 Volume 2, Rev D

Additional Recommendations

- LEA suit should be able to withstand water ingress in the event of a cabin egress during a water landing.

Soyuz 1 – April 24, 1967

On the maiden flight of the Russian Soyuz spacecraft, the cosmonaut encountered an anomaly with the parachute system. During the descent, the drag chutes successfully deployed, but the main chutes failed to deploy properly. Detecting increasing speeds, the computer deployed a backup parachute. Because the drag chute was still attached and failed to release, the backup chute became tangled with the drag chute, preventing the deployment of the backup chute and resulting in a high-speed impact with the ground. Vladimir Komarov died on impact.

Contributing factors:

- Exhaust residue from the attitude control jets fouled the craft's ion orientation sensors, making control difficult
- Drag and main parachutes malfunctioned, entangling the backup parachute as it deployed
- Underlying issues included manufacturing oversight, external political pressures and inadequate preparation

Soyuz 1 shortly after impact

Relevant Technical Requirements

[V2 6064] Sustained Translational Acceleration Limits, [V2 10165] Automation and Robotics Override and Shut-Down Capabilities

From: NASA-STD-3001 Volume 2, Rev D

Background

Soyuz 5 – January 18, 1969

Following retrofire, the explosive volts failed to fire and detach the capsule, causing the aircraft to be inverted and leaving the heat shield pointed in the wrong direction. As a result, the heat damage on Soyuz 5 caused the parachute to partially deploy and the soft-landing rockets failed to fire, resulting in a harder than normal landing. Because of the force of the impact, Boris Volynov broke several teeth due to the force of being torn from his seat and thrown across the cabin. As a result of the re-entry, the vehicle landed off-course in the Ural mountain wilderness of near freezing temperatures. Volynov left the vehicle in an attempt to find shelter as he expected a delay in rescue. He was only found due to rescuers following footsteps in the snow and blood spots from when he spit in the snow.

Relevant Technical Requirements
[V1 3004] In-Mission Medical Care
[V2 6064] Sustained Translational Acceleration Limits, [V2 8033] Crew Restraint Provision, [V2 10084] Communication Capability
From: NASA-STD-3001 Volume 1, Rev C & NASA-STD-3001 Volume 2, Rev D

Additional Recommendations

- Crew recovery operations should anticipate off-nominal landing in rough terrain or locations that could be inaccessible by vehicle or helicopter.

Soyuz 18-1 (18a) – April 5, 1975

During ascent, an excessive amount of vibration caused an electrical malfunction in the Soyuz booster to prematurely fire two of the four explosive latches holding the core of the first and second stage together. This severed the electrical connections necessary for firing the remaining two latches. When the core first stage burned out it could not be cast off as designed. Ignition of the second stage occurred nominally, but the booster was rapidly dragged off course by the weight of the depleted core first stage. When the course deviation reached 10-degrees, the automatic safety system activated, shutting down the booster and separating the Soyuz capsule from the launch vehicle. At the time of separation, the Soyuz was 180 km high and traveling at 5.5 km per second. The crew endured a 20+ g re-entry and landed in the Altai Mountains in southern Siberia. The capsule rolled down a snow-covered mountain side and was caught by the parachute in vegetation just short of a precipice. The cosmonauts were able to don their cold-weather clothing and clambered outside, waiting an hour in the sub-freezing cold next to the capsule. The crew was discovered by locals in the area, it wasn't until the next day that the crew were able to be air-lifted out. One crewmember suffered internal injuries from the high-g re-entry and downhill fall and never flew again.

Relevant Technical Requirements
[V1 3004] In-Mission Medical Care
[V2 6064] Sustained Translational Acceleration Limits, [V2 8033] Crew Restraint Provision
From: NASA-STD-3001 Volume 1, Rev C & NASA-STD-3001 Volume 2, Rev D

Additional Recommendations

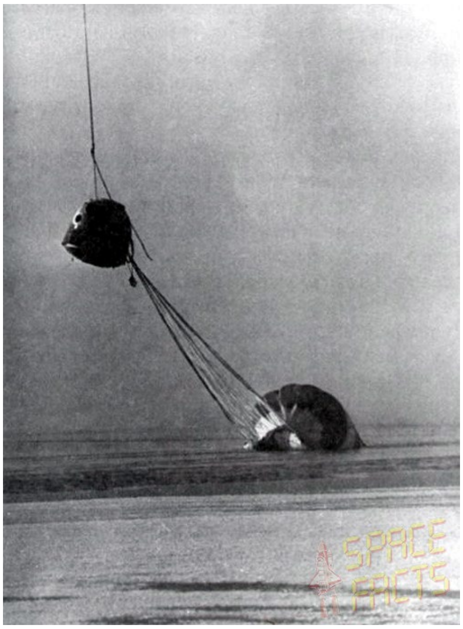
- Crew recovery operations should anticipate off-nominal landing in higher altitudes or locations that could be inaccessible by vehicle or helicopter.

Background

Soyuz 23 – October 16, 1976

During the attempted docking with Salyut 5, the vehicle suffered an automatic docking system malfunction during final approach. The cosmonauts were ordered to return to Earth. They had less than 2 days of battery power left and had already missed the landing opportunity for that day, so they powered down systems to conserve power. On October 16, 1976 the Soyuz 23 descent module landed in Lake Tengiz, 2 kilometers from shore. The water created an electrical short which caused the reserve parachute to deploy. Parachute lines from the main and reserve parachute kept the capsule lying on its side in the water, preventing the hatch from opening and blocking the air vent. Transmission antennas became inoperable due to submersion in the water, and the inner walls of the capsule became covered in ice.

The crew removed their pressure suits during this time to don their flight suits, however this took an hour and a half and required the use of a knife to cut themselves out. Attempts to recover the crew were not only thwarted by the icy waters of the lake, but also the bogs and marshes in the area. Due to the lack of light, the rescue had to be delayed further until daylight, leaving the crew in the capsule for 11 hours post-landing. The recovery team assumed the crew was dead due to the lack of communication, which was actually due to the crew losing consciousness from high levels of carbon dioxide in the cabin. They towed the capsule for 45-minutes back to the shore to await a special team to remove the bodies. After eleven hours in the capsule the crew finally opened the hatch from the inside.



Soyuz 23 during recovery (above) and shortly after recovery (below) from Lake Tengiz

Relevant Technical Requirements
[V1 3004] In-Mission Medical Care
[V2 6004] Nominal Vehicle/Habitat Carbon Dioxide Levels, [V2 6011] Post Landing Relative Humidity, [V2 6107] Nominal Vehicle/Habitat Atmospheric Ventilation, [V2 9053] Protective Equipment, [V2 10084] Communication Capability, [V2 11001] Suited Donning and Doffing
From: NASA-STD-3001 Volume 1, Rev C & NASA-STD-3001 Volume 2, Rev D

Additional Recommendations

- Manual parachute release capability
- Crew recovery operations should anticipate off-nominal landing in rough terrain or locations that could be inaccessible by vehicle or helicopter.

Soyuz TM-7 – April 27, 1989

A double-impact, "hard landing" resulted in an injury to a crew member's leg. The injury required medical treatment at the landing site. The hard landing was attributed to gusty winds at the landing site.

Relevant Technical Requirements
[V1 3004] In-Mission Medical Care, [V1 3012] Terrestrial Launch/Landing Medical Support
[V2 6064] Sustained Translational Acceleration Limits, [V2 8033] Crew Restraint Provision
From: NASA-STD-3001 Volume 1, Rev C & NASA-STD-3001 Volume 2, Rev D

Application

Vehicle design and operations must take into account the lessons learned from past incidents, either leading to the loss of crew or injury. As highlighted in previous examples, there were several events that happened during the most dynamic phases of the mission from a loss of oxygen and atmosphere to the ingress of toxic fumes due to an opening in the vehicle, and even an improper parachute deployment. In the most extreme event, the vehicle could break-up during entry leading to a loss of the crew.

Many of these events may have been preventable either through risk mitigation or verification testing. The crew may need to have the ability to perform tasks manually when the automatic functions fail, or alternatively, a nominally manual function may need to be automatic in the event the crew fails to perform a critical task. However, it can be as simple as providing quick access to the tools or life-saving equipment to the crew in the vehicle.

There are lessons that can be learned from minor events, as well as repeated ones. We cannot assume that an event that regularly happens is without fault or will *not* eventually lead to a failure, loss of vehicle, or even the loss of life.

Hanger housing the Columbia recovery during the accident investigation.

Back-Up

Major Changes Between Revisions

Rev A → Rev B

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

Original → Rev A

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

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

Referenced Technical Requirements

NASA-STD-3001 Volume 1 Revision C

[V1 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 standard).

[V1 3012] Terrestrial Launch/Landing Medical Support All programs shall have medical capability at the site of terrestrial launch and landing to address nominal operations and launch/landing contingencies, including, but not limited to the following:

a. HSP technical requirements for the crew, the crew's family, and supporting personnel for purpose of disease prevention.

b. Access to the full spectrum of medical capabilities, from routine medical and behavioral health care to advanced trauma life support (ATLS) capabilities, advanced cardiac life support (ACLS), or equivalent.

c. Incorporation of civilian and/or Department of Defense (DOD) facilities and Emergency Medical Services (EMS).

[V1 5009] Physiological Exposure Mission Training Physiological training shall be provided to assist crewmembers with pre-mission familiarization to in-flight exposures including but not limited to: carbon dioxide [CO_2] exposure training, hypoxia training/instruction, centrifuge, and high-performance aircraft microgravity adaptation training in preparation for each mission.

NASA-STD-3001 Volume 2 Revision D

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

[V2 3102] Human Error Analysis Each human spaceflight program or project shall perform a task-based human error analysis (HEA) to support systems and operations design.

[V2 6011] Post Landing Relative Humidity (RH) For nominal post landing operations, the system shall limit RH to the levels in Table 6.2-2—Average Relative Humidity Exposure Limits for Post Landing Operations.

[V2 6025] Contamination Monitoring and Alerting The system shall monitor and display atmospheric compound levels that result from contamination events, e.g., toxic release, systems leaks, or externally originated, before, during, and after an event and alert the crew locally and remotely in sufficient time for them to take appropriate action.

[V2 6048] Toxic Hazard Level Four The system shall prevent Toxic Hazard Level Four chemicals, as defined in JSC-26895, Guidelines for Assessing the Toxic Hazard of Spacecraft Chemicals and Test Materials, from entering the habitable volume of the spacecraft.

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

Referenced Technical Requirements

NASA-STD-3001 Volume 2 Revision D

[V2 6064] Sustained Translational Acceleration Limits The system shall limit the magnitude, direction, and duration of crew exposure to sustained (> 0.5 seconds) translational acceleration by staying below the limits in Figures 6.5-(2-7) and Tables 6.5-(1-6) for seated and standing postures.

[V2 6065] Rotational Velocity The system shall limit crew exposure to rotational velocities in yaw, pitch, and roll by staying below the limits specified in Figure 6.5-8—Rotational Velocity Limits and Table 6.5-7—Rotational Velocity Limits.

[V2 6066] Sustained Rotational Acceleration Due to Cross-Coupled Rotation The system shall prevent the crew exposure to sustained (> 0.5 second) rotational accelerations caused by cross-coupled rotations greater than 2 rad/s^2.

[V2 6067] Transient Rotational Acceleration The system shall limit transient (≤0.5 seconds) rotational accelerations in yaw, pitch, or roll as specified in Table 6.5-8—Head CG Rotational Acceleration Limits, to which the crew is exposed. The limits are appropriately scaled for each crewmember size from the 50^{th} percentile male limits of 2,200 rad/s^2 for nominal and 3,800 rad/s^2 for off-nominal cases.

[V2 6069] Acceleration Injury Prevention The system shall mitigate the risk of injury to crewmembers caused by accelerations during dynamic mission phases per Table 6.5-9—Acceptable Injury Risk Due to Dynamic Loads.

[V2 6081] Alarm Maximum Sound Level Limit The maximum alarm signal A-weighted sound level shall be less than 95 dBA at the operating position of the intended receiver.

[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 CO2 and thermal pockets from forming, except during suited operations, toxic cabin events, or when the crew is not inhabiting the vehicle.

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

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

[V2 9053] Protective Equipment Protective equipment shall be provided to protect the crew from expected hazards.

[V2 9055] Equipment Automation of Rescue Aids Automation of protective equipment rescue aids shall be provided when the crew cannot perform assigned life-saving tasks.

[V2 10165] Automation and Robotics Override and Shut-Down Capabilities Automated or robotic systems shall provide the human operator the ability to safely override and shut down automated systems or subsystems.

[V2 10002] Design-Induced Error The system shall provide crew interfaces that do not exceed the maximum observed error rates listed in Table 5.1-1—Maximum Observed Design-Induced Error Rates.

[V2 10084] Communication Capability The system shall provide the capability to send and receive communication among crewmembers, spacecraft systems, and ground systems to support crew performance, behavioral health, and safety.

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

Referenced Technical Requirements

NASA-STD-3001 Volume 2 Revision D

[V2 11001] Suited Donning and Doffing The system shall accommodate efficient and effective donning and doffing of spacesuits for both nominal and contingency operations.

[V2 11024] Ability to Work in Suits Suits shall provide mobility, dexterity, and tactility to enable the crewmember to accomplish suited tasks within acceptable physical workload and fatigue limits while minimizing the risk of injury.

[V2 11032] LEA Suited Decompression Sickness Prevention Capability LEA spacesuits shall be capable of operating at sufficient pressure to protect against Type II decompression sickness in the event of a cabin depressurization.

[V2 11100] Pressure Suits for Protection from Cabin Depressurization The system shall provide the capability for crewmembers to wear pressure suits for sufficient duration during launch, entry, descent (to/from Earth, or other celestial body) and any operation deemed high risk for loss of crew life due to loss of cabin pressurization (such as in mission dockings, operations during periods of high incidence of micrometeoroids and orbital debris (MMOD) or complex vehicle maneuvers).

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