NASA-STD-3001 Technical Brief

Behavioral Health Mishaps

OCHMO-TB-014
Rev B

Executive Summary

Spaceflight mishaps related to behavioral health problems have been quite low however, the actual incidence may be underestimated due to the reluctance of astronauts to report them. Behavioral health decrements can lead to performance-related effects that compromise the crew's ability to function, especially under abnormal or emergency conditions. Some reported spaceflight incidents indicate that sleep loss, circadian desynchronization, fatigue, and work overload, as experienced by ground and flight crews, may lead to performance errors, potentially compromising mission objectives. Managing behavioral health conditions during space missions is critical for the mental efficiency and safety of the crew and, ultimately, for the mission's success.

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 Preventive Health Care
[V1 3004] In-Mission Medical Care
[V1 4011] Mission Cognitive Status
[V1 4014] Completion of Critical Tasks
[V1 5002] Crewmember Training
[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 5007] Cognitive Workload
[V2 6017] Atmospheric Control
[V2 6078] Continuous Noise Limits
[V2 6079] Crew Sleep Continuous Noise Limits
[V2 6080] Intermittent Noise Limits
[V2 6082] Annoyance Noise Limits for Crew Sleep
[V2 6083] Impulse Noise Limit
[V2 6084] Narrow-Band Noise Limits
[V2 6092] Vibration Exposure Limits during Sleep
[V2 7002] Food Acceptability
[V2 7008] Food Preparation

Executive Summary (continued)

NASA astronaut Peggy Whitson completing Crew Autonomous Scheduling (CAS) test sessions to schedule future workday. Photo: NASA

Members of Expedition 60 crew gather together for dinner inside the galley of the Zvezda service module. Photo: NASA

Relevant Technical Requirements

NASA-STD-3001 Volume 2, Rev D

[V2 7012] Dining Accommodations
[V2 7038] Physiological Countermeasures Capability
[V2 7061] Nomenclature Consistency
[V2 7070] Sleep Accommodations
[V2 7071] Behavioral Health and Privacy
[V2 8001] Volume Allocation
[V2 8049] Window Light Blocking
[V2 8051] Illumination Levels
[V2 8055] Physiological Effects of Light (Circadian Entrainment)
[V2 9057] Hearing Protection Provision
[V2 10200] Physical Workload
[V2 10001] Usability
[V2 10003] Operability
[V2 10150] Display Standards
[V2 10022] Maximum System Response Times
[V2 10083] Communication System Design
[V2 10084] Communication Capability
[V2 10085] Communication Speech Levels
[V2 10091] Speech Intelligibility
[V2 10093] Private Audio Communication
[V2 10094] Video Communications Visual Quality

Background

Sleep Deprivation and Fatigue
Sleep deprivation is a serious problem in spaceflight and can lead to disastrous situations. Fatigue caused by sleep deprivation can affect performance, increase irritability, diminish concentration, and increase reaction time. Sleep-deprived subjects "perform considerably worse on motor tasks, cognitive tasks, and measures of mood than non-sleep-deprived subjects". Efforts are needed to improve sleep hygiene.

Hazards:
- Isolation
- Hostile/closed environment
- Distance from earth
- Radiation
- Altered gravity (micro-gravity and partial)

Contributing factors:
- Schedule shifting
- Environmental factors
- Work overload
- Stress from operational requirements
- Confined, limited volume

Potential impact:
- Fatigue
- Performance errors
- Team decrements
- Loss of mission (LOM)
- Loss of crew (LOC)

Risks of performance errors due to fatigue resulting from sleep loss, circadian desynchronization, extended wakefulness, and work overload.

Relevant Technical Requirements
[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
From: NASA-STD-3001 Volume 1 Rev C & NASA-STD-3001 Volume 2 Rev D

Relevant Technical Briefs
NASA OCHMO-TB-041 Sleep Accommodations & OCHMO-TB-016 Behavioral Health

Example
Gemini: Sleep-work schedules were responsible for considerable sleep disruption, fatigue, and circadian misalignment. One member of a two-crew operation needed to be awake at all times.

- **Gemini 11:** EVA 1 was terminated early due to astronaut fatigue.

NASA astronaut Megan McArthur, rests in her sleeping bag on the middeck of the Earth-orbiting Space Shuttle Atlantis. Photo: NASA

Background

Depression and Anxiety

Adverse cognitive and behavioral conditions are a risk for spaceflight operations, especially those of long duration and without real-time communication. Astronauts must cope with a stressful and dangerous environment in space, away from family and friends.

Hazards:

- Isolation
- Hostile/closed environment
- Distance from earth
- Radiation
- Altered gravity (micro-gravity and partial)

Contributing factors:

- Stress
- Environmental factors
- Workload
- Team functioning
- Family and social separation
- Sleep deficiency
- Deficient sensory stimulation

Potential impact:

- Stress levels
- Team performance decision making and reaction time
- Cognitive function
- Affected mood, morale, and well-being

Risk of adverse cognitive or behavioral conditions and psychiatric disorders.

Relevant Technical Requirements

[V1 4014] Completion of Critical Tasks, [V1 6001] Circadian Shifting Operations and Fatigue Management, [V2 5007] Cognitive Workload, [V2 6079] Crew Sleep Continuous Noise Limits, [V2 7070] Sleep Accommodations, and [V2 7071] Behavioral Health and Privacy

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

Relevant Technical Briefs

NASA OCHMO-TB-041 Sleep Accommodations, OCHMO-TB-016 Behavioral Health, and OCHMO-TB-032 Cognitive Workload

Examples

Soyuz T10-Salyut 7 (1984): Crew reported possible hallucinations to mission control.

Soyuz T14-Salyut 7 (1985): Depression may have contributed to evacuation and early termination of the mission.

Mir: U.S. astronauts that flew on MIR commented that ‘’Isolation is a tough thing’’, especially without any private space.

STS: A payload specialist became despondent when their experiment failed. The crew reported concerns about the potential for dangerous behavior, including opening a hatch. As a result, the STS hatches were fitted with locks.

ESA crewmember Samantha Cristoforetti inside of a sleeping bag in her personal crew quarters on the ISS. Photo: NASA

Background

Work Overload
Excessive workload demands on any one task can cause the operators to focus exclusively on one problem, leaving little or no spare capacity to deal with any other issues that may occur. Designers need to consider the workload of the user when designing and producing an interface or designing a task.

Hazards:
- Isolation
- Hostile/closed environment
- Distance from earth
- Radiation
- Altered gravity (micro-gravity and partial)

Contributing factors:
- Isolation
- Hostile/closed environment
- Distance from Earth
- Radiation
- Altered gravity (micro-gravity and partial)

Potential impact:
- Fatigue
- Performance errors
- Impairs decision making
- Reaction time
- Sleep deprivation
- Loss of Mission (LOM)
- Loss of Crew (LOC)

Risk of performance errors due to fatigue resulting from sleep loss, circadian desynchronization, extended wakefulness, and work overload.

Relevant Technical Requirements
[V1 4014] Completion of Critical Tasks, [V2 5007] Cognitive Workload, and [V2 10200] Physical Workload
From: NASA-STD-3001 Volume 1 Rev C & NASA-STD-3001 Volume 2 Rev D

Relevant Technical Briefs
NASA OCHMO-TB-032 Cognitive Workload, OCHMO-TB-018 Human-in-the-Loop (HITL), & OCHMO-TB-005 Usability, Workload, & Error

Examples
Skylab 3: Crewmembers reported that they quickly ran into difficulty due to work overload. The fast-paced schedule and workload of the mission had initially caused these crew members to consistently “feel” behind on tasks as well as demoralized. At the start of the 45th day of their 59-day mission, the crewmembers elected to have a sit-down, during which they refused to perform scheduled tasks.
Skylab 4: The astronauts reported to mission control their frustration and fatigue caused by an overloaded schedule, leading to mistakes.
Apollo: Some Apollo crews reported serious mental fatigue while performing Lunar EVAs (Scheuring et al., 2007).
ISS: Astronauts experience high-tempo operations and high workloads.
- *“The fatigue was evident when a couple of minor mistakes were made today on some payload activities. The ground caught the mistake and helped me out. But it is an obvious indicator of fatigue. ”I feel that the workload is going up; these last few weeks seem to have been pretty taxing. I’m very tired.”*

Background

Team Coordination and Collaboration

Numerous factors present during space missions disrupt effective teamwork and negatively affect team performance. Team conflict is a risk factor, especially in long-duration space missions, because of its potential impact on team member satisfaction, team cohesion, and performance. Team dynamics, in this case, are a key factor in exacerbating stress encountered.

Hazards:
- Isolation
- Hostile/closed environment
- Distance from earth
- Radiation
- Altered gravity (micro-gravity and partial)

Contributing factors:
- Work-rest schedule
- Fatigue
- Crew diversity
- Work overload
- Mission duration
- Sleep deficiency
- Individual mental health

Potential impact:
- Decrements in team performance
- Cognitive dysfunction
- Communication problems
- Loss of Mission (LOM)

Risk of performance decrements due to inadequate cooperation, coordination, communication, and poor psychosocial adaptation.

Relevant Technical Requirements

[V1 3001] Selection and Recertification

From: NASA-STD-3001 Volume 1 Rev C

Relevant Technical Briefs

NASA OCHMO-TB-041 Sleep Accommodations, OCHMO-TB-016 Behavioral Health, & OCHMO-TB-032 Cognitive Workload

Examples

Soyuz 21: Reportedly was ended prematurely due to unspecified "interpersonal issues" with the crew.

Salyut 5: Evacuation with interpersonal conflict as a primary contributing factor.

Soyuz TM2-Mir: Evacuation with interpersonal conflict as a primary contributing factor.

The Five Behaviors of a Cohesive Team Model

Application

Design Considerations to Minimize Sleep Deficiency:

- Provide restraints to secure blankets and maintain positioning, ranging from knees to chest to full body stature.
- Provide individual control of the sleep environment in order to ensure adequate sleep and maintain well-being during missions.
- Environmental factors such as noise, temperature, vibration, and light can inhibit sleep and affect well-being in space, and should be taken into consideration in system design.
- Examples of sleep accommodations include clothing, bedding, ear plugs, light blockers, eye masks, etc.

Relevant Technical Requirements

[V2 6078] Continuous Noise Limits, [V2 6079] Crew Sleep Continuous Noise Limits, [V2 7070] Sleep Accommodations, [V2 6080] Intermittent Noise Limits, [V2 6082] Annoyance Noise Limits for Crew Sleep, [V2 6083] Impulse Noise Limit, [V2 6084] Narrow-Band Noise Limits, [V2 6092] Vibration Exposure Limits During Sleep, [V2 7070] Sleep Accommodation, [V2 8049] Window Light Blocking, [V2 8055] Physiological Effects of Light (Circadian Entrainment), and [V2 9057] Hearing Protection Provision

From: NASA-STD-3001 Volume 2 Rev D

Design Considerations to Minimize Anxiety & Depression:

- Communication system should be provided in each private quarter.
- System that facilitates voice and text should be provided.
- Private communication with family.
- Private space with pictures of family members.

Relevant Technical Requirements

[V2 10083] Communication System Design, [V2 10084] Communication Capability, [V2 10085] Communication Speech Levels, [V2 10091] Speech Intelligibility, [V2 10093] Private Audio Communication, and [V2 10094] Video Communication Visual Quality

From: NASA-STD-3001 Volume 2 Rev D

NASA astronauts Scott Tingle, Joe Acaba, Alexander Misurkin, and Mark Vande Hei; Anton Shkaplerov of Roscosmos; and Norishige Kanai of the Japan Aerospace Exploration Agency (JAXA), are seen on a video monitor as they speak with family and friends at the Moscow Mission Control Center in Korolev, Russia a few hours after the Soyuz MS-07 docked to the ISS. Photo: NASA

Application

Design Considerations to Minimize Work Overload:

- When designing a human-system interface to support a crew task, designers are to assess the operation as part of a human-in-the-loop simulation to determine the workload associated with that operation. If the cognitive workload is judged to be so high that a human has little or no spare capacity to deal with a concurrent problem, the task and supporting interfaces are to be redesigned.
- The user must be able to cognitively process all information sources and physically execute all actions within the time required.

Relevant Technical Requirements

[V2 3006] Human-Centered Task Analysis, [V2 5007] Cognitive Workload, [V2 7061] Nomenclature Consistency, [V2 10001] Usability, [V2 10003] Operability, [V2 10150] Display Standards, [V2 10022] Maximum System Response Times, [V2 10200] Physical Workload

From: NASA-STD-3001 Volume 2 Rev D

Design Considerations to Maximize Team Coordination & Collaboration:

- A common area for recreation, large enough to accommodate all crewmembers at the same time.
- Include 'television' (or equivalent) for the crew to watch movies together (movies in the form of data can be transmitted from Earth also to provide sensory stimulation).
- A common area for dining, large enough to accommodate all crew members' concurrent dining. This can be the same as the common area for recreation (converted). Space is required for food preparation.
- Characteristics of the crew (team size, gender makeup, job roles, and cultural backgrounds), which are established prior to the mission, should be considered when defining the habitat requirements.

Relevant Technical Requirements

[V1 3001] Selection and Recertification, [V2 7002] Food Acceptability, [V2 7008] Food Preparation, [V2 7012] Dining Accommodations, [V2 7038] Physiological Countermeasures Capability

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

ESA astronaut Samantha Cristoforetti exercises and practices yoga maneuvers on the ISS. Photo: NASA

Expedition 60 crewmembers gather inside the Zvezda service module's galley for dinner on the ISS. Photo: NASA

Back-Up

Major Changes Between Revisions

Rev A → Rev B

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

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

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

[V1 5002] Astronaut Training Beginning with the astronaut candidate year, general medical training, including first aid, cardiopulmonary resuscitation (CPR), altitude physiological training, carbon dioxide exposure training, familiarization with medical issues, procedures of space flight, psychological training, and supervised physical conditioning training shall be provided to the astronaut corps.

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

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

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

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

[V2 6079] Crew Sleep Continuous Noise Limits For missions greater than 30 days, SPLs of continuous noise shall be limited to the values given by the NC-40 curve (see Figure 11, NC Curves, and Table 8, 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 7043] Medical Capability A medical system shall be provided to the crew to meet the medical requirements of NASA-STD-3001, Volume 1.

[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 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

[V2 6078] Continuous Noise Limits In spacecraft work areas, where good voice communications and habitability are required, SPLs of continuous noise (not including impulse noise) shall be limited to the values given by the Noise Criterion (NC)-50 curve in Figure 6.6-1—NC Curves, and Table 6.6-3—Octave Band SPL Limits for Continuous Noise, dB re 20 µPa (micropascals); hearing protection cannot be used to satisfy this requirement.

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

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

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

[V2 6083] Impulse Noise Limit The system shall limit impulse noise measured at the crewmember's head location to less than 140 dB peak SPL during all mission phases except launch and entry. Hearing protection cannot be used to satisfy this requirement.

[V2 6084] Narrow-Band Noise Limits The maximum SPL of narrow-band noise components and tones shall be limited to at least 10 dB less than the broadband SPL of the octave band that contains the component or tone.

[V2 6092] Vibration Exposure Limits During Sleep The system shall limit vibration to the crew such that the acceleration between 1.0 and 80 Hz in each of the X, Y, and Z axes, weighted in accordance with ISO 20283-5, Mechanical vibration—Measurement of vibration on ships; Part 5 - Guidelines for the measurement, evaluation and reporting of vibration with regard to habitability on passenger and merchant ships, Annex A, is less than 0.01 g (0.1 m/s2) RMS for each two-minute interval during the crew sleep period.

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

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

[V2 7012] Dining Accommodations Crewmembers shall have the capability to dine together.

[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 7061] Nomenclature Consistency The nomenclature used to refer to the items tracked by the inventory management system shall be consistent with procedures and labels.

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

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

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

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

[V2 8051] Illumination Levels The system shall provide illumination levels to support the range of expected crew tasks.

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

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

[V2 10001] Usability The system shall provide crew interfaces that result in a minimum average satisfaction score of 85 or higher of the NASA Modified System Usability Scale (NMSUS).

[V2 10003] Operability The system shall provide crew interfaces that enable tasks to be performed successfully within the appropriate time limit and degree of accuracy.

[V2 10150] Display Standards The system shall meet the Display Standard in Appendix F.

[V2 10022] Maximum System Response Times The system shall provide feedback to the crew within the time specified in Table 10.2-1—Maximum System Response Time(s).

[V2 10083] Communication System Design Communication systems shall be designed to support coordinated and collaborative distributed teamwork.

[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.

[V2 10085] Communication Speech Levels Audio communication systems shall allow crew to communicate with one another and with the ground at normal speech levels and with expected background SPLs.

[V2 10091] Speech Intelligibility For critical communications, the system shall ensure 90% English word recognition, using ANSI/ASA S3.2-2009, Method for Measuring the Intelligibility of Speech over Communication Systems.

[V2 10093] Private Audio Communication The system shall provide the capability for two-way private audio communication with the ground.

[V2 10094] Video Communication Visual Quality Video communications shall employ digital encoding or alternate coding of equivalent visual quality.

Reference List

1. Human Integration Design Handbook, Rev 1 https://www.nasa.gov/organizations/ochmo/human-integration-design-handbook/
2. Significant Incidents & Close Calls in Human Spaceflight. (2019). *JSC SMA Flight Safety Office*. https://sma.nasa.gov/SignificantIncidents/
3. Loss of Signal Aeromedical Lessons Learned from the STS-107 Columbia Space Shuttle Mishap https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20140008287.pdf