NASA-STD-3001 Technical Brief

Spaceflight Experience and Medical Care

OCHMO-TB-033
Rev D

Relevant Technical Requirements

This technical brief is inclusive of NASA-STD-3001 Volume 1, Rev C as a whole. The full document can be found at the following link: https://www.nasa.gov/directorates/esdmd/hhp/human-spaceflight-and-aviation-standards/

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 3012] Terrestrial Launch/Landing Medical Support
[V1 3016] Post-Mission Health Care
[V1 3017] Post-Mission Reconditioning

NASA-STD-3001 Volume 2, Rev D
[V1 7043] Medical Capability

Executive Summary

Regardless of mission length or objectives, all human spaceflight requires some degree of in-mission medical support. The transition from a gravitational environment to microgravity, coupled with living in a closed-loop environment, can result in variable physiological effects and health risks. For example, anticipated physiological impacts of the microgravity environment include fluid redistribution and subsequent head congestion, particularly during the space adaptation phase. Such effects typically occur within a predictable timeframe and will affect all crewmembers to some degree. To ensure mission success and a positive spaceflight experience, known physiological effects of the spaceflight environment must be anticipated and mitigated where possible. Integration of varied strategies, including crew selection processes, pre-mission quarantine, in-mission medical capabilities, and ground medical support, are necessary to ensure crew health and optimal performance. Simultaneously, vehicles must be designed to optimize crew health and performance and accommodate any necessary medical capabilities, equipment, crew training, and physical space. The knowledge and tasking of medical actions can be distributed among crewmembers, medical devices or aids, artificial intelligence systems, robotic systems, or similar. Additionally, incorporating ground medical support is key to many medical capabilities during flight and requires streamlined integration of variable technologies, ground communications, and support systems. Integration of these systems enables the provision of medical care and ensures crew health during a mission.

Background

This table displays the interaction between five key elements necessary to promote crew health and performance:

1. Crew Selection Standards – reference OCHMO-TB-034 Crew Selection and Recertification
2. Health Stabilization Program (HSP) – reference OCHMO-TB-006 Health Stabilization Program
3. In-mission Medical Treatment & Capabilities – discussed in this technical brief
4. Immediate Post-landing Medical Care i.e., care provided immediately upon return to Earth – discussed in this technical brief
5. Longitudinal Health Surveillance – reference OCHMO-TB-043 Longitudinal Health Surveillance

<table>
<tr><th colspan="2">Pre-mission</th><th>In-mission</th><th colspan="2">Post-mission</th></tr>
<tr><td>Selection Standards</td><td></td><td></td><td colspan="2"></td></tr>
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<tr><td colspan="2"></td><td>In-mission Medical Treatment & Capabilities</td><td>Immediate Post-landing Care</td><td></td></tr>
<tr><td colspan="5">Longitudinal Health Surveillance</td></tr>
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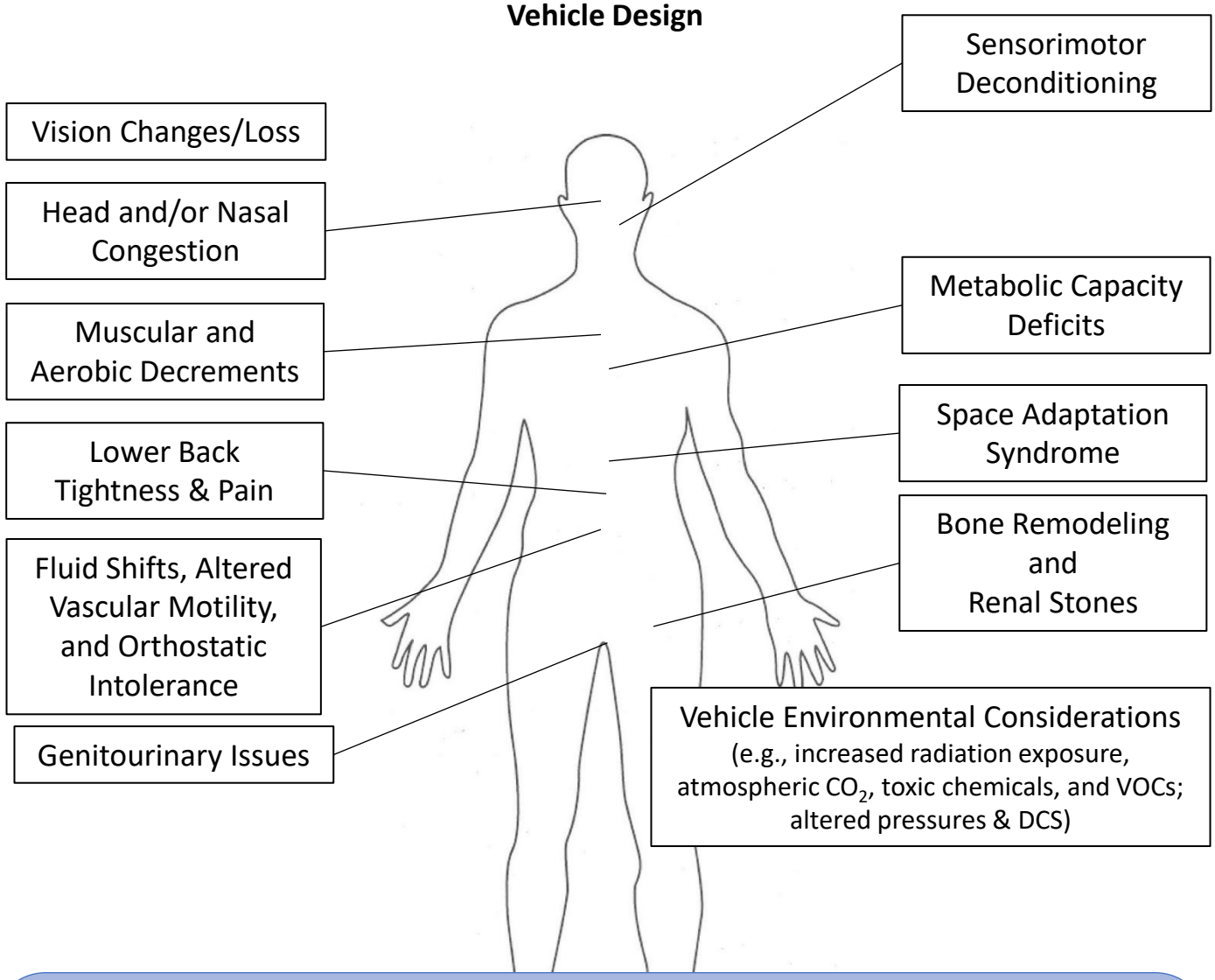
At NASA Kennedy Space Center's Shuttle Landing Facility, emergency rescue personnel gently place an "injured astronaut" onto a stretcher during a simulated emergency landing.

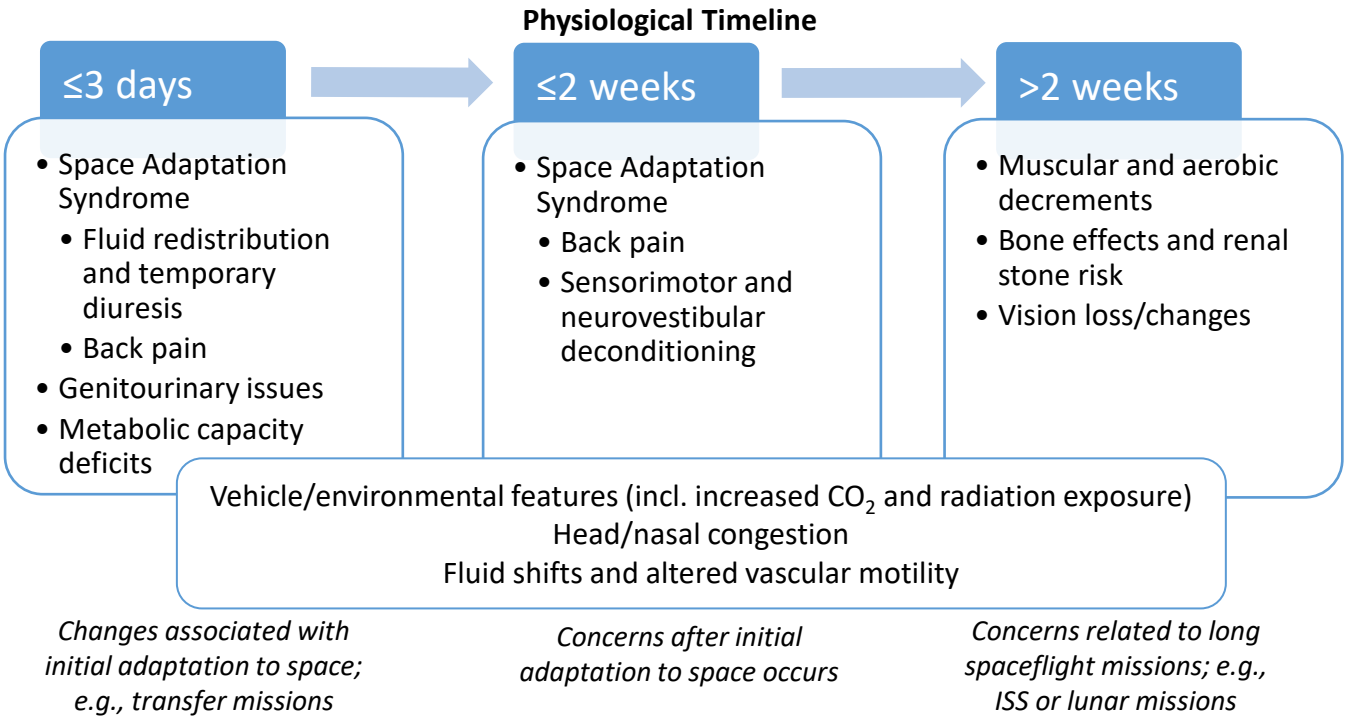
Background

Prevalent Physiologic Changes Experienced due to Microgravity and Vehicle Design



All crewmembers experience the above effects to some extent. Minimizing the potential for communicable disease transmission through screening and effective pre-flight quarantine in the Health Stabilization Program (HSP) (see OCHMO-TB-006 HSP) lessens potential in-mission impacts of infectious disease. Subsequent in-mission medical support is critical for the mitigation of the above effects and maximizing crew performance and experience. Finally, NASA crewmembers are selected through a rigorous set of procedures in order to minimize some of the above effects (see OCHMO-TB-034 Crew Selection & Recertification). For example, certain cardiac, musculoskeletal issues, and osteopenia are selected out to enhance mission success.

Background



≤3 Days – *changes associated with initial adaptation to space; e.g., transfer missions*

Space Adaptation Syndrome (SAS) – neurovestibular adaptation to microgravity; symptoms include nausea, emesis, headache, malaise, vertigo; cephalad shift of fluid, resulting in facial "stuffiness"

- Affects 50-70% of crewmembers
- Treatment: pharmaceutical options, inactivity, head movement exercises, head restraints, 1g orientation and pre-mission training / prophylaxis

Head/nasal congestion – space adaptation or CO_2-related

- Affects >50% of crewmembers
- Treatment: pharmaceuticals (congestion or allergy meds)
- Leading cause of prolonged medication use in-mission

Fluid redistribution – 12-15% reduction in whole body volume, temporary diuresis with polyuria

- Affects all crewmembers
- In-mission treatment is not needed; vehicle must accommodate temporary increased urine output
- Subsequent euvolemia, but continued third spacing of fluids throughout the mission

Genitourinary issues – subset of crew who experience urinary retention with space adaptation

≤2 weeks – *concerns after initial adaptation to space occurs*

Lower back tightness & pain (i.e., Space Adaptation Back Pain, SABP) – back pain associated with the physiological changes in spaceflight; SABP is distinguished from other types of back pain if it develops within the first few days of the mission

- Affects 52% of crewmembers
- Positioning, exercises, and pharmaceutical options to manage (≥85% pain relief effectiveness for all treatments)

Background

Physiological Timeline (cont.)

>2 weeks – *concerns related to longer missions; e.g., ISS or lunar missions*

Aerobic and muscular decrements – decrease in aerobic capacity and muscle mass and tone over the mission

- Begin for all crewmembers upon exposure to microgravity, but are mainly a concern for longer missions: more muscle & aerobic capacity are lost the longer the crew is in microgravity
- Countermeasures/treatment: exercise – resistive and aerobic, can be highly effective
- Upon re-exposure to gravity, decrements incurred due to spaceflight must be accounted for

Bone effects and renal stone risk – microgravity induces bone atrophy, approximated at 1.5%/month; almost fully mitigated by exercise; bone loss increases circulating calcium, which impacts renal stone risk

- Bone effects begin for all crewmembers upon exposure to microgravity, but are mainly a concern for longer missions – more bone is lost the longer the crew is in microgravity, which leads to an increased risk of renal stones
- Countermeasures/treatment: pharmaceutical options and exercise

Vision alterations (Spaceflight-Associated Neuro-Ocular Syndrome (SANS)) – ocular changes including disc edema, choroidal folds, globe flattening, and/or hyperopic shifts in refractive error; believed to be associated with cephalad fluid shifts and possibly with diet or environmental factors. Vision changes could impact performance.

- 16% of crewmembers show disc edema during/after long-duration missions; most findings subclinical, some require corrective lenses
- Treatment: corrective lenses, and adjustable glasses can be flown to aid vision adjustments; potential countermeasures: pharmaceuticals, environmental/dietary considerations

Altered vascular motility – stagnant or reverse flow in the internal jugular vein has been observed in 6 of 11 crew members (55%) tested in mission on approximately flight day 50; one crewmember was found to have an occlusive internal jugular vein thrombus. This is an emerging finding and has potential impacts on flight participants with cardiovascular conditions.

Increased radiation exposure – an increased risk of developing cancer post-mission

- Space Environment radiation exposure – increased exposure outside of low-Earth orbit
- Shielding is effective against some radiation exposure (solar particle events, but does not mitigate Galactic Cosmic Radiation exposure
- Primary risk is for carcinogenesis (post-mission); additional risks for cataract development and potential cardiovascular or neurological sequelae

Upon re-entry to 1g: descent and landing

Sensorimotor and neuro-vestibular deconditioning – the brain and neurological systems that control balance and motor skills adapt to microgravity within 2 weeks of spaceflight missions; it takes hours to days for the body to readapt to gravity upon landing, with associated balance issues and visual inconsistencies

- Affects all crewmembers post-landing to some extent; may be severe enough that crew cannot perform functional operational tasks (e.g., fall recovery)
- Impacts vehicle design (e.g., displays and controls)
- Prevention: in-mission exercise provides some benefit
- Treatment for symptoms similar to SAS

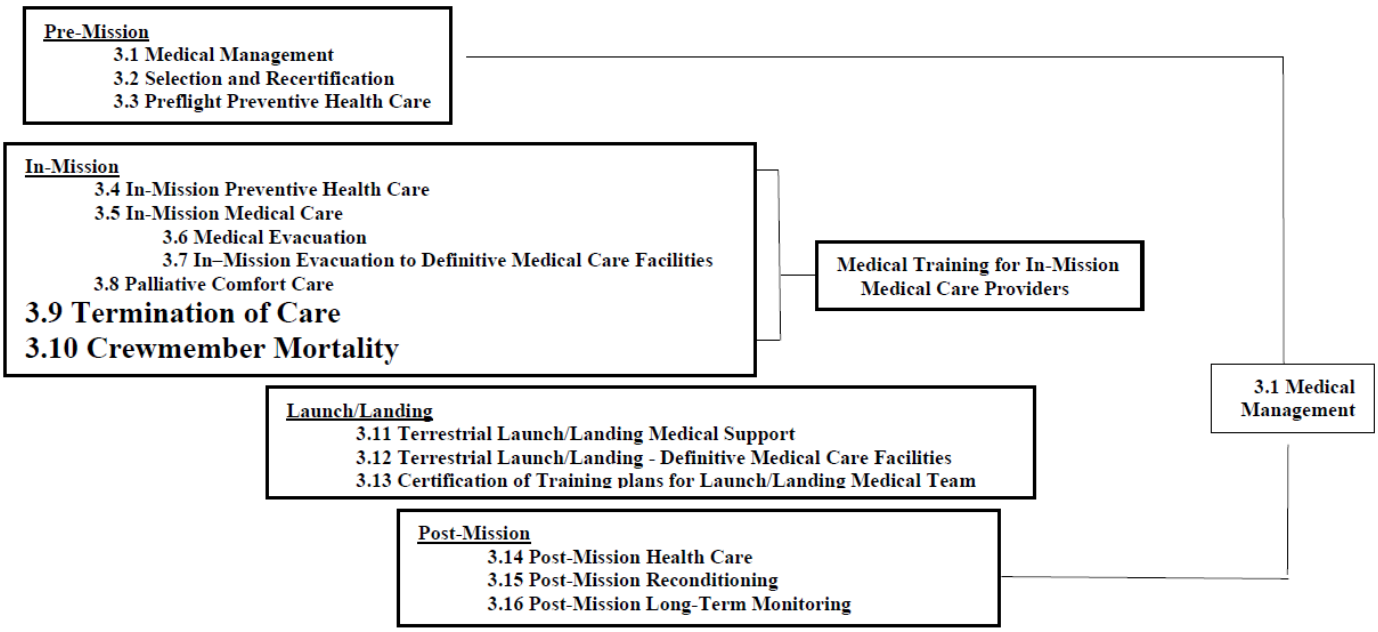
Relevant Technical Briefs
OCHMO-TB-030 Bone Loss
OCHMO-TB-020 Radiation Protection
OCHMO-TB-010 Sensorimotor

Reference Data

Health and Medical Care Standards for Astronauts

NASA updated the Health and Medical Care technical requirements for astronauts. The following requirements reflect this comprehensive approach to astronaut health and well-being, addressing screening, preventive health strategies, medical care, contingencies during launch and landing, and post-mission healthcare, reconditioning and long-term monitoring. These detailed requirements can be found in NASA-STD-3001, Volume 1, Revision C.

Comprehensive set of Health and Medical Technical Requirements from crew selection to post-mission health care.



Application

Medical Program Design Guidance Overview

- The importance of the interaction between crew selection, health stabilization programs, longitudinal health surveillance, in-mission medical capabilities, and immediate post-mission medical care cannot be overstated. These program aspects, in conjunction with vehicle design, work together to maximize crew health and performance over the mission, while helping to minimize resource footprint and wasted time during the mission.

  Medical Program Design begins with crew selection but is maintained throughout the pre-flight and mission cycle.

- By employing selection criteria and selecting out certain conditions, healthier individuals are flown and less risk is present in-mission.

  If the selection criteria is broadened, in-mission medical capabilities need to accommodate the anticipated conditions and if the conditions are exacerbated by spaceflight.

- Crewmembers participate in a health stabilization program (HSP) to promote success over the full length of the missions.

  HSPs help reduce the burden of spaceflight adaptation by ensuring the crew begin missions with good health & minimize risk of communicable diseases.

- To reduce the need for in-mission medical care and mitigate the risks of spaceflight, activities should be performed pre-, in-, and post-mission to help the crewmember achieve maximal health (i.e., longitudinal astronaut health surveillance, training, countermeasures, and reconditioning should be employed).

  By taking a preventive approach rather than a reactionary one, total onboard resources and required mission capabilities can be reduced and optimized.

- Based on the most common conditions expected and seen during missions, NASA tailors in-flight medical capabilities and skillsets to ensure that the most likely or impactful medical or physiological events can be managed and crew health optimized. There are additional conditions and capabilities that may be applicable after an overall mission architecture assessment is completed; these are similarly tailored to every program.

Application

Pre-Mission Healthcare

- Pre-Mission health care is all of the health care provided after crew selection
- Pre-Mission health care is focused on preventative care and reducing in-mission as well as long-term health risks
- Many studies and tests are conducted pre-mission to provide a baseline to be compared to post-flight results
- The longer the duration of the mission is, the greater the extent of the preventative interventions need to be

NASA commercial crew astronaut Victor Glover performs physical training on the Advanced Resistive Exercise Device (ARED) at the agency's Johnson Space Center in Houston.

Pre-Mission medical care includes but is not limited to the following strategies:

1. Optimization of Nutrition
2. Vitamin D Supplementation
3. Specialized Assessments and Exams (e.g., ECG, Ophthalmological exams, Photo documentation of skin)
4. Maintenance of Optimal Aerobic and Strength Physical Fitness
5. Maintenance of Flexibility, Agility, and Balance
6. Annual and Pre-Flight Physicals
7. Preventative Dental Care
8. Behavioral Health Resiliency Training
9. Total Radiation Dose Control/Monitoring (Bio-dosimetry Testing)
10. Pre-mission Health Stabilization Programs (e.g., communicable diseases prevention (influenza, cold), vaccinations)
11. Assisted Reproductive Technology (ART) to preserve gametocytes prior to mission exposure to radiation)

Care can be tailored (i.e., how assessments are performed) according to the mission profile and agency.

Application

Medical Program Design Guidance

In-mission medical care is influenced by the following:

1. Expected conditions due to spaceflight adaptation (e.g., neurovestibular adaptation, back pain, muscle loss, etc.)
2. Pre-mission Health Stabilization Programs (e.g., communicable diseases prevention (influenza, cold), vaccinations)
3. Mission architecture (EVAs, decompression protocols, environmental conditions of vehicle, etc.)
4. Crew selection criteria (e.g., cardiovascular conditions, behavioral conditions)
5. Mission duration
6. Distance from Earth, time to definitive medical care, and required autonomy
7. Destination/gravitational environment

Some conditions present due to the microgravity environment are treated differently compared to terrestrial practices. These conditions include, but are not limited to:

- **Sleep Loss and Alertness**: circadian shifts and abnormal sleeping orientations lead to loss of sleep in crewmembers and subsequent alertness deficits
  - Treatment may be as simple as sleep aids (~71% use in crew; 10x higher than use in adult ambulatory medicine) and alertness aids (~21% use in crew)
  - Sleep aids are the leading reason for acute medication use in-mission
- **Headaches**: increased incidence during spaceflight, with contributory factors including elevated CO_2 levels, fluid shifts, pressure changes, and other non-spacecraft-associated factors
- **Joint and Muscle Pain**: increased incidence due to extravehicular activity (EVA) and exercise equipment used during the missions

Most conditions can be treated as they are on Earth, though mass, volume, consumables, and capability restrictions may limit the scope of in-mission medical treatment. Since full terrestrial care and treatment may not be possible, medical kits should be optimized to provide the best available care. Pertinent considerations include minimizing long-term health impacts and future mission success. In addition, prioritization should be given to medications that can serve multiple purposes and minimize adverse or unwanted side effects.

Extensive consideration should be given to all medications administered in-mission due to the closed-loop environment. For example, a medication that increases urinary calcium output is not only putting the crewmember at a greater risk of developing kidney stones but may also cause further stress on a vehicle's water reclamation system. Another consideration is the pharmaceutical treatment pathway. Sprays, for example, may not be as desirable as solid medications due to lack of gravity and vehicle air flow patterns.

Side effects of all medications should also be considered due to the bevy of spaceflight-induced physiological changes. For example, cardiovascular deconditioning and fluid redistribution is seen in all crewmembers. Thus, medications that produce effects such as cardiac depression or vasodilation should be avoided.

Application

In-Mission Preventive Health Care & In-Mission Medical Care

All programs shall provide training, in-mission capabilities, and resources to monitor and treat physiological and psychosocial well-being and enable delivery of in-mission preventive health care, **based on epidemiological evidence-based probabilistic risk assessment (PRA)** that takes into account the needs and limitations of each specific design reference mission (DRM), and parameters such as mission duration, expected return time to Earth, mission route and destination, expected radiation profile, concept of operations, and more.

Epidemiological evidence-based probabilistic risk assessment (PRA) approach utilizing ISS experience and terrestrial data.

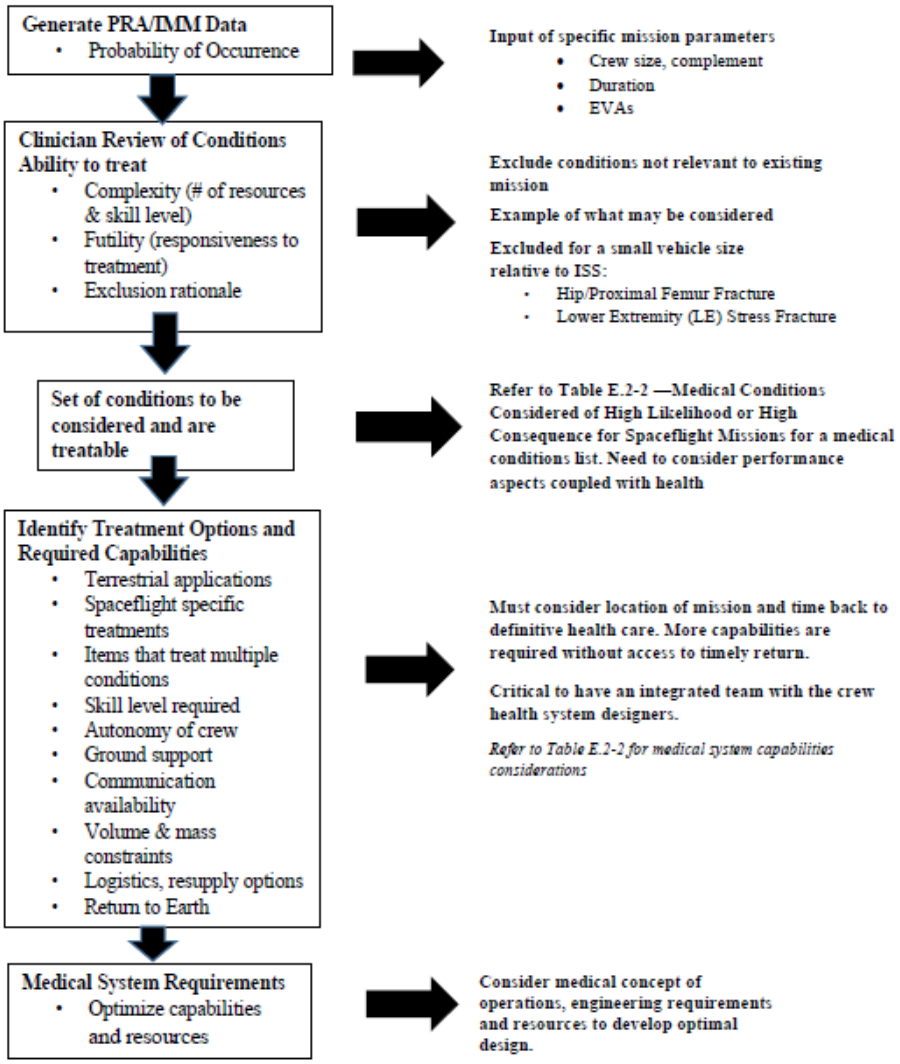


Figure E.2-1— Notional Sample Outline for the use of PRA data to aid in the generation of a medical conditions list

From NASA-STD-3001 Volume 1, Rev C

Application

Table E.2-1—Sample IMM Output

	Medical Condition	Likelihood
1	Late Insomnia	13.85 per mission
2	Skin Abrasion	9.86 per mission
3	Skin Rash	9.83 per mission
4	Eye Abrasion	7.42 per mission
5	Late Headache	5.25 per mission
6	Space Motion Sickness (SAS)	4.37 per mission
7	Diarrhea	3.53 per mission
8	Nasal Congestion	3.51 per mission
9	Respiratory Infection	3.46 per mission
10	Back Injury	3.41 per mission
11	Barotrauma (Ear/Sinus Block)	3.28 per mission
12	Back Pain (SAS)	3.15 per mission
13	Insomnia (SAS)	2.70 per mission
14	Shoulder Sprain/Strain	2.43 per mission
15	CO_2 Headache	2.15 per mission
16	Headache (SAS)	2.11 per mission
17	Spaceflight Associated Neuro-ocular Syndrome (SANS)	2.08 per mission
18	Urinary Tract Infection	1.44 per mission
19	Skin Infection	1.38 per mission
20	Elbow Sprain/Strain	1.32 per mission
21	Ankle Sprain/Strain	1.22 per mis
22	Allergic Reaction	1.18 per mis
23	Pharyngitis	1.17 per mis
24	Constipation	1.02 per mission
25	Neck Injury	0.99 per mission
26	Mouth Ulcer	0.96 per mission
27	Dental Caries	0.88 per mission
28	Knee Sprain/Strain	0.78 per mission
29	Paresthesia [Extravehicular Activity (EVA)]	0.65 per mission
30	Indigestion	0.64 per mission
31	Eye Chemical Burn	0.64 per mission
32	Sinusitis	0.64 per mission
33	Hearing Loss	0.57 per mission
34	Wrist Sprain/Strain	0.55 per mission
35	Eye Infection	0.53 per mission
36	Hip Sprain/Strain	0.45 per mission

The Integrated Medical Model probability risk assessment output includes a list of potential medical conditions experienced during spaceflight and is utilized by flight physicians to generate an inflight medical system.

Table E.2-2—Medical Conditions Considered of High Likelihood or High Consequence for Spaceflight Missions

Category	Specific Condition
Environmental or spaceflight-induced medical conditions	Acute radiation syndrome **Allergic reaction** * Altitude sickness **Anaphylaxis** * **Back pain (space-adaptation related)** * Barotrauma (ear/sinus block) Burn (thermal) Burns secondary to fire Celestial dust exposure Choking/obstructed airway Cold injury (chilblains frostbite) **Constipation (space-adaptation related)** * Decompression sickness Embolism Electrical injury Epistaxis (nosebleed, space adaptation related) EVA-related dehydration **Headache (CO_2 related)** * **Headache (space-adaptation related)** * Hearing loss (noise related) Heat illness Hypothermia Medication adverse reaction **Nasal congestion (space-adaptation related)** * Nutritional deficiency **Space motion sickness (space-adaptation related)** * Smoke/combustion product inhalation Toxic inhalation injury **Urinary incontinence (space-adaptation related)** * **Urinary retention (space-adaptation related)** *
	Loss of vision Penetrating eye injury Retinal detachment/injury SANS
Ear, nose, and throat conditions	Acute sinusitis Cerumen impaction Epistaxis (nose bleed) Hearing loss Otiti Otiti Phar Resp
Dental/oral conditions	Carie Crow Dent Filli Fract Oral Toot
Cardiovascular conditions	Acut Angi Card Card Grav Hype Sudd Trau Vene
Pulmonary and other chest conditions	Ches Ches Reac Resp Resp
Gastrointestinal and other abdominal conditions	Abdo Abdo Acut Acut Acut Appe Cons Diar Gast Hem Indi Refl Smal
Genitourinary conditions	Abno Acut Acut Bact Neph Urin Unpr
	Vaginal yeast infection *
Musculoskeletal conditions	Acute arthritis Acute compartment syndrome Back injury (sprain/strain) Dislocation (finger, elbow, shoulder) Fingernail delamination (EVA related) Fracture (finger, hand, wrist/arm, distal leg, hip/proximal femur, thoracolumbar spine, cervical spine) Hand injury (EVA related) Joint sprain/strain (shoulder, elbow, wrist, hip, knee, ankle) Lower extremity stress fracture Muscular sprain/strain Neck injury (sprain/strain) Overuse injury – Upper or lower extremity Paresthesia Subungual hematoma Suit contact injury (EVA related) Vertebral disc injury
Dermatological conditions	Burn – Chemical, skin **Cellulitis – Bacterial skin infection** * Herpes zoster (Shingles) **Skin abrasion** * **Skin laceration** * **Skin rash** * Toxic dermal exposure Viral/fungal skin infection
Neurologic conditions	Benzodiazepine/Opiate overdose Cerebrovascular accident **Gravity transition neurovestibular disturbance** * **Headache** * Head trauma (major) Head trauma (minor) Neurogenic shock Neuropathy (Central – impingement) Paresthesia Seizure
Psychological, cognitive, or behavioral conditions	**Acute stress** * **Adjustment reaction** * **Anxiety/panic** * Apathy/low motivation **Cognitive disturbance** * Delirium Depression Grief reaction **Insomnia/sleep disturbances/circadian dysregulation** * **Interpersonal conflict (i.e., team, ground, family)** * Lack of meaningful work and/or monotony **Mood disturbance (e.g., irritability)** * Neurocognitive disorders (adjustment, mood, anxiety, trauma-related, or stress-related) Psychosis Relationship problems (family, crew, mission support personnel) Work overload/burnout/exhaustion

From NASA-STD-3001 Volume 1, Rev C

Application

Required In-Mission Capabilities

The following are examples of in-mission capabilities (i.e., procedures, protocols, vehicle accommodations, etc.) that might be required for a spaceflight mission.[1]

- Administer and manage medications
- Assess and store vital signs
  - e.g., blood pressure, oxygen saturation, heart rate, respiratory rate, etc.
- Perform physical exam and conduct screening exams/tests
- Perform procedures
  - e.g., inserting a catheter, suturing, blood draw, etc.
- Delivery of basic behavioral health and performance countermeasures
  - e.g., recreational time, books, movies, music, crew care packages, access to fresh produce, Earth viewing opportunities
- Assess and monitor physical, behavioral and cognitive health with neurobehavioral measurements
  - e.g., private medical/psychological conferences, computer-based programming, cognitive and psychological assessments, etc.
- Monitor, manage, and control sleep/fatigue
- Dietary control and nutrition monitoring
- Evacuation

Procedures & Protocols

- Configure environment for care
- Physical or pharmaceutical restraints for physiological and psychological use
  - e.g., restraint systems, various medications
- Medical support system (i.e., inventory monitoring/maintenance, etc.)
- Private two-way audio and video communication with ground
  - with ground medical and psychological support, family, and crew support system
- Knowledge augmentation
  - e.g., in-mission computer-based therapy, smart medical devices, just-in-time training, etc.

Vehicle Accommodations

[1]Capabilities can be tailored (i.e., added in or taken out) according to the mission profile and spacecraft design

Application

Additional In-Mission Conditions for Program Consideration

Based on the required overall mission architecture assessment (activities, duration, vehicle design, etc.), the following conditions may need to be treated in-mission. **While some of the conditions can be treated as they are on Earth, mass, size, consumables, and capability restrictions may limit the scope of in-mission medical treatment.** Since full terrestrial care and treatment may not be possible, medical kits should be optimized to provide the best available care.

The below conditions are dependent on mission length, mission architecture, spacecraft design, launch/landing loads, the program's Health Stabilization Program (HSP), and mission activities. Thus, this subset of conditions may not apply to every spaceflight mission. Conditions from this list that are required to be treated in-mission should be tailored to each program. Such conditions may include:

- *Musculoskeletal conditions* – muscular sprain/strain; joint sprain/strain (shoulder, elbow, wrist, hip, knee, ankle); dislocation (finger, elbow, shoulder); fracture (wrist, hip/proximal femur, lumbar spine); lower extremity stress fracture
- *Ophthalmic conditions* – eye penetration (foreign body) / chemical burn / corneal ulcer / infection; SANS and potential vision changes; retinal detachment; acute glaucoma
- *Dental conditions* – caries; exposed pulp; dental abscess / filling loss / avulsion / crown loss
- *Abdominal conditions* – abdominal wall hernia; nephrolithiasis; acute pancreatitis; acute cholecystitis / biliary colic; small bowel obstruction; appendicitis; acute diverticulitis; acute prostatitis; hemorrhoids abnormal uterine bleeding
- *Psychological, Cognitive, or Behavioral Conditions* – work overload / burnout / exhaustion; lack of meaningful work and/or monotony; apathy / low motivation; grief reaction; depression; delirium; relationship problems (family, crew, mission support personnel); adjustment, mood, anxiety, trauma-related, stress-related, and neurocognitive disorders; psychosis
- *Infectious/Immune diseases* – pharyngitis; influenza; gastroenteritis; respiratory infection; herpes zoster reactivation
- *Other traumatic injuries* – back, neck, head, chest, abdominal injury; traumatic hypovolemic shock; neurogenic shock; barotrauma
- Hearing loss
- Paresthesia
- Decompression Sickness, secondary to EVA
- Fingernail delamination
- Burns, secondary to fire
- Smoke inhalation
- Choking / obstructed airway
- Altitude sickness
- Toxic exposure (e.g. ammonia, hydrazine, methane, formaldehyde, Freon, etc.)
- Sepsis
- Acute Compartment Syndrome

Rigorous crew selection should prevent major conditions from occurring. At NASA, individuals with any substantial risk of significant medical illness or decompensation from conditions are not certified for flight. If NASA-level crew selection criteria is not used, additional conditions may need to be considered for treatment in-mission, such as:

- Major cardiovascular events, e.g., myocardial infarctions and atrial fibrillation
- Major neurologic events, e.g., seizures and strokes (cerebrovascular accident (CVA))

Application

Additional In-Mission Capabilities for Program Consideration

The following list of additional in-mission capabilities (i.e., procedures, protocols, vehicle accommodations, etc.) may be required based on mission length, mission architecture, spacecraft design, launch/landing loads, the program's HSP, and mission activities. Capabilities should be tailored to each program based on applicability and mass/volume constraints. *Asterisked (*) conditions are capabilities that may be needed for medically autonomous missions (i.e., no real-time ground communications).*

Procedures & Protocols

- Delivery of physical health countermeasures
  - countermeasures intended to counteract cardiovascular, musculoskeletal, and neurovestibular deconditioning; e.g., exercise
- Monitor and trend vital signs
- Perform imaging
- Perform cardiac waveform monitoring
- Perform laboratory analyses
- Monitor and alter work/rest schedule and balance
- Individualized behavioral health and performance countermeasures suite*
  - e.g., each crewmember has access to their own personal device with entertainment, photos, audio, personal video clips, virtual reality, store and forward communications with family and friends
- Evidence-based asynchronous behavioral health treatment protocols available on electronic devices*
- Medical devices for treating neurobehavioral disorders
- Sensory deprivation countermeasures*
  - e.g., novelty, virtual reality, greenhouse
- Social isolation countermeasures*
  - e.g., games, observance of important holidays/events

Vehicle Accommodations

- Monitor and assess environment
- Access to private personal spaces and sleep accommodations with visual and auditory privacy

See the OCHMO-TB-006 Pharmaceuticals for additional information regarding the medical kit and pharmaceuticals used in-mission

Application

Post-Landing Considerations and Crewmember Treatment

Pre-landing Preparations

- Crewmembers can take measures before reentry to mitigate symptoms post-landing. These measures may include prophylactic medication use, fluid loading, and orthostatic intolerance compression garments.

Neurovestibular

- Cause / Background: neurovestibular system is still adapted to the spaceflight environment (i.e., microgravity)
- Symptoms: vertigo; unstable gait; nausea; vomiting
- Medical Recommendations & Treatment: medications (e.g., meclizine, promethazine); avoid rapid head movements; slow, progressive increase in activity; rest

Cardiovascular

- Cause / Background: fluid redistribution, third-spacing of total body water, relative intravascular depletion
- Symptoms: orthostatic intolerance; decreased blood pressure; increased heart rate; nystagmus and/or blurry vision; nausea; weakness/malaise; syncope
- Medical Recommendations & Treatment: compression garment (often donned prior to reentry); oral fluids (as tolerated); normal saline bolus; medications to treat symptoms; rest
- Due to relative intravascular depletion, IVs can be challenging to start. Thus, ground crew personnel need to be prepared appropriately.

Musculoskeletal

- Cause / Background: weightlessness causes bone and muscular atrophy; may be mitigated by in-mission countermeasures, such as exercise
- Symptoms: weakness; fatigue; poor coordination; impaired physical abilities; feeling of heaviness; slow & deliberate movements; muscle pain due to gravitational forces (esp. back aches from spinal recompression)
- Medical Recommendations & Treatment: assistance with ambulation; rest; long-term rehab and physical therapy may be needed

Egress is often difficult for crewmembers upon landing. Assisted egress will most likely be needed for missions >2 weeks.

Vehicle-Induced Trauma and Toxic Exposures

- Spaceflight re-entries and landings may result in traumatic injuries to the crew (e.g., fractures, neck injuries, etc.) or exposures to toxic chemicals (e.g., hypergolic substances). Upon landing, ground medical personnel must be able to accommodate and care for a crewmember who incurs injury or exposure due to the vehicle operations.

Back-Up

Major Changes Between Revisions

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

Rev B → Rev C
- Added additional pre-mission medical care information
- Added references to OCHMO technical briefs

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
- Added 'fluid shifts and altered vascular motility' to spaceflight changes
- Added a crew selection page
- Changed the medical care philosophy
  - Removed '14 day' time break from the Levels of Care and created a two-step process for selecting applicable conditions
  - The two steps include: 1. conditions required for every mission; 2. conditions tailored to each program based on mission architecture assessments
  - Further sorted conditions and capabilities
  - Deleted the Levels of Care pyramid
- Updated the total medical conditions list
- Reformed the example medical kit, including removal of the short- vs. long-duration denotations
- Updated the example medical kit contents to become closely aligned with current medical kits

Referenced Technical Requirements

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

NASA-STD-3001 Volume 1 Revision C

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

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

[V1 3003] In-Mission Preventive Health Care All programs shall provide training, in-mission capabilities, and resources to monitor physiological and psychosocial well-being and enable delivery of in-mission preventive health care, based on epidemiological evidence-based probabilistic risk assessment (PRA), individual crewmember needs, clinical practice guidelines, flight surgeon expertise, historical review, mission parameters, and vehicle derived limitations. These analyses consider the needs and limitations of each specific vehicle and design reference mission (DRM) with particular attention to parameters such as mission duration, expected return time to Earth, mission route and destination, expected radiation profile, concept of operations, and more. In-mission preventive care includes, but is not limited to: (see NASA-STD-3001 Volume 1 Rev C for full technical requirement).

[V1 3004] In-Mission Medical Care All programs shall provide training, in-mission medical capabilities, and resources to diagnose and treat potential medical conditions based on epidemiological evidence-based PRA, individual crewmember needs, clinical practice guidelines, flight surgeon expertise, historical review, mission parameters, and vehicle-derived limitations. These analyses consider the needs and limitations of each specific vehicle and design reference mission (DRM) with particular attention to parameters such as mission duration, expected return time to Earth, mission route and destination, expected radiation profile, concept of operations, and more. In-mission capabilities (including hardware and software), resources (including consumables), and training to enable in-mission medical care, and behavioral care, are to include, but are not limited to: (see NASA-STD-3001 Volume 1 Rev C for full technical requirement).

[V1 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 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 mental health care to advanced trauma life support (ATLS) capabilities, or equivalent.

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

[V1 3016] Post-Mission Health Care Post-mission health care shall be provided to minimize occurrence of deconditioning-related illness or injury, including but not limited to: (see NASA-STD-3001, Volume 1 Rev C for full requirement).

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 3017] Post-Mission Reconditioning All programs shall provide the planning, coordination, and resources for an individualized post-mission reconditioning program, specific to each crewmember, mission type, and mission duration. The post-mission reconditioning starts with crew egress at landing and includes a guided, phased reconditioning protocol. The goals of the reconditioning program include the following:

a. To ensure the health and safety of returning crew.

b. To actively assist the crew's return to full functional abilities and return-to-flight status.

c. To actively assist in the crew's return to pre-mission fitness.

NASA-STD-3001 Volume 2 Revision D

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

Reference List

1. Human System Risk Board Risk Packages – including Orthostatic Intolerance; Radiation; Back Pain; Sensorimotor Alterations; Reduced Muscle Mass, Strength; Reduced Aerobic Capacity; Renal Stone Formation; and Vision Alterations
2. Space Operations Medical Support Training Course: Space Physiology and the Deconditioned Astronaut. NASA JSC, Space Medicine Operations Division
3. Wotring, V. E. Medication use by U.S. crewmembers on the International Space Station. *FASEB J*. 29, 4417–4423 (2015).
4. Marshall-Goebel K, Laurie SS, Alferova IV, et al. Assessment of Jugular Venous Blood Flow Stasis and Thrombosis During Spaceflight [published correction appears in JAMA Netw Open. 2020 Jan 3;3(1):e1920195]. *JAMA Netw Open*. 2019;2(11):e1915011. Published 2019 Nov 1.