NASA-STD-3001 Medical Technical Brief

Space Adaptation Sickness (SAS) and Space Readaptation Syndrome

OCHMO-MTB-004
Rev A

Executive Summary

Space Adaptation Sickness (SAS), which includes Space Motion Sickness (SMS), is a well-known problem that affects up to 73% of crewmembers during the first 2-3 days of spaceflight. It is thought to be caused by the body's neurological and perceptual systems response to the microgravity environment. The severity of crew symptoms varies from mild to severe. SAS symptoms include congestion, headache, back pain, lethargy constipation, and urinary retention. SMS symptoms include malaise, sluggishness, disorientation, impaired concentration, stomach awareness, decreased appetite, nausea, and vomiting. Symptoms are generally worse on initial flights and last 2-3 days (or longer in some crew). Concerns include health decrements (dehydration and weakness) and decreased crew performance. Treatments range from pharmacological to pre-flight crew training. Symptoms can also appear with the gravity shift upon return to earth called Terrestrial Readaptation Motion Sickness (TRMS) and could potentially affect landing and egress operations. This technical brief describes the theories of causes, symptoms, and treatments provided to crew to help minimize the impact of Space Adaptation Sickness.

Reference: Chapter 14, Principles of Clinical Medicine for Spaceflight. Barrat et al. (2019).

Relevant Technical Requirements

NASA-STD-3001 Volume 1, Rev C

[V1 3002] Pre-Mission Preventive Health Care
[V1 3003] In-Mission Preventive Health Care
[V1 3004 In-Mission Medical Care
[V1 3016] Post-Mission Health Care
[V1 3017] Post-Mission Reconditioning
[V1 4006] In-Mission Fitness-for-Duty Sensorimotor
[V1 4007] In-Mission Fitness-for-Duty Sensorimotor Metrics
[V1 4008] Sensorimotor Performance Limits
[V1 4009] Sensorimotor Countermeasures
[V1 4010] Post-Mission Sensorimotor Reconditioning
[V2 5002] Crewmember Training
[V1 5009] Physiological Exposure Mission Training
[V1 6002] Private Medical Communications Schedule
[V1 6006] Extravehicular Activities

NASA-STD-3001 Volume 2, Rev E

[V2 5006] Situation Awareness
[V2 7043] Medical Capability

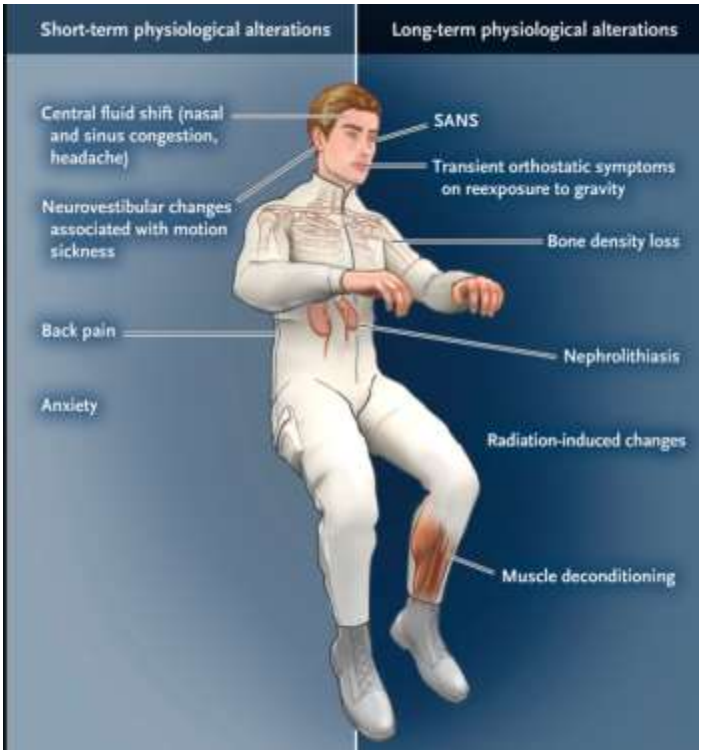
Image: Project Archinaut

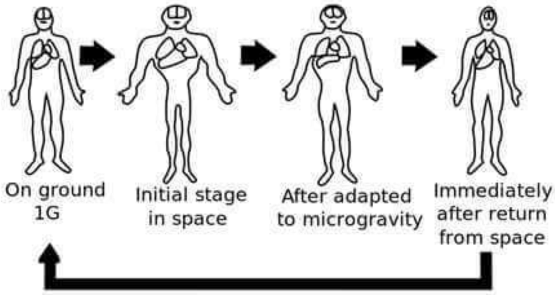
Physiology (Space Adaptation Sickness)

Space Adaptation Sickness (SAS) is a condition experienced by 70-90% of crewmembers during spaceflight, ranging from mild to severe symptomology. Initial symptoms occur in most crew in the first 3-7 days. The causes of SAS are not definite; it appears that microgravity-associated changes including neurovestibular adaptation and fluid shifts can cause symptoms and affect health. SAS is concerning as symptoms can lead to risk of dehydration and compromised astronaut performance and operational abilities. SAS symptoms include congestion, facial fullness, headache, back pain, drowsiness, constipation, urinary retention, and space motion sickness symptoms (covered in detail later in this brief). Treatment includes pharmaceuticals, inactivity, head movement exercises, head restraints, 1g orientation, and pre-mission training/prophylaxis.

Fluid shift symptoms

- Shortly after entering microgravity there is a cephalad shift in body fluids, resulting in congestion of the head and nose. Facial and periorbital edema is most evident during the first 3 days of flight (*Safe Passage, 2001*). Crewmembers complain of facial/head fullness and discomfort in the head, sinuses, and nose. The SAS related nasal congestion lasts from a few hours to a few days and resolves to tolerable levels as the body's fluid levels readjust.
- Treatment: pharmaceuticals such as pseudoephedrine (congestion or allergy medications). Exercise and lower body negative pressure is used later in-flight to counteract physiologic decrements associated with fluid shifts.
- Fluid shits and resulting congestion is the leading cause of prolonged medication use in-mission (*Nasal Congestion, HRWiki 2016*).





Fluid Redistribution When astronauts enter microgravity the loss of hydrostatic pressure in the lower body causes fluid shifts from lower body to the head. This can potentially increase intracranial pressure causing headaches, facial puffiness, face/head congestion, and increased pressure to the inner ear. The fluid shifts affect all crewmembers; causing temporary diuresis with polyuria and reduction in whole body volume. The vehicle must accommodate temporary increased urine output. Crew is monitored for fluid management as well as physical (cardiovascular) changes.

Physiology (Space Adaptation Sickness)

Symptoms and Medical Issues Associated with SAS

Headache Microgravity causes fluid shifts and redistribution of blood, lymph, and cerebrospinal fluid from the lower body. This may increase intracranial pressure on nerves and vascular structures in the brain and surrounding tissues triggering tension type headaches and migraine-like symptoms. Headaches are reported by up to 90% of astronauts during the first few days. Associated nausea, vomiting, facial edema, and nasal congestion is more prevalent in the first week. Treatment includes sleep, exercise, hydration, coffee intake, and analgesics including acetaminophen, aspirin, or NSAIDS. Astronauts adapt after several days, but headaches can be experienced throughout mission (*Van Oosterhout, 2024*).

Back pain Space Adaptation Back Pain (SABP) occurs in 52% of space travelers during the first 2-5 days of flight. Microgravity reduces the usual back curve causing it to straighten, potentially causing pain and degrading spine stability. Positioning exercises, analgesic medications, and exercise are used to manage symptoms with ≥85% pain relief effectiveness for all treatments (*Kerstman, 2012*).

Drowsiness (unrelated to medications) Caused by vestibular system confusion. In microgravity, the inner ear's balance system (vestibular apparatus) receives conflicting signals compared to what the eyes perceive. This sensory mismatch leads to disorientation, fatigue, and nausea. Fatigue symptoms can be treated with stimulant medications including dextroamphetamine.

Metabolic capacity Fluid shifts can lead to decreased stomach motility, reduced appetite, and microgravity related vestibular issues. Metabolic conditions including hormone effects, altered insulin sensitivity, and cortisol changes, have early effects altered by microgravity. Symptoms of nausea, vomiting, diarrhea, malaise, and marked lack of appetite often occur in the first few days resulting in decreased caloric intake and dehydration. Some crew experience constipation that may be caused by alterations in bowel induced by microgravity. Crew is treated with fluid management and fiber in diet; stool softeners and laxatives are available if needed (*Safe Passage, 2001*).

Genitourinary issues Cephalad fluid shifts from lower to upper body can increase central blood volume and suppress ADH hormone. Fluid shifts may cause the body to perceive excess fluid causing fluid intake reduction, while nausea and vomiting reduces fluid volume increasing dehydration risk, altered sensation of bladder fullness, and psychosocial factors – getting used to using bathroom in space, and neuromuscular changes affecting voiding reflex can cause urinary retention in the first few days. Crew is treated with fluid management, nausea/vomiting medications including promethazine, meclizine, and intermittent catheterization as needed (*Stepaniak, 2007*).

Predicting whether someone will experience SAS is not definitively possible. Someone who suffers from car sickness may not suffer from SAS, and vice versa. Age, sex, career/non-career do not show statistically significant differences. It does appear however *that previous SAS experience can predict reoccurrence, SAS is worse in first flyers, and training or familiarity with SAS management or deterrent behavior can reduce symptoms (Davis, 1988).*

Background

The prevention or treatment of SAS is determined per discretion of crew in coordination with their flight surgeon. Pre-launch medications may be given the night before and/or morning of launch for prevention of SAS, however current data collection shows early administration of medications does not provide significant reduction in symptoms. Once in orbit, treatment is given as clinically indicated based on symptoms. ISS crew have daily private medical conferences (PMC) on launch day and daily for 5 days per the NASA Medical Operations Requirements Document (MORD). Crew is also allotted time (table below) per the Exploration Crew Scheduling Constraints (ESCS) to provide space adaptation time. Other programs may follow different monitoring and treatment schedules.

4.6 SPACE ADAPTATION

Space Adaptation Syndrome (SAS) is defined as a set of physical symptoms that can be experienced during the initial days of space travel due to the gravitational adjustment to microgravity (e.g., dizziness, disorientation, vertigo, nausea, etc.).

Table 4.6-1 Space Adaptation Matrix

Flight Day	Adaptation Time
1	1 hour
2	2.5 hours
3-4	1 hour

[ECSC-036] Time will be provided (per Table 4.6-1) to each crewmember on Flight Days 1-4 to mitigate the impacts to crew efficiency due to the physiological effects of SAS.

Rationale: SAS causes reduced work efficiency as the crew acclimates to their new environment. One or more crewmembers could be ill, scheduling Adaptation time builds margin into the plan which allows for this reduced efficiency to not affect the ability of the crew to complete their tasks.

ISS MORD Section 5.2 Medical Evaluations/Scheduling

IN-FLIGHT MEDICAL EVALUATIONS

These evaluations are used to:

A. Assess the health and fitness of the crew, including behavioral health and performance.

B. Assess the impacts of degraded physical as well as behavioral health and performance capabilities of the crew due to long duration spaceflight.

C. Assess the workload and work rest schedules of the crew.

D. Evaluate and prescribe appropriate countermeasures and treatment.

E. Predict and enhance tolerance for physical challenges, such as EVA and entry/landing.

F. Provide a basis for in-flight medical certification, such as EVA

PRIVATE MEDICAL CONFERENCE SCHEDULING

The ISS Program shall schedule PMCs per the following schedule:

A. Daily for the first five days after docking (15 minutes for each crewmember).

B. Weekly after the first five flight days (15 minutes each crewmember).

C. Prior to each EVA; conducted within 24 hours of EVA suit donning.

D. Following each EVA; conducted within 24 hours following EVA suit removal.

E. Daily beginning five days prior to entry and on the morning of entry/landing.

F. At any time during the mission if requested by the FD, Mission Commander or other crewmember, the CS or his designee.

Capabilities needed for diagnosis: Auscultation device, blood analysis (check electrolytes if vomiting)
Capabilities needed for treatment: Antiemetics [oral, suppository, intramuscular, or intravenous (IV)], intravascular volume replacement, such as IV fluids (*NASA HRP Research Roadmap, 2016*)

Physiology (Space Motion Sickness)

The specific cause of SMS is not certain, but the most accepted theory assumes that spaceflight involving fluid shifts, altered gravity, and changes in our neurovestibular capacity, creates disruption in the information received through sensory systems including the visual, vestibular (information received though the semicircular canals and otoliths), proprioceptive, and tactile systems. See OCHMO-TB-010 Sensorimotor.

Terrestrially, our visual and vestibular systems provide sensory inputs related to gravity which enable us to orient ourselves, and have body positioning, touch pressure, and visual cues that are consistent in keeping us upright. In space – those clues are gone. Our orientation does not have the help of gravity to find direction, and what we expect to encounter in our brain does not match what we see and experience, causing confusion and sensory conflict. The intensity and duration of the conflict will impact the SMS severity. When the environment is altered in such a way that this information does not match previously stored neural patterns, motion sickness may occur.

Human Vestibular System

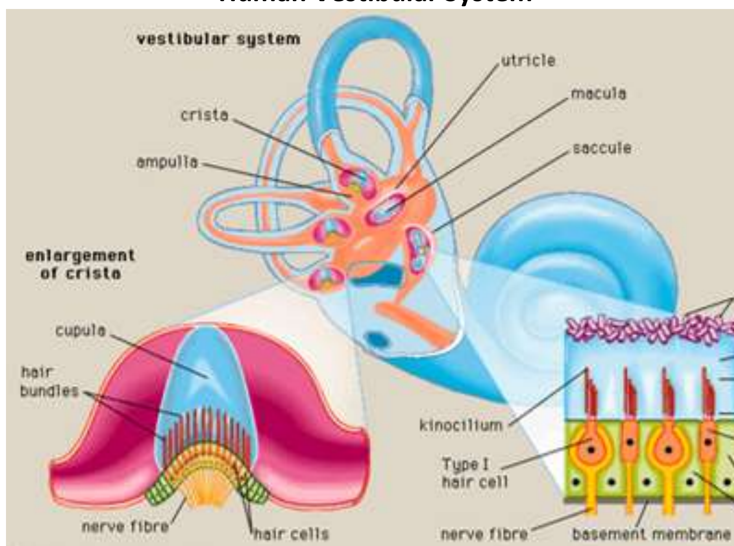


Image: Britannica

Operational constraints during Shuttle spaceflight missions Crewmembers experiencing SMS led to operational constraints. EVAs are scheduled after 72 hours to allow recovery from symptoms and 3 flight days to permit recovery from SMS before entry and landing. Private Medical Conferences on the ISS are conducted frequently in the first week of spaceflight to provide better inflight assessment and treatment of SMS. *Source: Davis et al., 1993.*

Images: NASA

[V1 6006] Extravehicular Activities (EVAs) All crewmembers shall be medically cleared to perform an EVA by ground medical support personnel prior to each EVA. *From NASA-STD-3001 Volume 1.*

Pathophysiology

Severity Score	Signs and Symptoms SMS Grading Criteria
None (0)	None except for mild, transient headache or mild decrease in appetite
Mild (1)	One to several symptoms of a mild nature; may be transient and only brought on as the result of head movements; no operational impact; may include single episode of retching or vomiting; all symptoms resolve in 36-48 hours
Moderate (2)	Several symptoms of a relatively persistent nature that may wax and wane; loss of appetite; general malaise, lethargy, and epigastric discomfort may be the dominant symptoms; includes no more than 2 episodes of vomiting, minimal operational impact; all symptoms resolve in 72 hours
Severe (3)	Several symptoms of a relatively persistent nature that may wax and wane; in addition to loss of appetite and stomach discomfort malaise; lethargy or both are pronounced; strong desire not to move head; includes more than 2 episodes of vomiting; significant performance decrement may be apparent; symptoms may persist beyond 72 hours

Principles of Clinical Medicine for Space Flight. Barratt et al., 2019

Common SMS Symptoms:

- Sensitivity to motion, body/head movements
- Stomach awareness
- Headache
- Drowsiness
- Nausea & vomiting
- Loss of initiative
- Pallor
- Sweating
- Dizziness
- Malaise
- Loss of appetite
- Irritability

A Case Study of Severe Space Motion Sickness. Reschke, Wood, Clément, 2018.

Attenuating Factors

- Concentration on performing a task
- Applying strong tactile inputs
- Closing eyes
- Restricting activity
- Restricting head motion

Sample of flight crew debrief

Indicate SMS symptomatology and the factor(s) that made them worse.

SYMPTOM(S) — FACTOR
✓ head or body movement and axes
✓ sensory conflicts
✓ visual upside down (eyes open/eyes closed)
odors
food odors
foods
noise
✓ temperature
workload
disturbed sleep
looking out windows
non 1-G orientation

Indicate SMS symptomatology and the factor(s) that made them better.

SYMPTOM(S) — FACTOR
rest
sleep
diet
treadmill
✓ eyes open or closed
✓ cooler
1-G orientation
✓ medications (fill in following med chart)

SAS Space Adaptation Sickness
SRS Space Readaptation Syndrome
SMS Space Motion Sickness
TRMS Terrestrial Readaptation Motion Sickness

Compounding Factors:
The incidence and severity of SMS can vary, and some crew symptoms can be exacerbated by specific stimuli such as:

- Unpleasant sights, noxious odors, certain foods, excessive warmth, loss of IG orientation
- Increase in head/body movements; pitch movements have been anecdotally reported as the most provocative, followed by roll and yaw

Similarly, TRMS may be exacerbated by heat stress, excessive head movements, or noxious stimuli after landing

Countermeasures & Treatment

Space Motion Sickness affects approximately 73% of crew in the first days of initial flight. Over half the cases have mild to moderate symptoms including nausea, vomiting, fatigue, and malaise. The symptoms are concerning regarding both crew health, such as being able to maintain strength and hydration, as well as symptom-related increased risk of performance decrements.

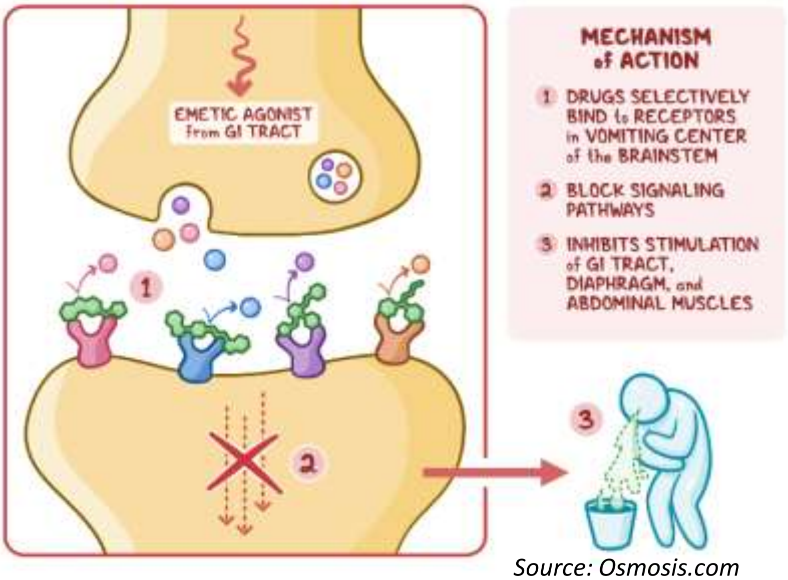
Management includes:

- Training to eliminate provocative activities and head/body movement
- Delay of important performance-related activities (EVA) while crew performance may be compromised
- Pharmacological treatment to treat the SMS symptoms
- Historically, medications including scopolamine (no longer available), promethazine, meclizine, and ondansetron have been used for management of symptoms. Promethazine is considered most effective with the most data available. *Managing Space Motion Sickness. Jennings, 1998, Davis 1993, 1998.*

Promethazine (Brand Name: Phenergan)

NASA treatment of choice and most effective in-flight SMS treatment found to date is promethazine. Promethazine has up to 90% initial response rate, and important reduction in residual symptoms the next flight day. Promethazine is available in oral, IM, IV, and suppository form; all routes have been utilized during spaceflight and are found to be effective. In more severe cases of SMS, IM or PR may be preferred as vomiting can interfere with oral dosing. Terrestrially, promethazine is dosed at 25-50mg; however ongoing studies are investigating how more specific weight-based dosing may better treat SMS. Drowsiness/lethargy is a common terrestrial side effect; however, sedation is not commonly associated with use of promethazine in the first few days of spaceflight. Stimulants, such as dextroamphetamine, can be given with promethazine to offset possible side effects. *A Case Study of Severe Space Motion Sickness. Reschke, Wood, & Clément, 2018, Bagian 1994.*

Images: Shutterstock



Source: Osmosis.com

Promethazine is a histamine (H1) receptor antagonist, and a weak dopamine antagonist that competes with histamine-1 and dopamine-2 receptors in the chemoreceptor trigger zone to decrease nausea, vomiting, and motion sickness. Promethazine is known to have sedating side effects during terrestrial use however does not appear sedating or to have operational decrements during the first few days of spaceflight.

Countermeasures & Treatment

Non-Promethazine Pharmaceuticals

NASA has trialed numerous medications in addition to Promethazine to help prevent or treat SMS. Cyclizine, meclizine, dimenhydrinate, ondansetron, and scopolamine are all anticholinergic medications that have been historically flown (not all used), to manage SMS symptoms. Medications have been used alone or in combination during pre-flight, in-flight, or post-flight treatment. Anticholinergic medications all carry risk of increased lethargy/sedation and pose concerns of increased risk to performance terrestrially; however recent data collections have shown in-flight use is not associated with sedation or performance compromise. To date, promethazine remains the most successful medication in management of SMS symptoms. Stimulants, such as caffeine or dexamphetamine, can be paired with anticholinergic antihistamine medications to decrease risk of side effects of lethargy/sedation and performance decrements.

Comparison of treatment strategies for SMS

A study used results of post-flight oral briefings following Space Shuttle flights reporting medication effectiveness. Comparison was made between 19 crew who were treated with oral combination of scopolamine and dextroamphetamine (Scopdex) and 15 crew treated with IM or suppository promethazine. Three of the 15 treated with Scopdex had symptom resolution, 14 of the 15 IM promethazine users and six of the eight suppository users had symptom resolution.

Comparison of treatment strategies for Space Motion Sickness. Davis et al., 1993

Pharmacological SMS prophylaxis

It has been common practice to use pharmacological treatment pre-launch to prevent SMS symptoms. Data has been analyzed showing crew taking meclizine, scopolamine, ad promethazine prophylactically have no significant differences of SMS symptoms, including vomiting, compared to those who did not pretreat.

Non-Pharmacological Countermeasures and Treatments

- Training to minimize head and provocative movements
- Increased air movement/circulation
- Maintain hydration
- No EVAs scheduled within 72 hours of launch to accommodate SAS symptom resolution
- If SMS or TRMS is severe, consider IV hydration

Stroboscopic Goggles

Vestibular ocular reflex (VOR) normally moves the eyes. In space when a crewmember and an image is moving, the VOR is not as effective to stabilize the image on the retina and contributes to SMS. Stroboscopic goggles, which provide a brief snapshot on the retina, have been studied to potentially help prevent motion sickness, but have not been associated with success and are not routinely used.

Image: Flashy goggles combat space sickness. New Scientist

Literature Review

Treatment efficacy of intramuscular promethazine for space motion sickness

J.R. Davis, R.T. Jennings, B.G. Beck, & JP. Bagian. (1993). *Aviation and Space Environmental Medicine, 64*(3 Pt 1): 230-233.

Assessed the efficacy of treatment for Space Motion Sickness with IM promethazine versus no treatment.

TABLE I. SPACE MOTION SICKNESS GRADING CRITERIA.

Symptom scoring	Criteria
None = 0:	No signs or symptoms reported with the exception of mild transient headache or mild decreased appetite.
Mild = 1:	One to several symptoms of a mild nature; may be transient and only brought on as the result of head movements; no operational impact; may include single episode of retching or vomiting; all symptoms resolved within 36–48 hours.
Moderate = 2:	Several symptoms of a relatively persistent nature which may wax and wane; loss of appetite; general malaise, lethargy and epigastric discomfort may be most dominant symptoms; includes no more than two episodes of vomiting; minimal operational impact, all symptoms resolved in 72 hours.
Severe = 3:	Several symptoms of a relatively persistent nature which may wax and wane; in addition to loss of appetite and stomach discomfort, malaise and/or lethargy are pronounced; strong desire not to move head; includes more than two episodes of vomiting; significant performance decrement may be apparent; symptoms may persist beyond 72 hours.

- SMS severity was assessed for each crew as none (0) to severe (3).
- Treatment sickness score developed from 4 most frequently reported SAS symptoms: nausea, vomiting, stomach awareness, loss of appetite.
- Sick on flight day 2 defined as any episodes of vomiting, severe symptoms, or combined score greater than 3.
- Crew with SAS symptoms who requested treatment were given a promethazine IM dose of 25-50mg, second dose given 8-10 hours later if symptoms unresolved.
- Symptom score determined for flight day 2 after promethazine administered on flight day 1.

PROMETHAZINE & SMS—DAVIS ET AL.

SMS MATRIX

Symptom/ Flight Day	1	2	3	4	5	6	7	8	9	10
Headache			1	1						
Malaise	2									
Sluggishness	2									
Impaired Concentration	1									
Disorientation										
Decreased Appetite	2									
Stomach Awareness	3	1								
Nausea	2									
Vomiting	2									

<u>Results</u>

Medicated with 25-50mg promethazine IM

- 20 crew used promethazine
- 75% (15/20) reported symptom resolution
- 90% immediate relief (within 1-2h) of SMS symptoms
- 3 reported drowsiness after IM injection
- 3 required repeat dosing
- 5 crew treated on day 2; two decrease in appetite only, one had single vomiting episode, one had moderate nausea, decreased appetite, and stomach awareness

No medication

- 74 crew had no promethazine
- 50% (37/74) were sick on flight day 2
- 26/74 tried Scopdex, others tried metoclopramide or prochlorperazine – all were reported ineffective

Preflight testing of medication was considered mandatory to test for idiosyncratic reactions and side effects. Terrestrial studies have shown significant decrements in performance, psychomotor function, and alertness with promethazine. This has not shown true in spaceflight. Concurrent administration of dextroamphetamine with promethazine may eliminate any possible side effects.

Literature Review

Space Motion Sickness: Phenomenology, Countermeasures, and Mechanisms
E.L. Matsnev, I.Y. Yakovleva, I.K. Tarasov, et al. (1983). *Aviation and Space Environmental Medicine*, 54: 312-317.
Study provided a summary of SMS experience in 27 soviet cosmonauts on missions from 2-185 days using questionnaire establishing Illusionary sensations or SMS symptoms.
Illusionary sensations Inversion type symptoms, feeling of forward or backward tumbling, upside-down, or head-down position, and feeling of displacement of surroundings objects, or body spinning, 88% of crew (24 inflight, 8 postflight) experience illusionary sensations mostly upon insert into orbit, or several hours later.
SMS Indisposition, pallor, perspiration (cold sweat), stomach awareness, nausea, and vomiting, 44% of crew (12 inflight, 9 postflight) experienced SMS symptoms in varying degrees.
*** A correlation was shown between SMS and increased head and body movements.*
Findings:
- Distinct correlation between space motion sickness and head movements
- Strong sensory mismatch of the afferent information from the otolith organs, semicircular canals, and eyes, as well as of proprioceptive and musculo-skeletal afferentation, is a major etiological factor to SMS.
- Most cosmonauts adapted to zero G better on second flight than first.
- Cosmonauts attributed SMS to fluid shift of blood to head, increased motor activity, or optokinetic stimulation.
- All crew staggered and fell during postflight Romberg test

SMS Countermeasures:
- Dramamine use diminished vestibuloautonomic disorders but did not eliminate.
- Pneumatic cuffs used to hip area and LBNP reported to improve health state with SMS symptoms
- Neck Pneumatic Shock Absorber (NPSA) cap reported to inhibit symptoms during adaptation.
- Foot pressure devise reduced level of spatial illusions and motor disturbances.

** *Russian countermeasures not necessarily used by U.S. ISS crew*

Postflight Exam	% Cosmonauts
Spontaneous/positional nystagmus	7.4%
Optokinetic nystagmus	
Function of postural equilibrium	96%
Otolith function	Up to 55%
Functional of semicircular canals	Up to 62%
perception of spatial coordinates	59%
Index-finger target test	

Crew were evaluated using preflight, inflight, and postflight examinations at the recovery site and later if indicated. Exams conducted L-30-45d, and R+0,1-2,3-5,and 8-9, R+30 for longer duration flights.

Literature Review

A Case Study of Severe Space Adaptation Sickness
M.F. Reschke, S.J. Wood, & G.R. Clément. (2018). *Aerospace Medicine and Human Performance, 89*(8): 749-753.
Case study of crewmember experiencing severe SAS after flying in space for the first time for >7 days on Space Shuttle. This study illustrates some of the potential risks SAS poses. SAS symptoms started immediately after launching and lasted several days into the mission. Causes were oscillopsia induced by head movements, wearing prescription eyeglasses, and body movement.

- Crewmember was trained to score SAS on scale of 0-20 with 20 being vomiting and 10 midway between normal and vomiting. Scores reported throughout the working day.
- Crewmember had pilots license and was a copilot to subsonic jet trainer for 3 years prior to spaceflight.
- Had no known damage to vestibular system (i.e., trauma or infections).
- Demonstrated average susceptibility to motion sickness during visual and vestibular tests performed 2 years before spaceflight. Experienced some severe motion sickness during testing.

Day	Symptoms	Treatment
1	SAS score 15-18. Full head, oscillopsia, marked stomach awareness, vomiting, head movements provocative, disorientation	Oral Phenergan – vomited, 50mg IM, 2nd dose 50mg IM
2	Restricted activities, vomiting, head movements provocative	PO 25mg Phenergan
3	SAS score 10. Reflux, fatigue, yawning, back pain, distorted smell and taste, moderate persistent headache, disorientation, drowsiness, marked concentration impairment, glasses provocative, vision decrements, appetite loss, nausea, diarrhea	No medication
4	No report	
5	SAS score 5-8 with some periods of 20; vomiting	None
6	SAS score 5. Heavy feeling in head, heaviness when moving eyes, head movements cause nausea, reflux,	None
7	Landing day– provocative head and eye movements, nausea	2 IM Promethazine injections

This case represented unusually severe SAS. Severity of SAS improved with Promethazine and decreased throughout the flight, but the crewmember was still not able to complete all activities by flight day 7. SAS symptoms lasted 8 days post-flight.

Pre-landing Assessments

When crew return to Earth after spending time in space, they must physically and mentally adjust, just as they adjusted to entering the microgravity environment. They may experience terrestrial readaptation motion sickness (TRMS), with symptoms similar to SAS or SMS.
"Returning to Earth after living and working in space has an impact on the body, vestibular disturbance and fluid shifts combination can increase Astronaut's risk of fainting due to mixture of reduced ability to control their blood pressure, heart changes and dehydration. Astronauts establish a new set point in space," Sergi explains. "So, when they come back, they can be quite dizzy and experience sensations that are like seasickness. Any acceleration, especially with rotation, completely disorients the brain. This results in nausea and unstable gait." (*Back to Earth-Medical Perspective Ally ESA, 2018*).

Astronauts will experience many physical changes during spaceflight depending on the length of flight and the amount of activity endured (exercise/EVA activity). Changes in muscle/aerobic, bone, cardiovascular, vision changes as well as the fluid shifts can affect how healthy and fit crewmembers are for landing and re-entry. NASA flight surgeons and physical trainers monitor the crew throughout flight to ensure they are supplied with adequate time, equipment, and direction to maintain health and fitness and ability for safe landing and re-entry.

NASA protects crew with document requirements. ISS MORD requirements:
8.6.1 Post-Flight Rehabilitation Program: The ISS program shall implement a post-flight rehabilitation program as described in Rehabilitation Document (JSC 27050<TBD 8-5>).
8.6.2 Post-flight Medical Assessment Test ISS crewmembers shall participate in post-flight medical assessment activities as defined in SSP 50667.
NASA 100.1A shows ISS sample requirements that define medical evaluations and schedule needed post-flight

Motion Sickness

Time since landing	Motion Sickness Score (Circle)						
0-2 hours	Did Not Ask	0	1	2	3	4	5
2-4 hours	Did Not Ask	0	1	2	3	4	5
4-8 hours	Did Not Ask	0	1	2	3	4	5
8-12 hours	Did Not Ask	0	1	2	3	4	5
12-16 hours	Did Not Ask	0	1	2	3	4	5
16-20 hours	Did Not Ask	0	1	2	3	4	5
20-24 hours	Did Not Ask	0	1	2	3	4	5
24-28 hours	Did Not Ask	0	1	2	3	4	5
28-32 hours	Did Not Ask	0	1	2	3	4	5
32-36 hours	Did Not Ask	0	1	2	3	4	5

ISS Crew Surgeon Landing Assessment

Clinical Assessment and Monitoring	Med Eval Requirement	Annual ***	PRE-FLIGHT (L-)	IN-FLIGHT	POST-FLIGHT (R+)
Ophthalmology/Optometry	[6011]	Table 6	AME L-12/6 m Retinal photographs and OCT On Record		R+0/1, R+3 d and ACI R+1/10 d - Retinal photographs and OCT
On-Orbit Strength & Conditioning Monitoring	[6025]			FD3 through the day prior to undock and ACI. Resistance: 3x/wk (60 min) Aerobic: 3x/wk (30 min)	

Upon landing, NASA flight surgeons assess crew for health and medical status. Most TRMS clears in 2-3 days but crew are monitored for the first 30-45 days and assessed for appropriate activity levels.

Back-Up

Major Changes Between Revisions

Original → Rev A

- Made edits throughout to better distinguish between Space Adaptation Sickness (SAS) and Space Motion Sickness (SMS).
- Added additional information on SAS symptomology and fluid redistribution (Pages 2 and 3).
- Added information on crew schedule constraints from the NASA Medical Operations Requirements Document (MORD) (Page 4).
- Added additional content on SMS symptom evaluation (Page 6).
- Added additional information on pharmaceutical countermeasures for SAS and SMS symptomology (Page 7).
- Added an additional case study to the literature review (Page 10).
- Added information on prelanding and postflight crew assessments (Page 12).

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 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 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 technical requirement).

[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 postmission reconditioning starts with crew egress at landing and includes a guided, phased reconditioning protocol. The goals of the reconditioning program include the following: (see NASA-STD-3001 Volume 1 Rev C for full technical requirement).

[V1 4006] In-Mission Fitness-for-Duty Sensorimotor In-mission Fitness-for-Duty technical requirements shall be guided by the nature of mission-associated critical operations (such as, but not limited to, vehicle control, robotic operations, EVAs).

[V1 4007] In-Mission Fitness-for-Duty Sensorimotor Metrics In-mission Fitness-for-Duty technical requirements shall be assessed using metrics that are task specific.

[V1 4008] Sensorimotor Performance Limits Sensorimotor performance limits for each metric shall be operationally defined.

[V1 4009] Sensorimotor Countermeasures Countermeasures shall maintain sensorimotor function within performance limits.

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[V1 4010] Post-Mission Sensorimotor Reconditioning Post-mission reconditioning shall be monitored and aimed at returning to baseline sensorimotor function.

[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 [CO2] exposure training, hypoxia training/instruction, centrifuge, and high-performance aircraft microgravity adaptation training in preparation for each mission.

[V1 5002] Crewmember Training Beginning with the astronaut candidate year, general medical training, including, but not limited to, 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 6002] Private Medical Communication Schedule Private medical communications shall be scheduled on a routine basis, as determined by the Flight Surgeon, at a frequency dictated for short or long-duration missions.

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[V2 5006] Situation Awareness Systems shall provide the Situation Awareness (SA) necessary for efficient and effective task performance and provide the means to recover SA, if lost, for anticipated levels of crewmember capability and anticipated levels of task demands.

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

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