



Space Medicine Capabilities and Challenges for Exploration Missions

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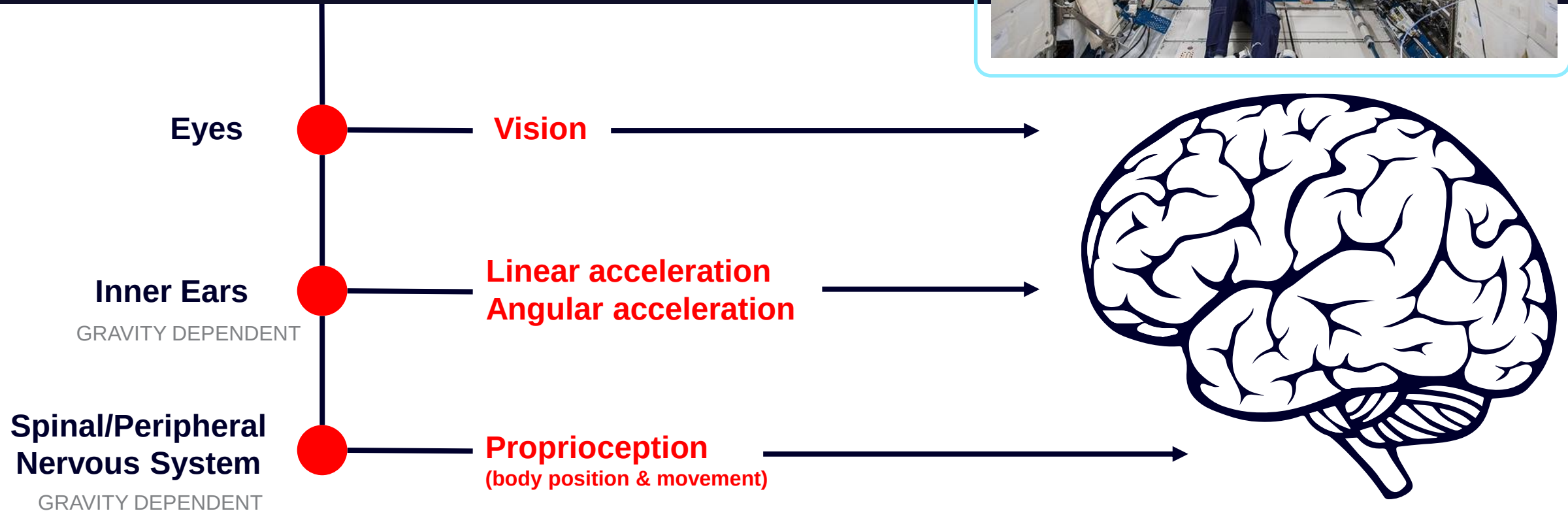
Human Response to Spaceflight



- Ocular
- Neurovestibular
- Cardiovascular
- Renal
- Skeletal
- Muscular
- Immunological
- Nutritional
- Behavioral

Neurovestibular Effects

- Sense of orientation
- Balance/posture
- Pursuit tracking
- Maintaining gaze
- Smooth movement



Space Motion Sickness

- **Predominate Theory: Sensory conflict**
 - Affects ~80% of crewmembers
- **Symptoms: Loss of appetite, nausea, vomiting**
 - Can occur within minutes of exposure to microgravity
 - Typically resolves after 24-48 hrs
 - Resolves completely within 4-7 days
- **Treatment:**
 - 1-G orientation
 - Medications
 - Inactivity/sleep
 - Preflight adaptation training



Fluid Shifts

In-flight

In space, the fluid tends to redistribute toward the chest and upper body. At this point, the body detects a “flood” in and around the heart.

In-flight

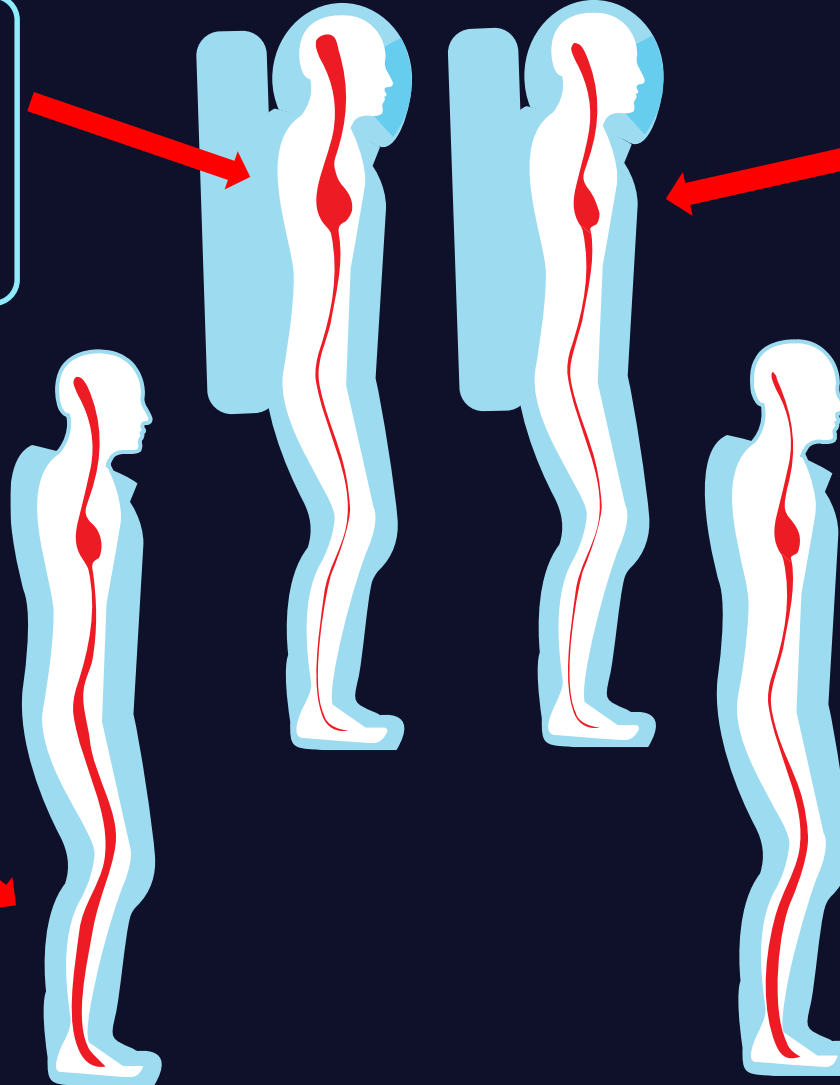
The body rids itself of this perceived “excess” fluid. The body functions with less fluid and the heart becomes smaller.

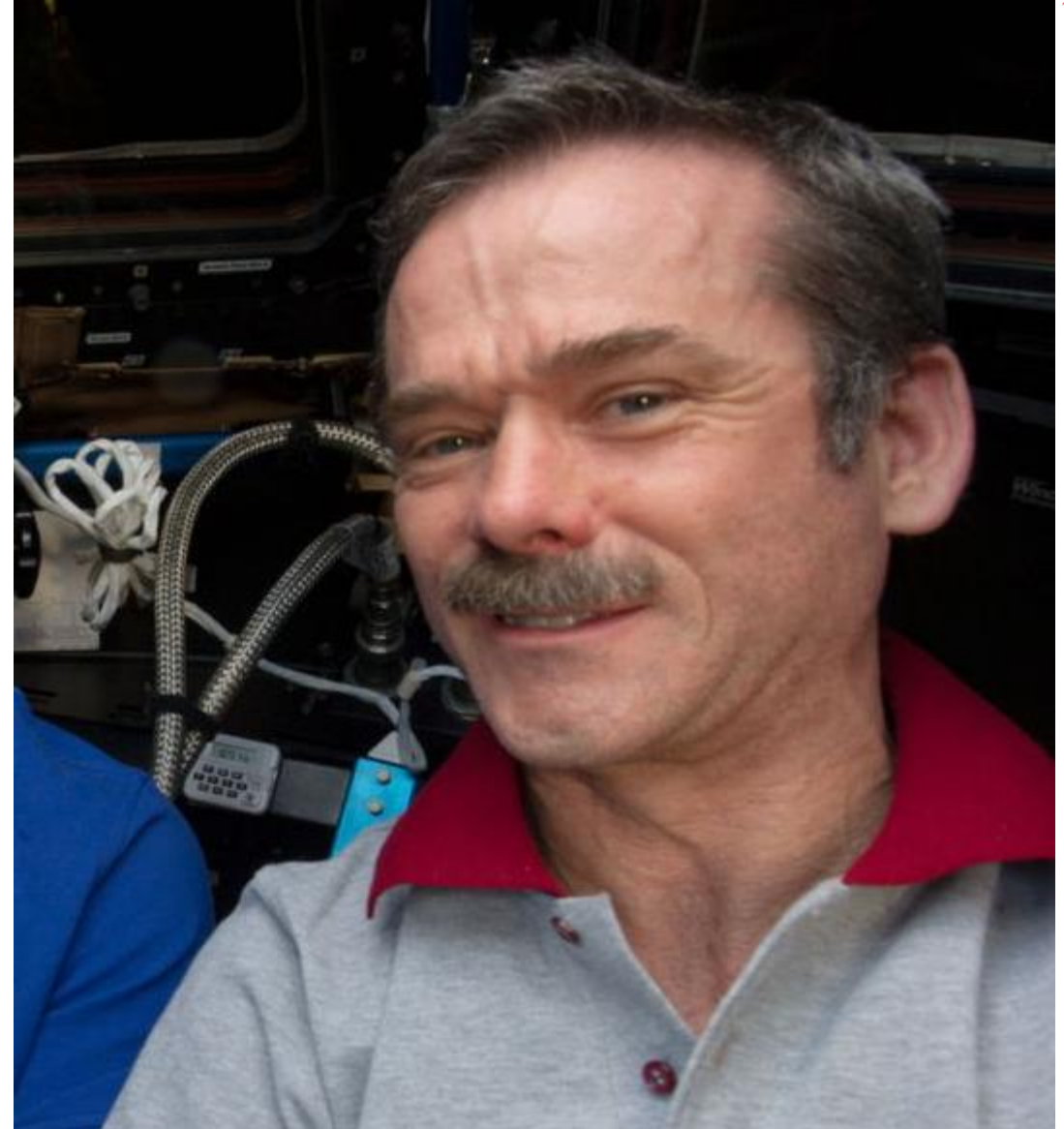
Pre-flight

On Earth, gravity exerts a downward force to keep fluids flowing to the lower body.

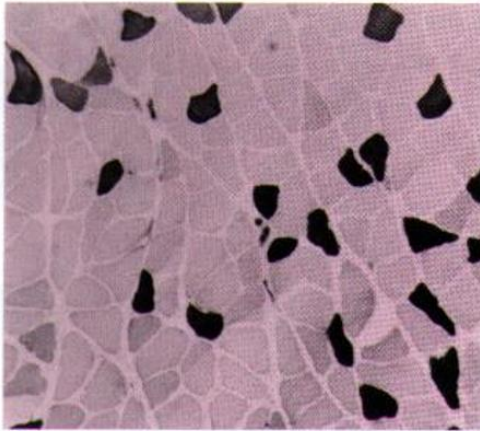
Post-flight

Upon return to Earth, gravity again pulls the fluid downward, but there is not enough fluid to function normally on Earth.

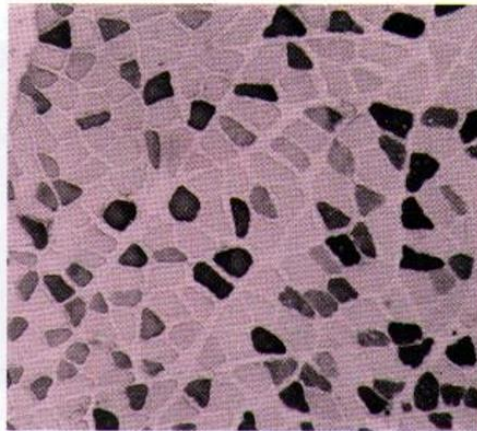




Muscle Atrophy



Ground control

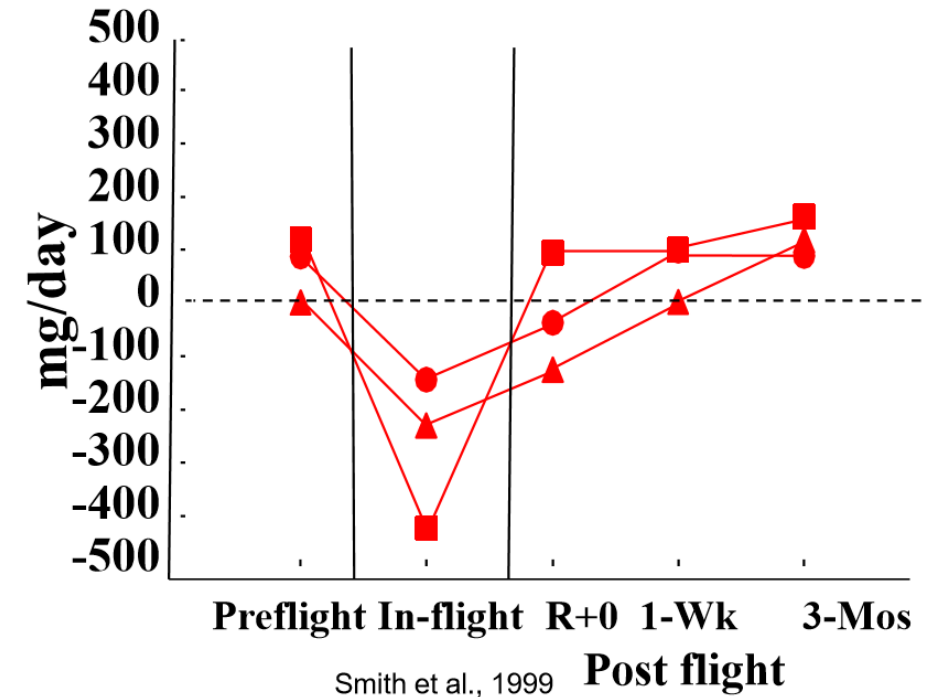


Flight

- 20% loss of muscle mass on spaceflights lasting 5-11 days
- Affects stabilizing muscles:
 - Calf, quadriceps, back and neck
 - Extensors > flexors

Bone Remodeling

- When bones don't bear weight, they lose density and strength
- Bone demineralization 1-2.4% per month in lower extremities and spine

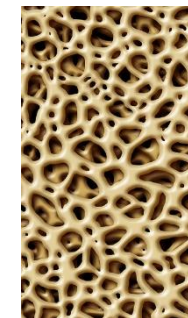


OSTEOCLASTS

(resorb bone)

OSTEOBLASTS

(build bone)



In-flight Medical Conditions

Allergic Reaction	Headache (Late)	Pharyngitis
Ankle Sprain/Strain	Headache (Space Adaptation)	Respiratory Infection
Back Injury	Hemorrhoids	Shoulder Sprain/Strain
Back Pain	Herpes Zoster Reactivation (Shingles)	Sinusitis
Barotrauma	Indigestion	Skin Abrasion
Chocking/Obstructed Airway	Influenza	Skin Infection
Constipation	Insomnia (Space Adaptation)	Skin Laceration
Diarrhea	Insomnia (Late)	Skin Rash
Elbow Sprain/Strain	Knee Sprain/Strain	Smoke Inhalation
Eye Abrasion (Foreign Body)	Mouth Ulcer	Space Motion Sickness
Eye Chemical Burn	Nasal Congestion	Urinary Incontinence
Eye Infection	Neck Injury	Urinary Retention
Finger Dislocation	Nose Bleed	Urinary Tract Infection
Fingernail Delamination (EVA)	Otitis Externa	SANS
Gastroenteritis	Otitis Media	Wrist Sprain/Strain
Headache (CO2 induced)	Paresthesias	Etc.

<https://humanresearchroadmap.nasa.gov/Evidence/reports/Medical.pdf>



CURRENT MEDICAL OPERATIONS





ISS Medical Kits







Behavioral Health and Performance Support

- **Physical and Psychosocial Stressors**
 - **Environmental:** noise, odors, confined space
 - **Mission :** reliance on ground teams, overwork and underwork, monotony of schedule and diet, life-threatening events onboard
 - **Interpersonal:** personality differences, cultural differences, family illnesses or events back home
 - **Intrapersonal:** isolation and confinement, reduced personal space, drive to succeed





EXPLORATION MEDICAL CONSIDERATIONS



EARTH RELIANT

MISSION: 6 TO 12 MONTHS
RETURN TO EARTH: HOURS

- Real Time Communications
- Evacuation Capability (1.5 – 36 hrs)
- Strong Consumables Resupply



PROVING GROUND

MISSION: 1 TO 12 MONTHS
RETURN TO EARTH: DAYS

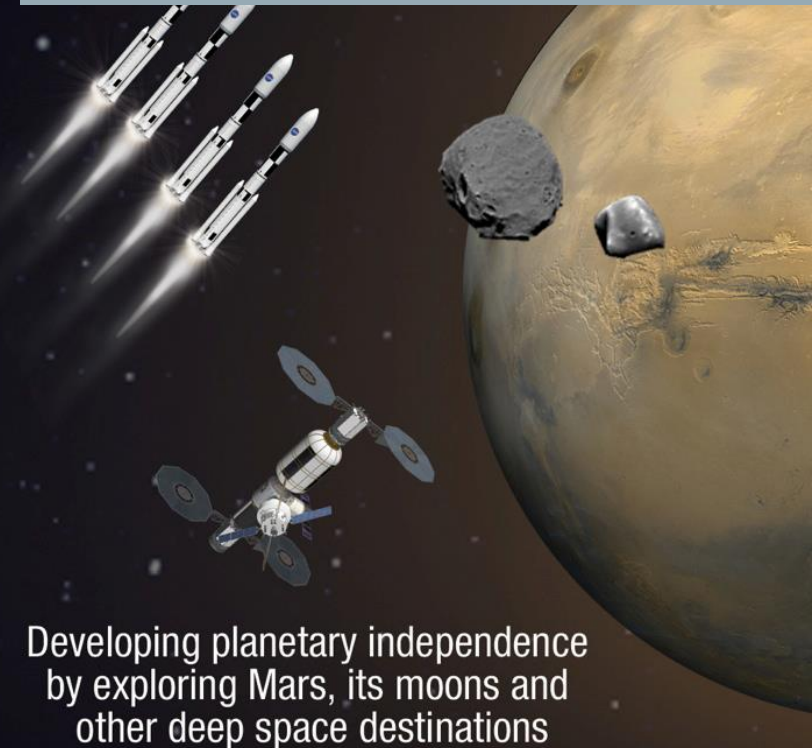
- Near Real Time Communications
- Evacuation Capability (72 – 144 hrs)
- **Limited** Consumables Resupply



EARTH INDEPENDENT

MISSION: 2 TO 3 YEARS
RETURN TO EARTH: MONTHS

- **No** Real Time Communications
- **No** Evacuation Capability
- **No** Consumables Resupply





Exploration Medical Considerations

- Longer duration missions
- Exposure to the deep space environment
- Communication delays & blackout periods
- Inability to re-supply
- Medical evacuation limited or impossible
- Limited flight resources (mass, power, volume, data)
- CHP will need to be more integrated part of system



Planned vs Unplanned Medical Activities

- An exploration medical system will need to provide for planned/routine activities
 - Private medical conference
 - Private psychological conf
 - Vital signs assessment
 - Eye exam
 - Dental exam
 - On-Orbit Hearing Assessment
- Provision of diagnosis and treatment of acute, unplanned medical events is also required



Level of Care

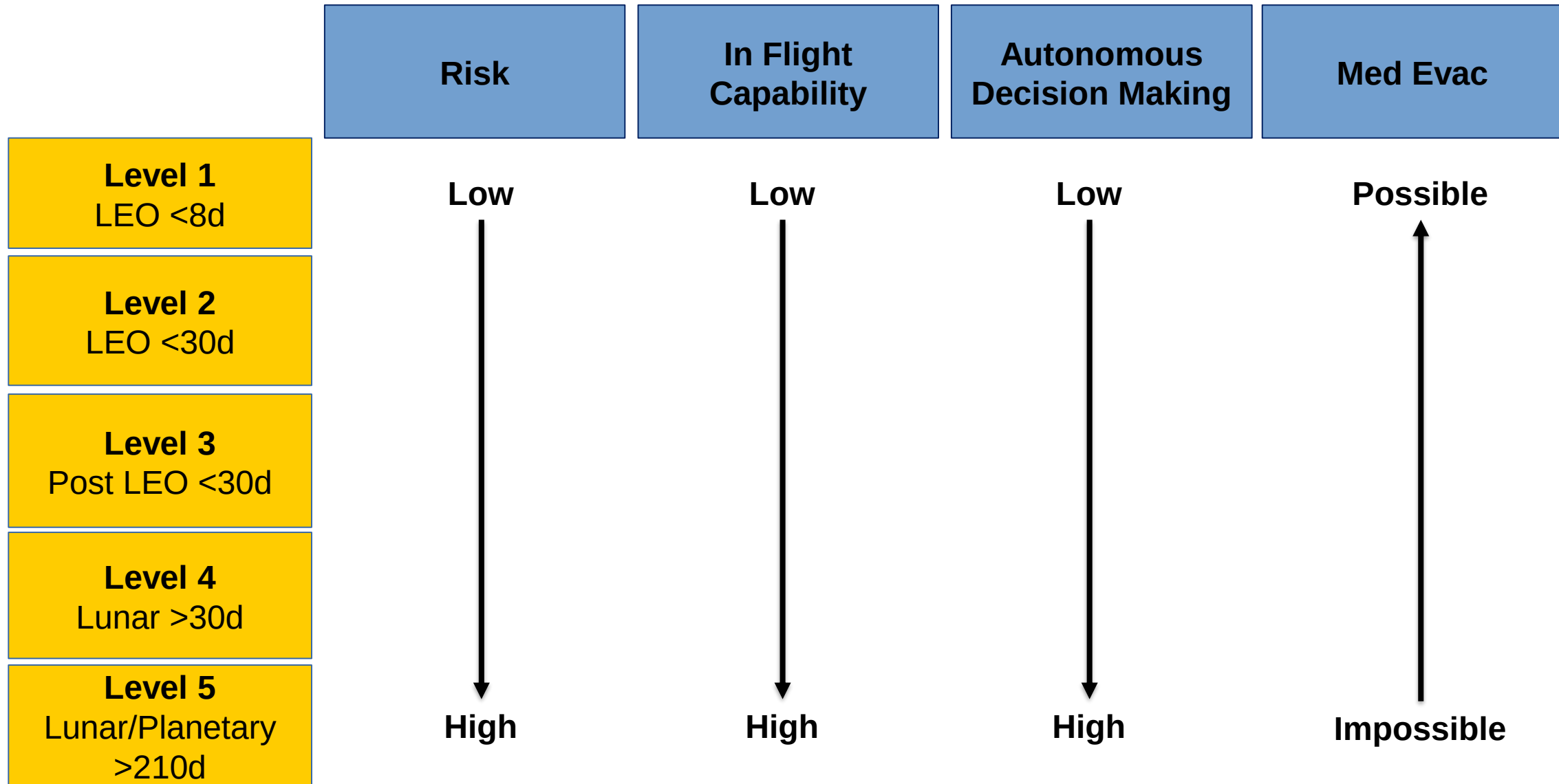
- Terrestrially, Level of Care refers to the **amount and type of medical care rendered** based on perceived need and the ability of the provider.
- Levels of Care for human space flight missions are defined in **NASA-STD-3001, Volume 1**.
- The Level of Care provided for exploration missions is based on **multiple factors**:
 - Mission duration
 - Destination
 - Time to definitive medical care
 - Level of crew autonomy
 - Health / performance
 - Medical training of the provider
- As Level of Care increases, the required pre-flight screening, onboard diagnostic and treatment capabilities, and medical training of the provider also increase.



NASA-STD-3001 Levels of Care

Level	DRM	Example	Medical Capability
I	LEO Transfer	Commercial Crew	Space Motion Sickness, Basic Life Support, First Aid, Private Audio, Anaphylaxis Response
II	LEO <30 days	Shuttle	Level I + Clinical Diagnostics, Ambulatory Care, Private Video, Private Telemedicine
III	Beyond LEO <30 days	EM-2	Level II + Limited Advanced Life Support, Trauma Care, Limited Dental Care
IV	Beyond LEO 30 -210 days	Gateway	Level III + Medical Imaging, Sustainable Advanced Life Support, Limited Surgical, Dental Care
V	Beyond LEO >210 days	Mars	Level IV + Autonomous Advanced Life Support and Ambulatory Care, Basic Surgical Care, Physician CMO

Level of Care Capabilities



Exploration Medical High Level Gaps

Medical Diagnostics
The ability to provide diagnostic capabilities while optimizing mass/volume and allowing for semi-autonomous medical operations is needed for exploration missions.
Medical Imaging
The ability to provide low mass/volume medical imaging solutions that are less reliant on remote guidance and interpretation is needed for exploration missions.
Medical Treatment
The ability to provide medical treatment for anticipated medical conditions in a manner that optimizes mass/volume and decreases reliance on ground support is needed for exploration missions.
Behavioral Health and Performance
The capability to provide behavioral health diagnosis, treatment, and support with decreasing access to ground support is needed for exploration missions.
Pharmacy
The ability to provide medications that are safe and effective for exploration mission paradigms is needed.
Medical Risk Assessment
The ability to provide quantitative medical risk modeling and trade space analysis capabilities based upon a database of updated medical evidence is needed for exploration missions.
Medical System Architecture
The ability to provide a cohesive, semi-autonomous medical system that allows for inventory and data management with Electronic Health Record integration is needed for exploration missions.

Exploration Medical Gaps

- Medical Diagnostics
 - Multifunctional Medical Devices
 - Compact Lab Analysis
 - Autonomous Diagnostic Aides
- Medical Imaging
 - Handheld ultrasound
 - Autonomous Acquisition and Interpretation Aide
- Medical Treatment
 - Regenerable IV Fluids
 - Just-in-time procedure training

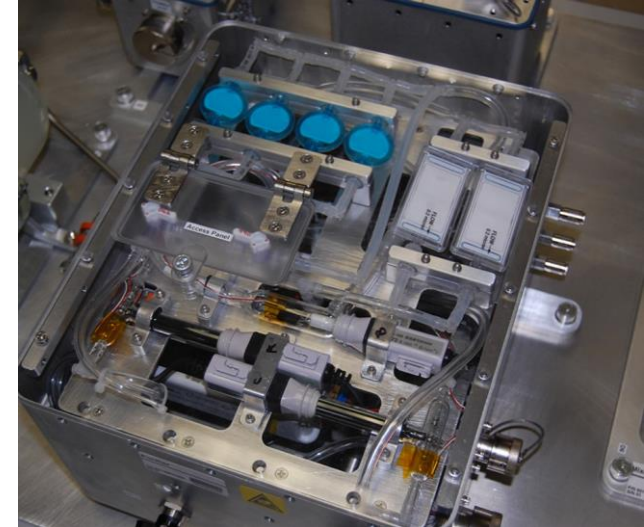


ESA Tempus Pro



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- Medical Treatment
 - Regenerable IV Fluids
 - Just-in-time procedure training
- Behavioral Health and Performance
 - Autonomous Diagnostic Aid
 - Autonomous Support Modality
- Pharmacy
 - Exploration Formulary
 - Medication Stability and Toxicity Understanding
- Medical Risk Assessment
 - Trade Space Analysis Tool
 - Quantitative Medical Risk Model
- Medical System Architecture
 - Inventory Tracking Tool
 - Electronic Health Record
 - CHP Integrated Data Architecture



Intravenous Fluid Generation (IVGEN)

- Successfully demonstrated on Expedition 23 in 2010
- IV Fluids met USP standards
- Smaller unit in development for exploration missions



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Questions?