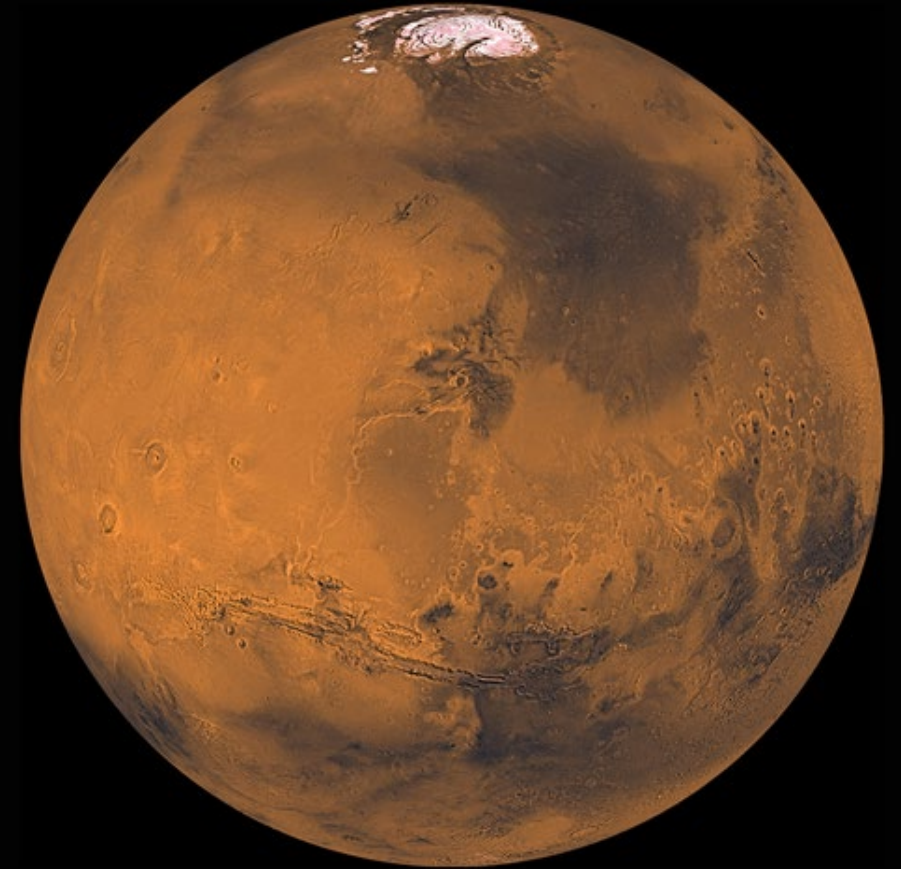




Human Research Program Mission Statement

To enable space exploration beyond Low Earth Orbit by reducing the risks to human health & performance



Hazards of Human Spaceflight

1

Space Radiation

Invisible to the human eye, radiation increases cancer risk, damages the central nervous system, and can alter cognitive function, reduce motor function and prompt behavioral changes.

2

Isolation and Confinement

Sleep loss, circadian desynchronization, and work overload may lead to performance reductions, adverse health outcomes, and compromised mission objectives.

3

Distance from Earth

Planning and self-sufficiency are essential keys to a successful mission. Communication delays, the possibility of equipment failures and medical emergencies are some situations the astronauts must be capable of confronting.

4

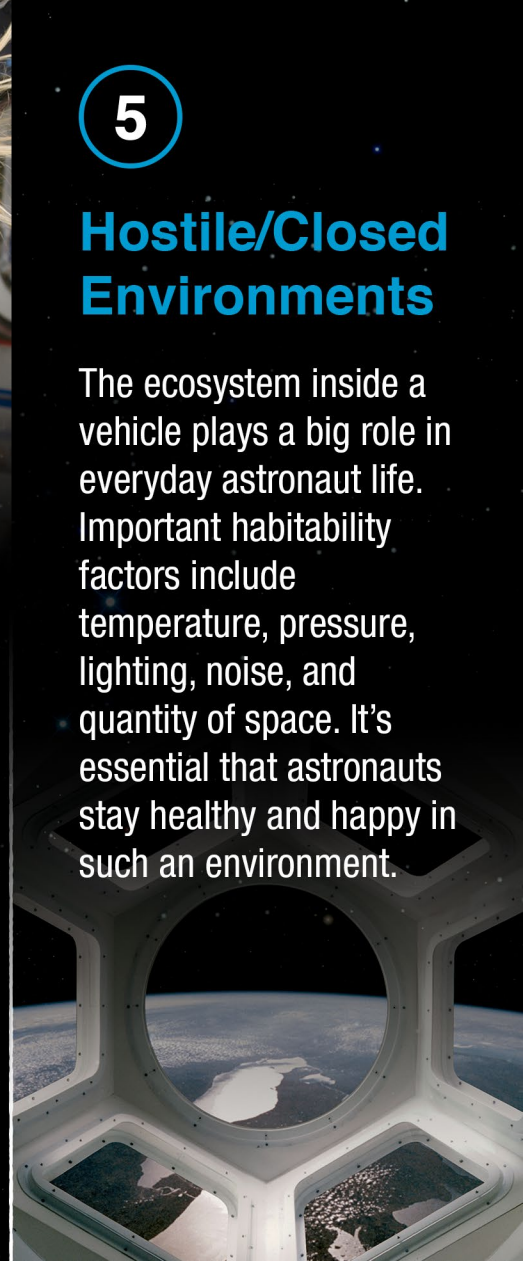
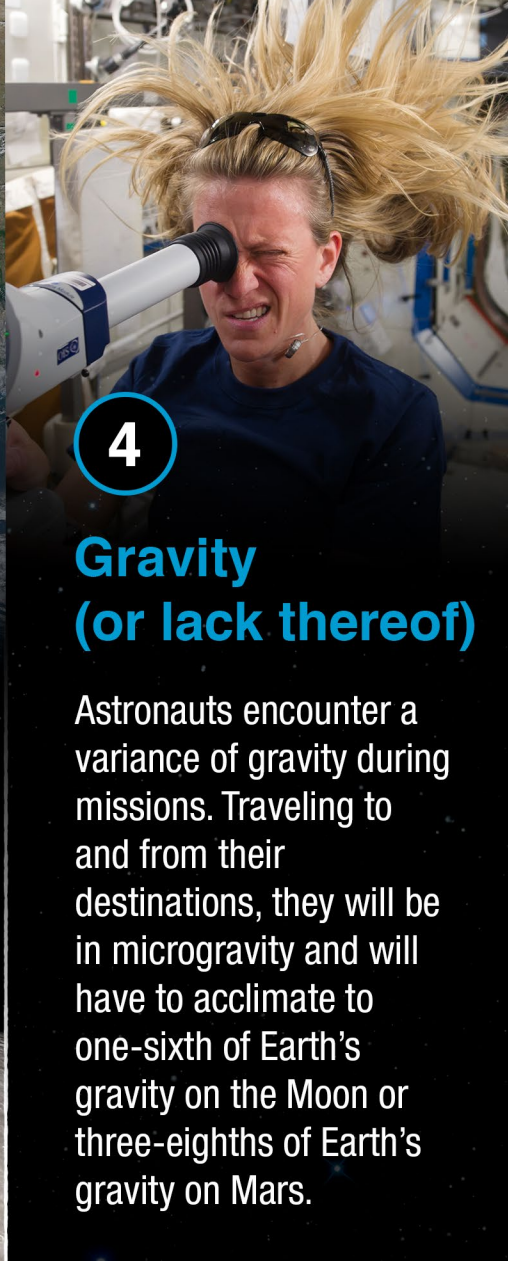
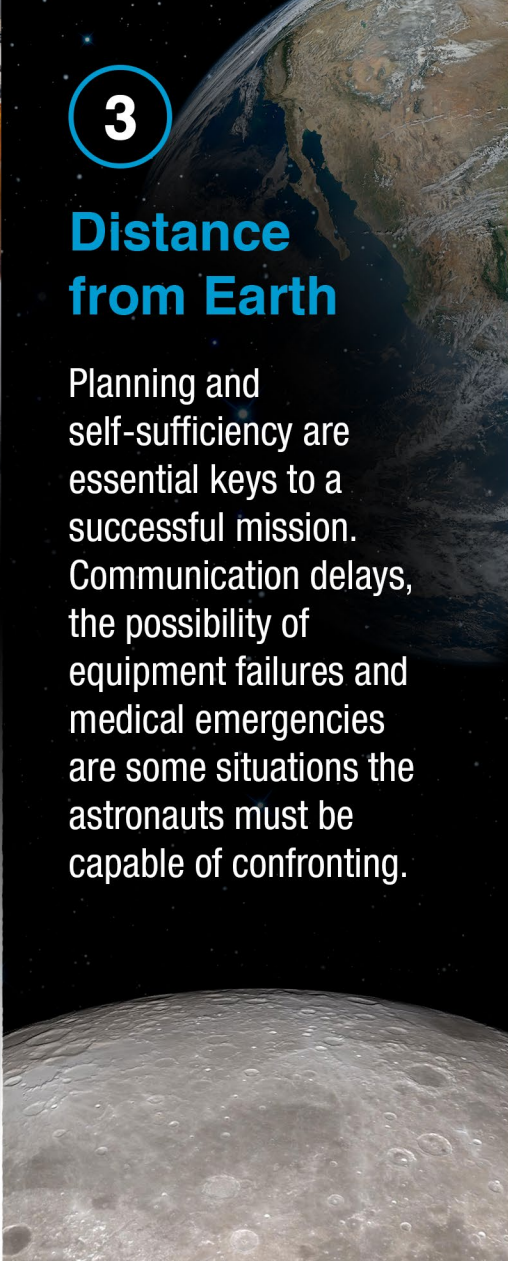
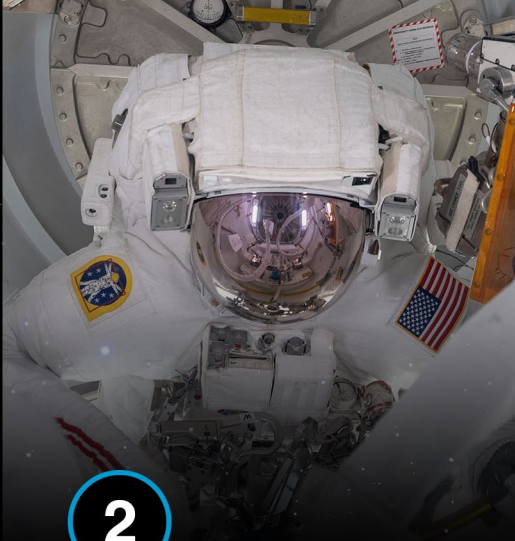
Gravity (or lack thereof)

Astronauts encounter a variance of gravity during missions. Traveling to and from their destinations, they will be in microgravity and will have to acclimate to one-sixth of Earth's gravity on the Moon or three-eighths of Earth's gravity on Mars.

5

Hostile/Closed Environments

The ecosystem inside a vehicle plays a big role in everyday astronaut life. Important habitability factors include temperature, pressure, lighting, noise, and quantity of space. It's essential that astronauts stay healthy and happy in such an environment.



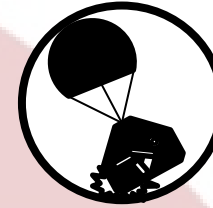
Human System Risks	Low Earth Orbit (Short)	Low Earth Orbit (Long)	Lunar Orbital (Short)	Lunar Orbital (Long)	Lunar Orbital + Surface (Short)	Lunar Orbital + Surface (Long)	Mars (Preparatory)	Mars (Planetary)
	< 30 D	30 D - 1 Y	< 30 D	30 D - 1 Y	< 30 D	30 D - 1 Y	< 1 Y	730-1224D
Distance from Earth								
* Human Systems Integration Architecture (HSIA) Risk ^{5x5}	A	A	RM/SR	RM/SR	RM	RM	RM	RM
* Medical Conditions Risk ^{5x5}	A	A	A	RM	RC	RM	RM	RM
* Food and Nutrition Risk	AO	A	A	RM	A	RM	RM	RM
* Pharm Risk	AM	A	A	A	A	A	A	RM
Isolation and Confinement								
* Behavioral Risk ^{5x5}	AM	RM	AM	RM	RC	RM	RM	RM
* Team Risk	AM	AM	AM	RM	AM	AM	RM	RM
Altered Gravity								
* Sensorimotor Risk ^{5x5}	A	RM/SR	AM	RM/SR	RM/SR	RM/SR	RM/SR	RM/SR
* Bone Fracture Risk ^{5x5}	A	A	A	RC	A	RC	RC	RC
* Cardiovascular Risk ^{5x5}	A	AM	AM	AM	AO	AO	AM	RM/SR
* Renal Stone Risk	A	A	A	A	A	A	RM	RM
* SANS Risk	A	A	A	A	A	A	A	RM
Crew Egress Risk ^{5x5}	AM	AM	RC	RC	RC	RC	RC	RC
* Microhost Risk	AM	AM	AM	AM	AM	AM	AM	RM
Urinary Retention Risk	A	A	A	A	A	A	A	A
* Aerobic Risk	A	AM	AO	AO	AO	AO	AO	AO
* Muscle Risk	A	AM	AO	AM	AO	AO	AO	AO
Venous Thromboembolism (VTE) Concern	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hostile Closed Environment								
* EVA Risk	A	A	AO	AO	RM	RM	AO	RM
* Dynamic Loads Risk	AM	AM	AM	AM	RM	RM	AM	RM
Carbon Dioxide (CO2) Risk ^{5x5}	AM	AM	AM	AM	AM	AM	AM	AM
Toxic Exposure Risk ^{5x5}	AM	AM	AM	AM	AM	AM	AM	AM
* Immune Risk	AM	AM	AM	AM	AM	RM	RM	RM
* Sleep Risk	A	AO	AO	AO	AO	RM	RM	RM
Decompression Sickness (DCS) Risk	A	A	RM	RM	RM	RM	RM	RM
Hypoxia Risk (LTH)	A	RM	A	RM	A	RM	RM	RM
* Dust Risk	N/A	N/A	A	A	A	RM	N/A	TBD
Electric Shock ^{5x5}	A	A	A	A	RC	RC	RC	RC
Hearing Loss (LTH)	AM	AM	AM	RC	AM	AM	RC	RC
Radiation								
* Radiation Carcinogenesis Risk (LTH)	A	RC	A	RC	A	RC	RM	RM
Non-Ionizing Radiation Risk	A	A	A	A	A	A	AO	AO



Top Crew Health and Performance System Capability Challenges for Mars v1.0



**Earth-Independent Human
Operations**



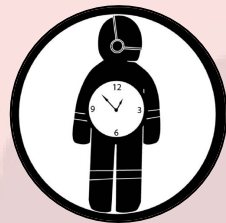
**Computational Injury &
Anthropometric Models**



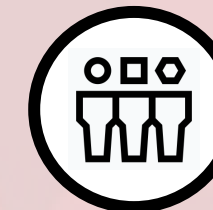
Mars Duration Food System



**Exploration Exercise
Countermeasures**



**Mars Duration Effects on
Human Physiology**



**Understanding Individual
Variability in Spaceflight**



**Risk Mitigations for Vehicle
Atmospheres**



**Sensorimotor
Countermeasures**

Notional Human Spaceflight Strategy for Integrated Research and Testing for Mars Mission Readiness



FIRST MISSIONS TO MARS



OPERATIONAL VALIDATED
CREW HEALTH &
PERFORMANCE

Mission Verification & Validation



ARTEMIS LUNAR-BASED ANALOGS



MICROGRAVITY /
PARTIAL
GRAVITY



DEEP
SPACE
RADIATION



EXPLORATION
MEDICAL
CAPABILITY



EXTENDED
MISSIONS

Risk mitigation of integrated hazards

Human systems validation



LOW-EARTH ORBIT RISK REDUCTION



MICROGRAVITY /
1G TRANSITIONS



GENE /
MICROGRAVITY
INTERACTIONS



CROP
PRODUCTION



TEST NEW
SYSTEMS



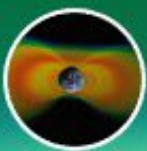
INTEGRATED
SIMULATIONS

Risk mitigation of single hazards

Risk mitigation of integrated and simulated hazards



GROUND-BASED RESEARCH



SPACE
RADIATION
SIMULATION



BEDREST



ISOLATION
ANALOGS



ANALOG FIELD
TESTS



CREW HEALTH
AND PERFORMANCE
SYSTEM
FORMULATION

TIME →

GROUND & ISS

LEO COMMERCIALIZATION

ARTEMIS BASECAMP

FIRST MISSION TO MARS