EXERCISE IS SPACE MEDICINE

OPTIMIZING ASTRONAUT PERFORMANCE

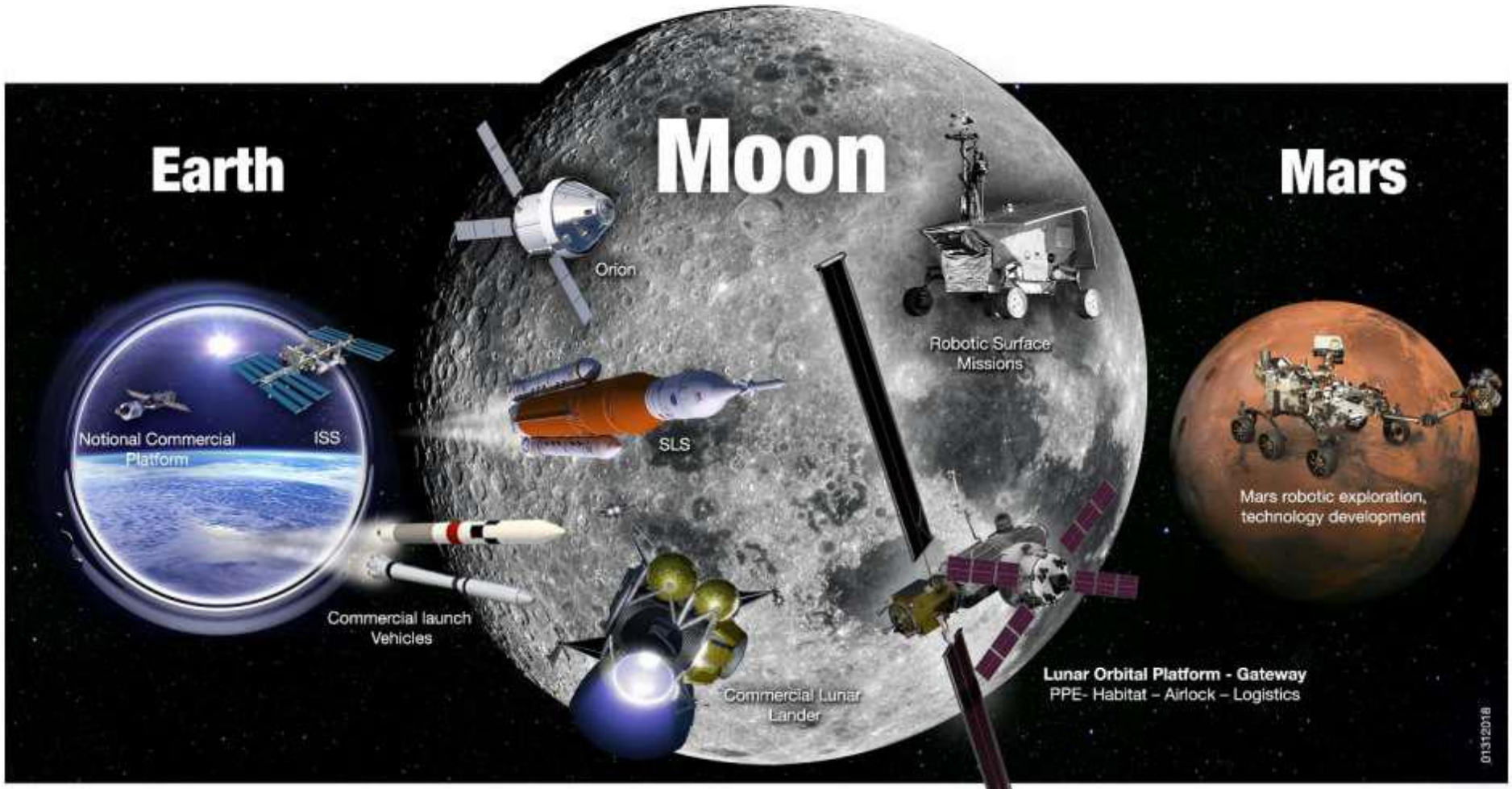
HUMAN HEALTH & PERFORMANCE DIRECTORATE

NASA | JOHNSON SPACE CENTER

Judith Hayes

Chief Science Officer

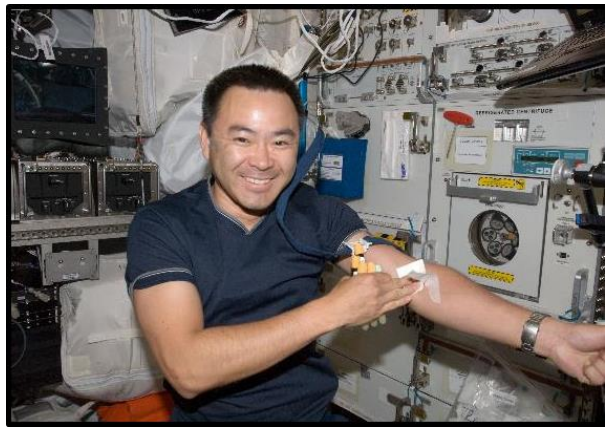
EXPLORATION CAMPAIGN



In LEO
Commercial & International partnerships

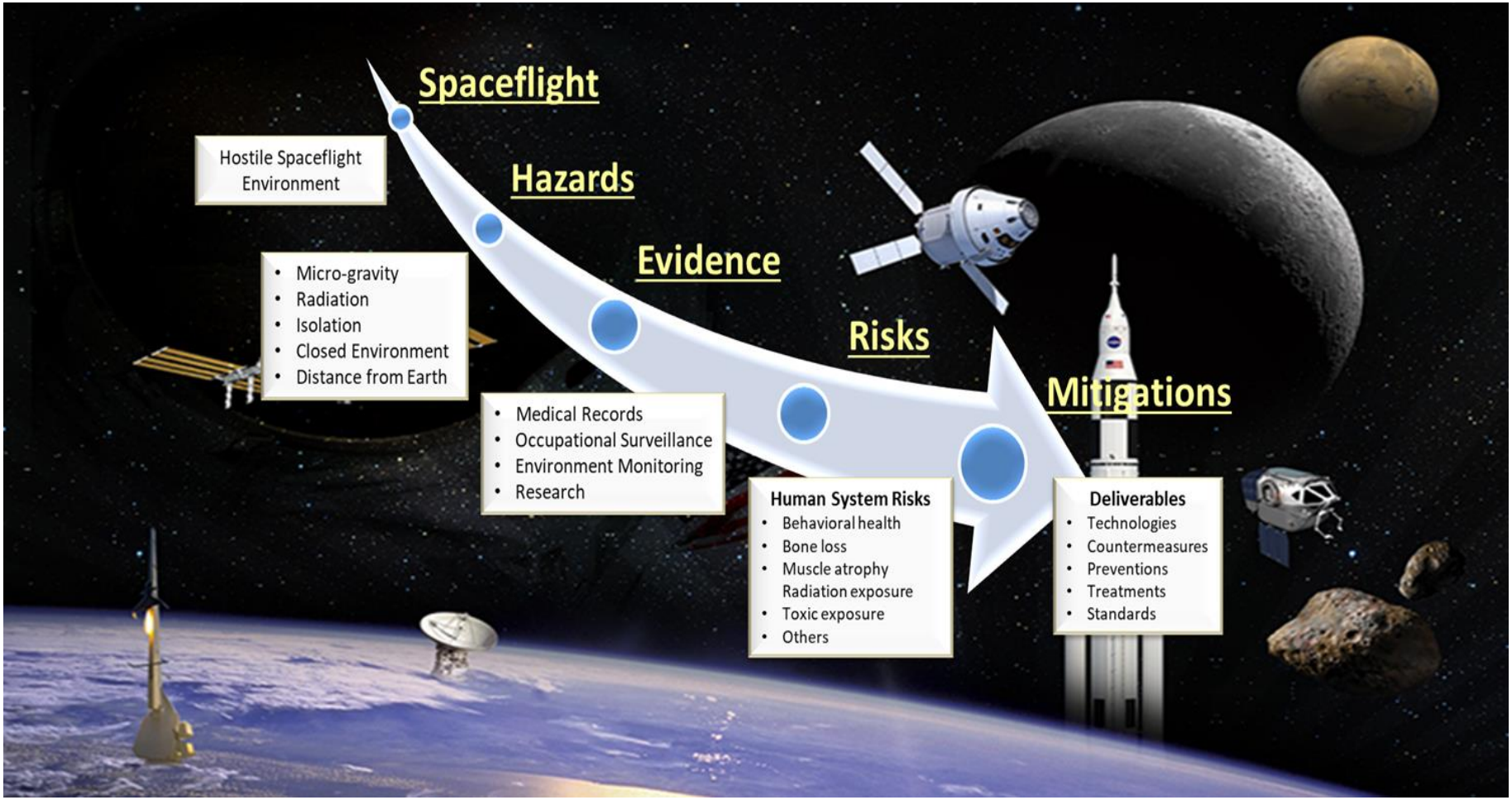
In Cislunar Space
A return to the moon for long-term exploration

On Mars
Research to inform future crewed missions



Human Health & Performance Directorate

Exploring Space | Enhancing Life



GOAL

Enable Successful Space Exploration by Minimizing the Risks of Spaceflight Hazards on Astronauts

Human System Risks of Spaceflight

Grouped by Hazards – 30 Human Risks

Altered Gravity Field

1. Spaceflight-Induced Intracranial Hypertension/Vision Alterations
2. Renal Stone Formation
3. Impaired Control of Spacecraft/Associated Systems and Decreased Mobility Due to Vestibular/Sensorimotor Alterations Associated with Space Flight
4. Bone Fracture due to spaceflight Induced changes to bone
5. Impaired Performance Due to Reduced Muscle Mass, Strength & Endurance
6. Reduced Physical Performance Capabilities Due to Reduced Aerobic Capacity
7. Adverse Health Effects Due to Host-Microorganism Interactions
8. Urinary Retention
9. Orthostatic Intolerance During Re-Exposure to Gravity
10. Cardiac Rhythm Problems
11. Space Adaptation Back Pain

Concerns

1. Clinically Relevant Unpredicted Effects of Meds
2. Intervertebral Disc Damage upon & immediately after re-exposure to Gravity

Radiation

1. Adverse Health Outcomes and Performance Decrements resulting from Space Radiation Exposure(cancer, cardio & CNS)

Distance from Earth

1. Adverse Health Outcomes & Decrements in Performance due to inflight Medical Conditions
2. Ineffective or Toxic Medications due to Long Term Storage

Isolation

1. Adverse Cognitive or Behavioral Conditions & Psychiatric Disorders
2. Performance & Behavioral health Decrements Due to Inadequate Cooperation, Coordination, Communication, & Psychosocial Adaptation within a Team

Hostile/Closed Environment-Spacecraft Design

1. Acute and Chronic Carbon Dioxide Exposure
2. Performance decrement and crew illness due to inadequate food and nutrition
3. Reduced Crew Performance and of Injury Due to Inadequate Human-System Interaction Design (HSID)
4. Injury from Dynamic Loads
5. Injury and Compromised Performance due to EVA Operations
6. Adverse Health & Performance Effects of Celestial Dust Exposure
7. Adverse Health Event Due to Altered Immune Response
8. Reduced Crew Health and Performance Due to Hypobaric Hypoxia
9. Performance Decrements & Adverse Health Outcomes Resulting from Sleep Loss, Circadian Desynchronization, & Work Overload
10. Decompression Sickness
11. Toxic Exposure
12. Hearing Loss Related to Spaceflight
13. Injury from Sunlight Exposure
14. Crew Health Due to Electrical Shock

HUMAN SYSTEM RISKS OF SPACEFLIGHT

GROUPED BY HAZARDS – 30 HUMAN RISKS

Human System Risk Board* June 2022		In Mission Risk - Operations							
		Low Earth Orbit		Lunar Orbital		Lunar Orbital + Surface		Mars	
Primary Spaceflight Hazard	Human Spaceflight Risks	< 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	Food and Nutrition Risk								
	Human System Integration Architecture Risk								
	Medical Conditions Risk								
	Ineffective or Toxic Medication (Pharm) Risk								
Altered Gravity	Bone Fracture Risk								
	Cardiovascular Risk								
	Crew Egress Risk								
	Renal Stone Risk								
	Spaceflight Associated Neuro-ocular Syndrome Risk								
	Sensorimotor Risk								
	Muscle Size, Strength and Performance Risk								
	Aerobic Capacity Risk								
	Urinary Retention Risk								
	Venous Thromboembolism (VTE) Concern								
Hostile Closed Environment	Dynamic Loads Risk								
	EVA Injury Risk								
	CO_2 Risk								
	Decompression Sickness Risk								
	Electrical Shock Risk								
	Hearing Loss Risk								
	Immune Risk								
	Microhost Risk								
	Sleep Loss Risk								
	Toxic Exposure Risk								
Isolation and Confinement	Behavioral Med. Risk								
	Team Risk								
Radiation	Non-Ionizing Radiation Risk								
		Post Mission Risk - Long Term Health							
Radiation	Carcinogenesis Risk								
Hostile Closed Environment	Celestial Dust Risk								
	Hypoxia Risk								

Physiological & Behavioral Manifestations Associated with Space Flight

Collective Knowledge

Bone

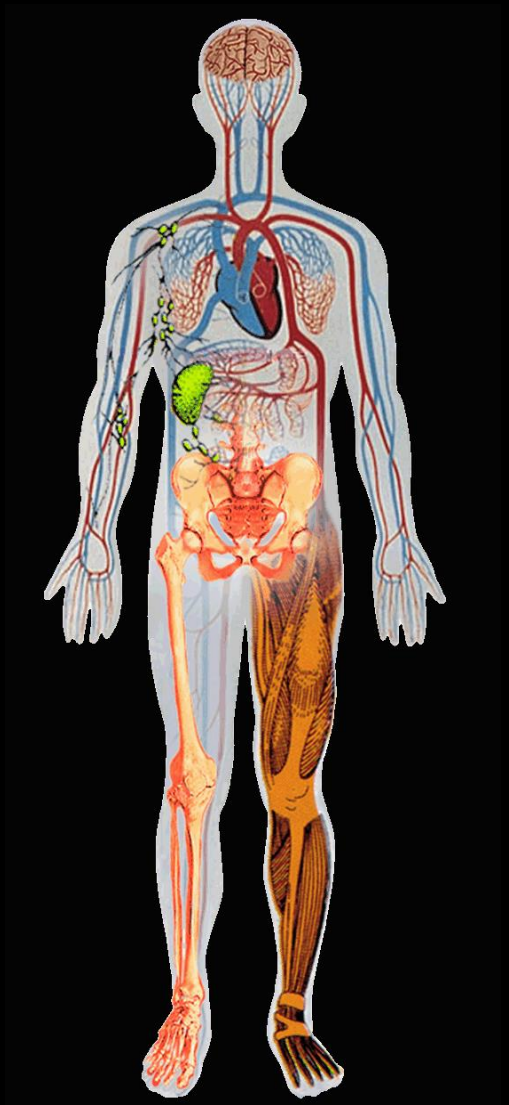
- ↓ Bone mineral content
- ↓ Bone mineral density
- ↑ Urinary calcium
- ↑ Renal stone risk

Skeletal Muscle

- ↓ Skeletal muscle mass
- ↓ Skeletal muscle strength
- ↓ Skeletal muscle endurance
- ↓ Skeletal muscle capillary density

Neurosensory

- ↑ Vestibular disturbances
- ↑ Space motion sickness
- ↓ Sensorimotor function
- ↓ Postural & locomotor stability



Cardiovascular

- ↓ Fluid volume
- ↓ Orthostatic tolerance
- ↓ Aerobic capacity
- ↑ Intracranial Pressure
- ↑ Spaceflight Associated Neuro-Ocular Syndrome (SANS)
- ↔ Dysrhythmias

Psychosocial

- ↑ Team issues
- ↑ Confinement issues
- ↑ Fatigue
- ↑ Stress
- ↑ Errors
- ↓ Cognitive Function

Environmental

- ↑ Hearing loss due to acoustics
- ↑ Radiation exposure
- ↑ Risk of cataracts/cancers
- ↑ Skin irritations due to microbial growths

History of Space Exercise

Gemini
- Isometrics
- Bungee exercise

Apollo
- Rope-pull system

Skylab II
- Cycle ergometer

Skylab III
- Cycle ergometer
- MKI isokinetic rope-pull
- MKII handle/spring assembly

Skylab IV
- Cycle ergometer
- MKI isokinetic rope-pull
- MKII handle/spring assembly
- Treadmill

Shuttle
- Cycle ergometer
- Rower
- Treadmill (Teflon)

Soyuz-Salyut & Mir
- Velo Ergometer
- Penguin Suit
- Treadmill
- Resistance Exercise (Expanders)

International Space Station
- **US**
  - Cycle Ergometer (CEVIS)
  - Treadmill (TVIS, T2)
  - Resistance Exercise (iRED, ARED)
- **Russian**
  - Velo Ergometer
  - Penguin Suit
  - Treadmill (BD-1, BD-2)
  - Resistance Exercise (Expanders)

GOALS

Minimize the deconditioning effects associated with space flight

Optimize in-flight performance

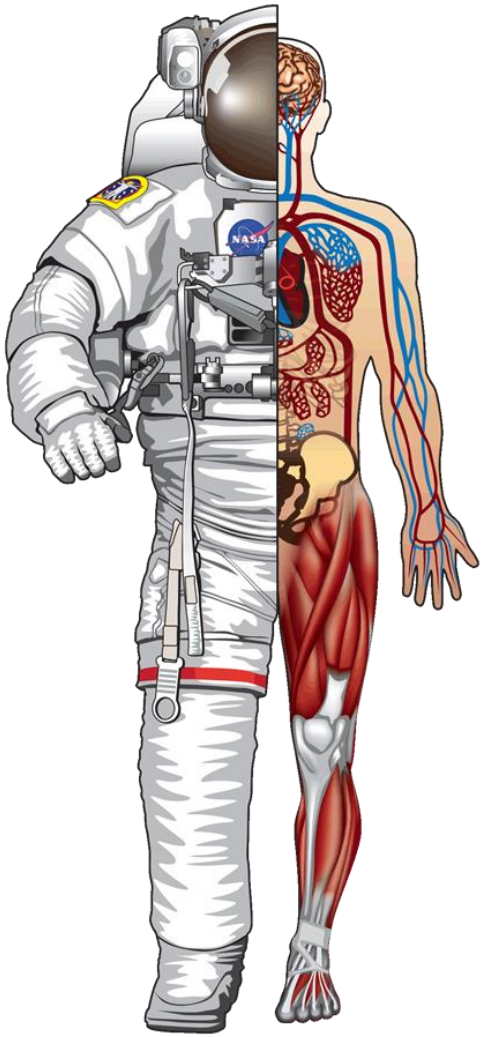
- Physiological
  - Skeletal Muscle conditioning
    - strength, endurance, flexibility
  - Aerobic/anerobic fitness
- Behavioral Health

Prepare for EVA

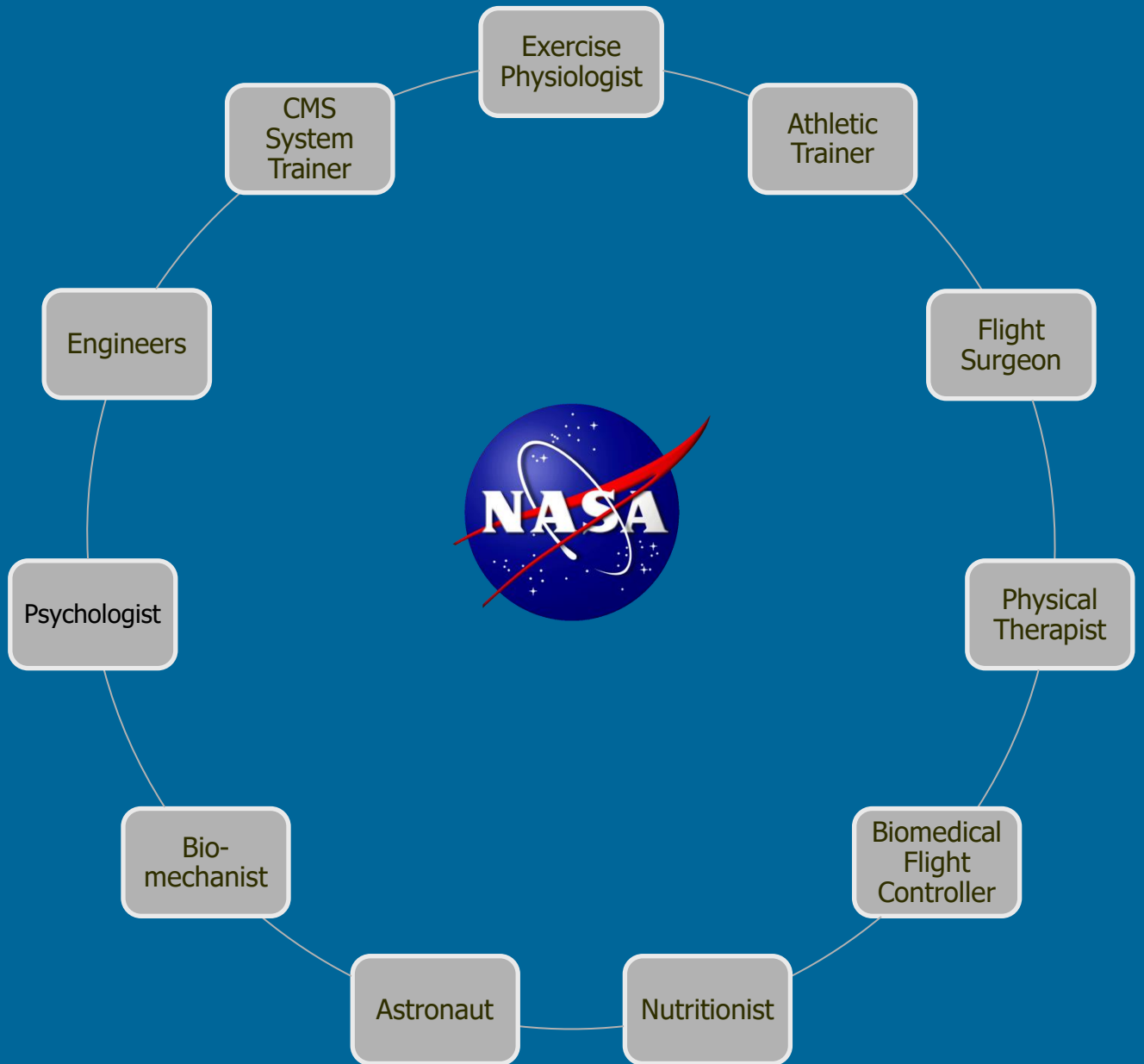
- Microgravity
- Planetary operations

Prepare for rapid egress

Promote optimal rate of recovery



Space Flight is a Team Sport

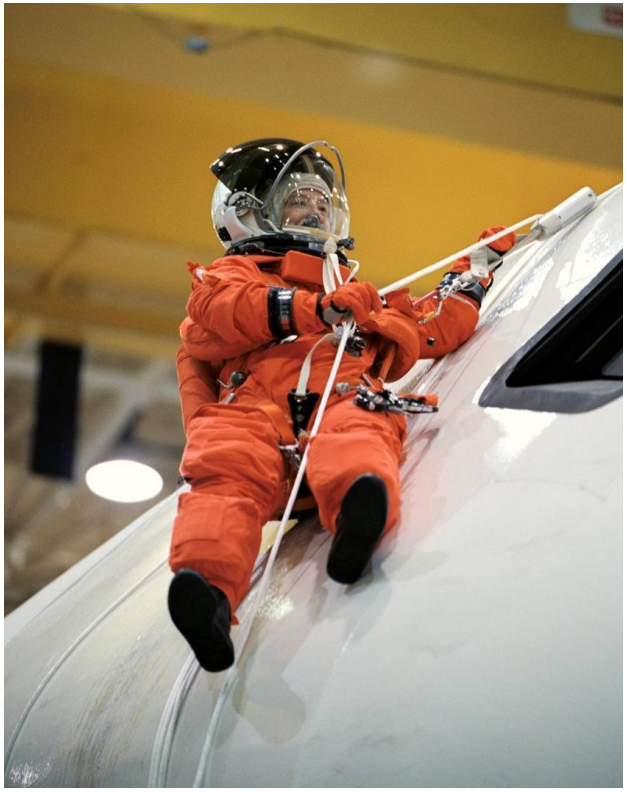


Going to Work in Space

EVA

- Inflight
- Planetary Operations

Emergency Egress



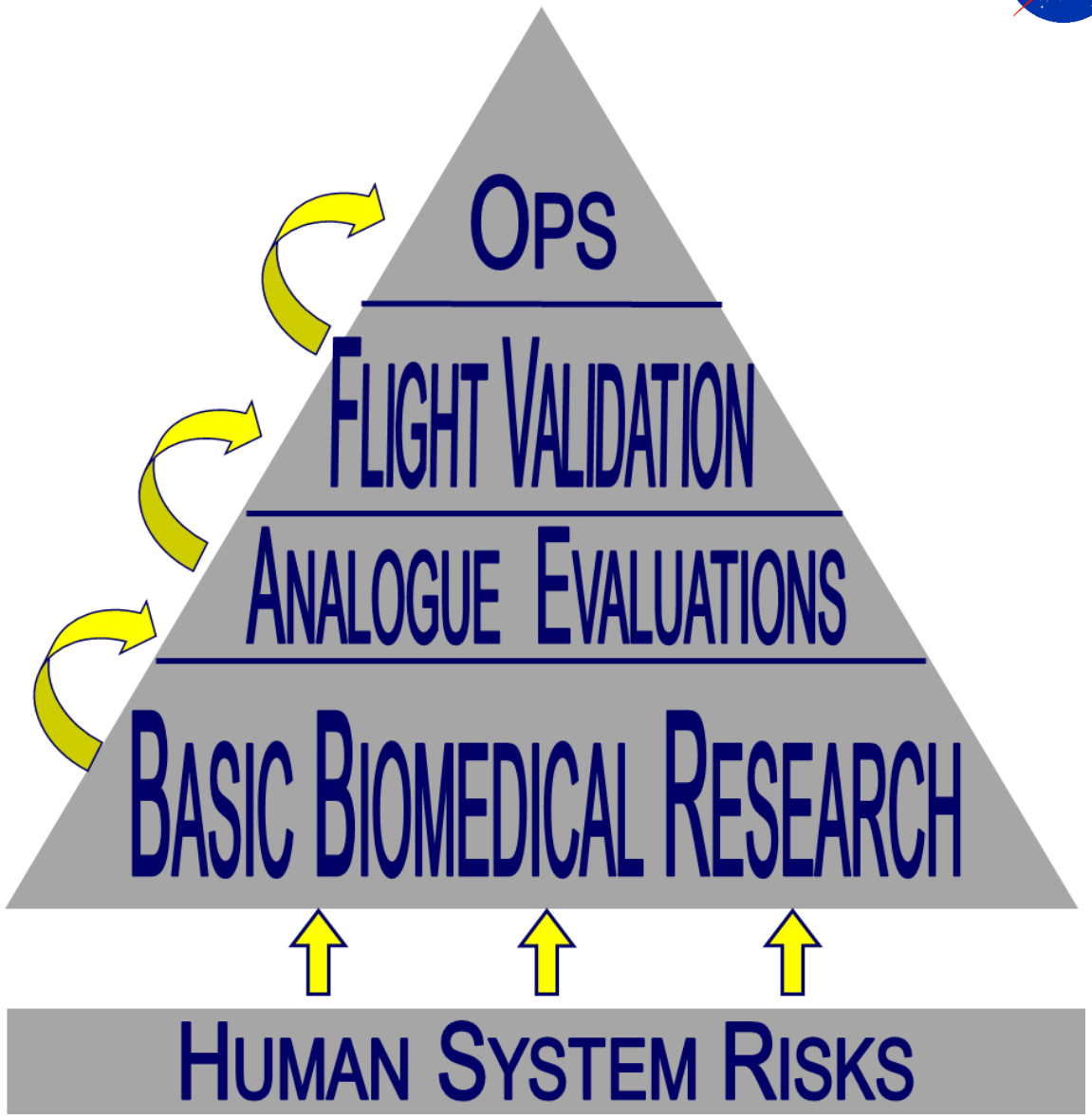
Space Shuttle Landing

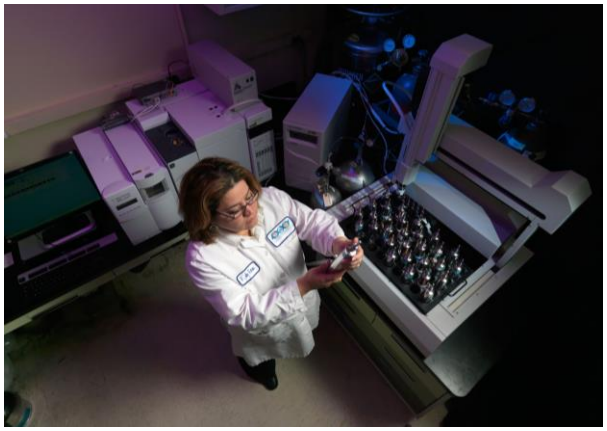
- Piloting
- Breaking

Soyuz Landing

SpaceX Landing

Transition to Operations





Operations

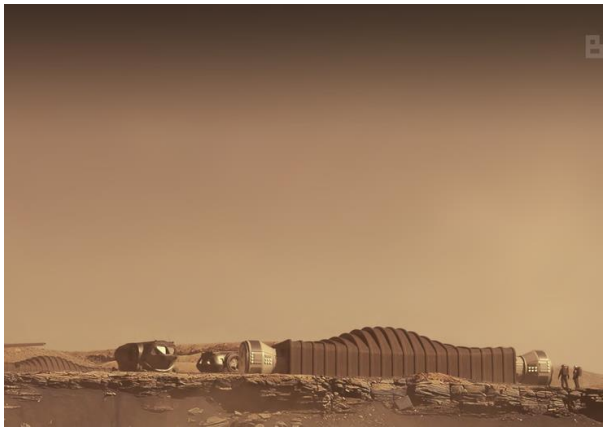
Protecting astronaut health & performance from 5 key hazards of spaceflight

Exploring Space | Enhancing Life

Applied Research

Human adaptation to spaceflight & planetary environments

Exploring Space | Enhancing Life

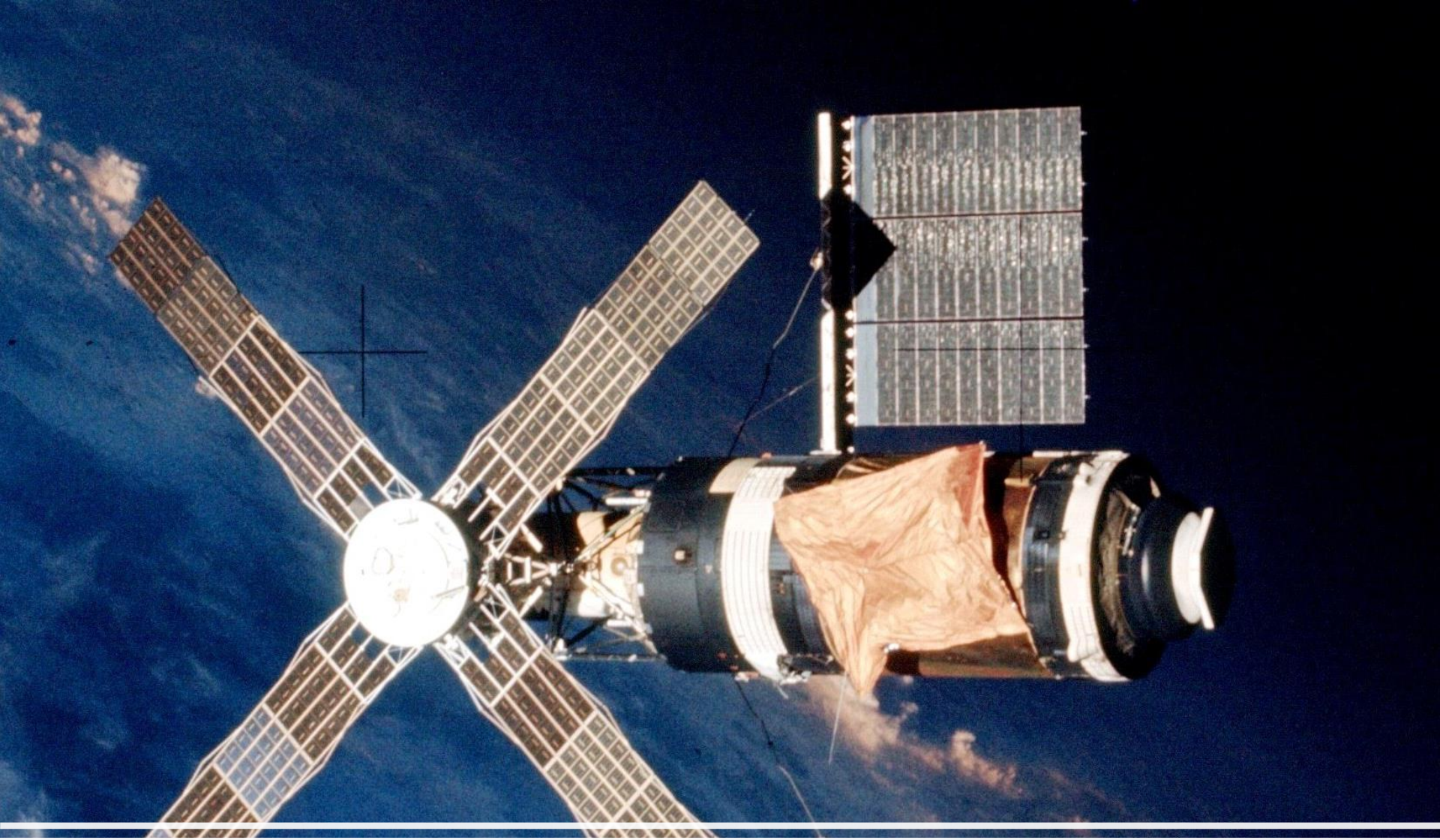


SPACEFLIGHT CHAMBER ANALOGS

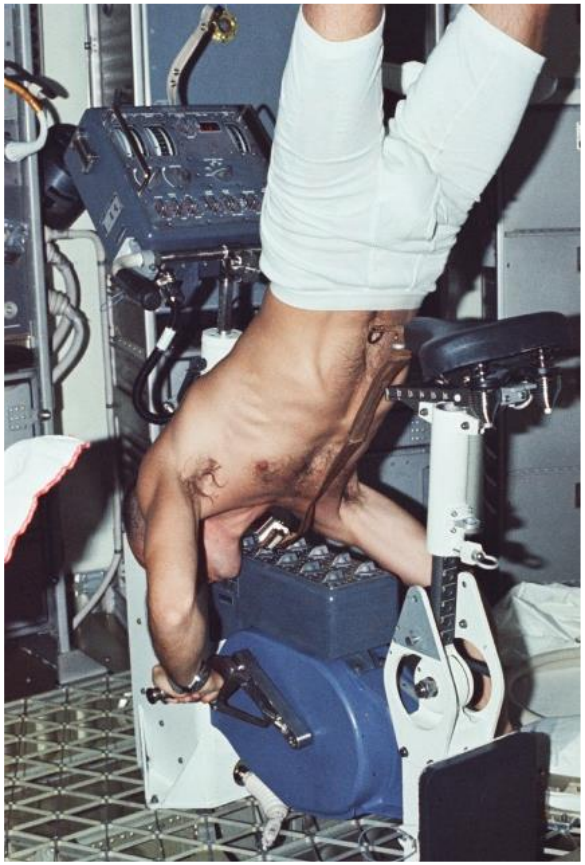
Exploring Space | Enhancing Life

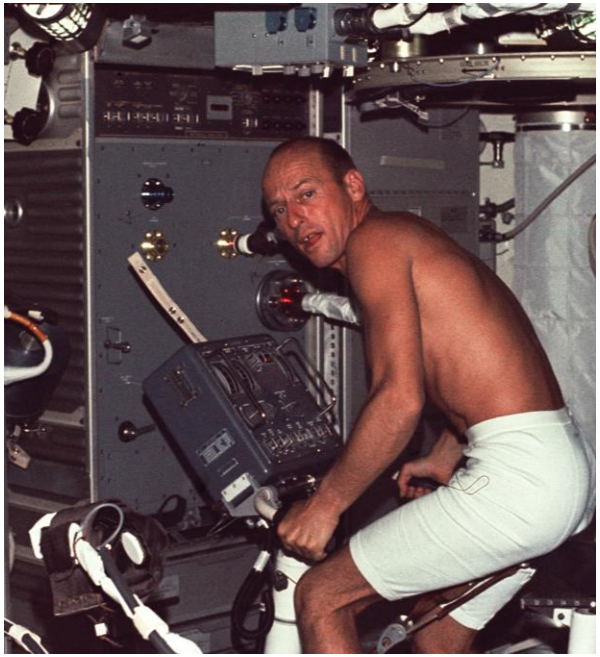

APOLLO
NASA

Exer-Genie

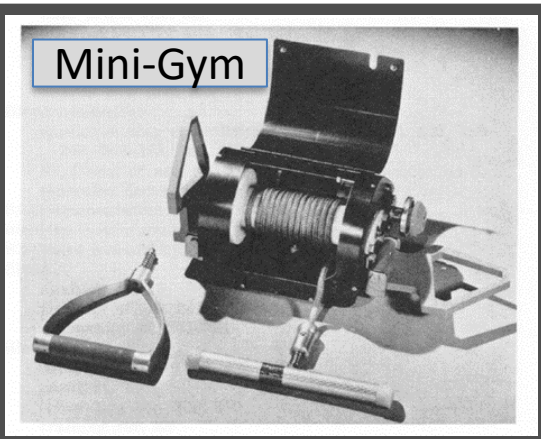


Skylab

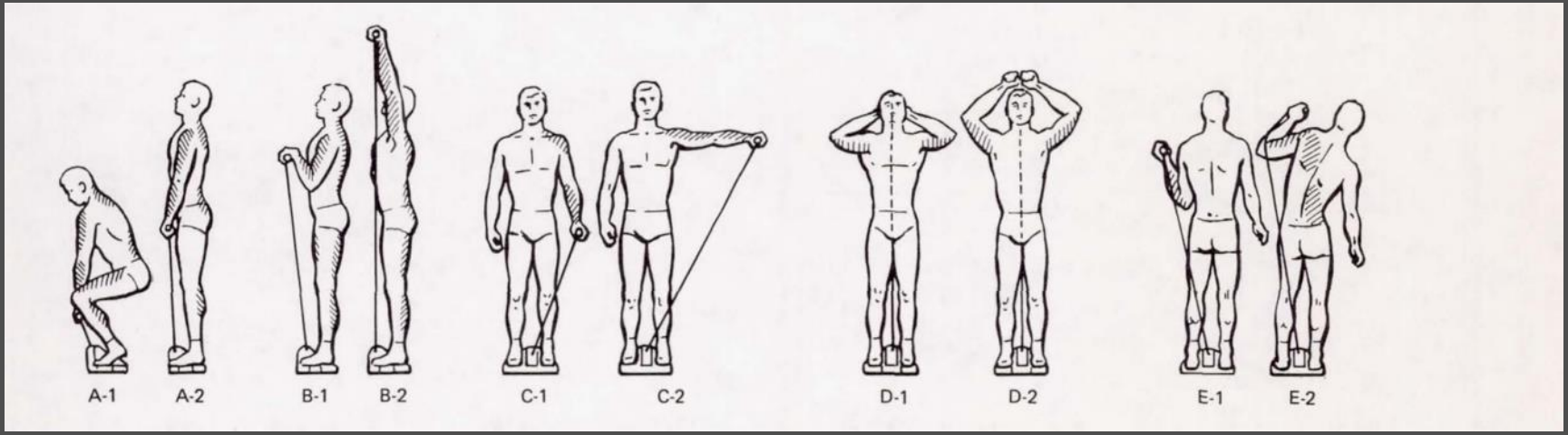




Skylab II



Skylab III



Skylab IV

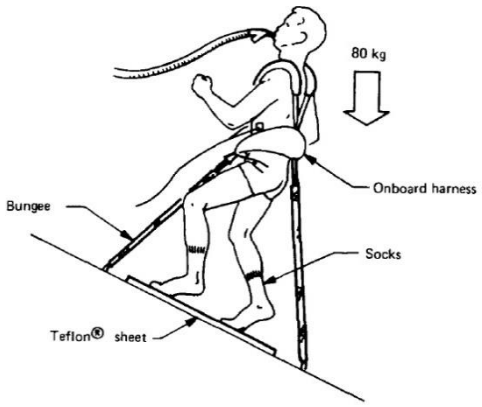


FIGURE 21–7.—Treadmill arrangement.


08:02:48

[1] Bicycle ergometer.
[2] Bicycle ergometer, MK-I and MK-II exercisers.
[3] Bicycle ergometer, MK-I and MK-II exercisers, treadmill.

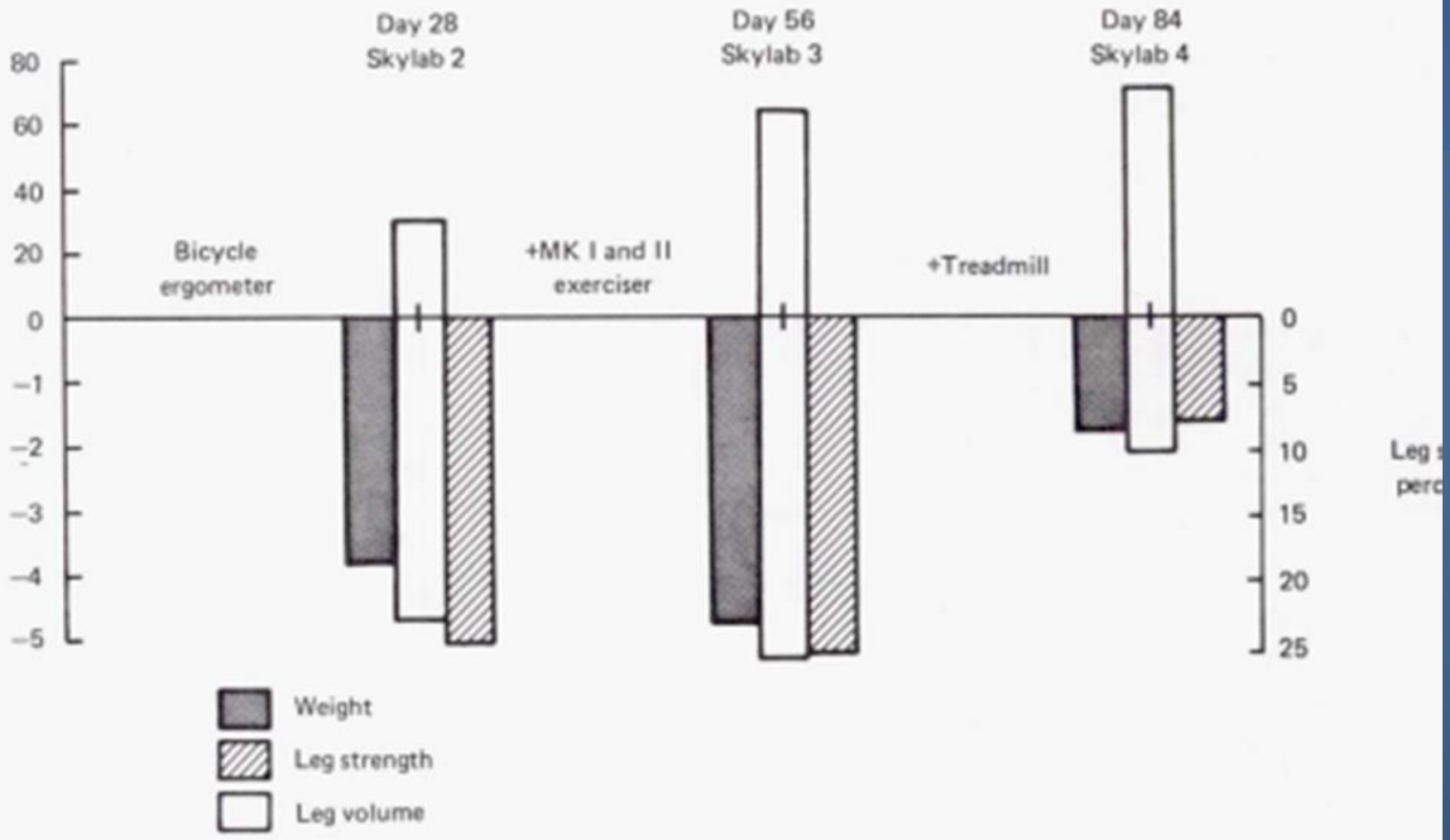


FIGURE 21–11.—Exercise related quantities on Skylab missions.

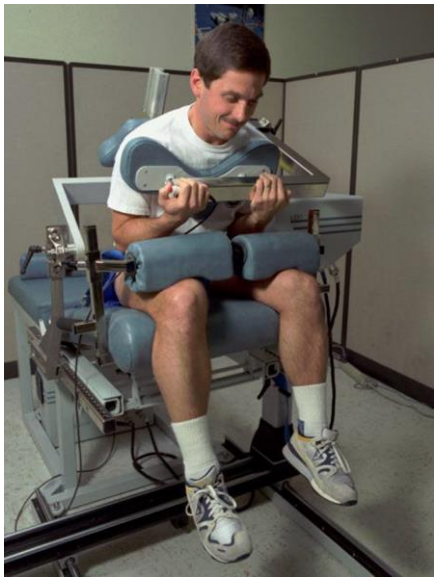
Space Shuttle

Space Shuttle Exercise

Inter-Limb Rope-Pulley
Free Floating Exercise

Postflight Egress Test

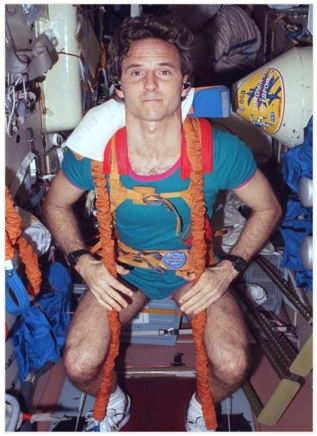
NASA-Mir



Pre/Post Flight
Clinical Assessments

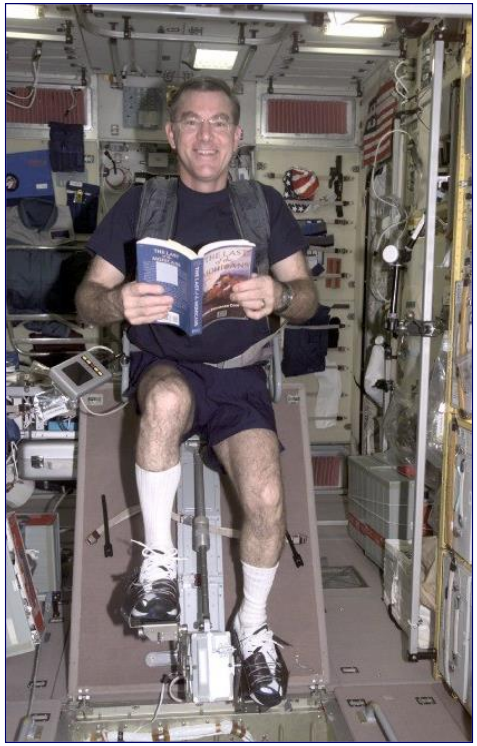
Russian Countermeasures

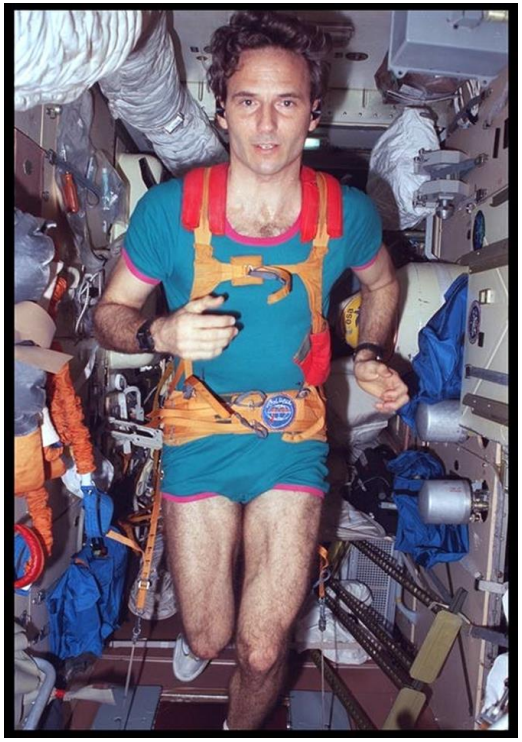
Expanders (Эспандеры)



BD-2 (БД-2) Treadmill

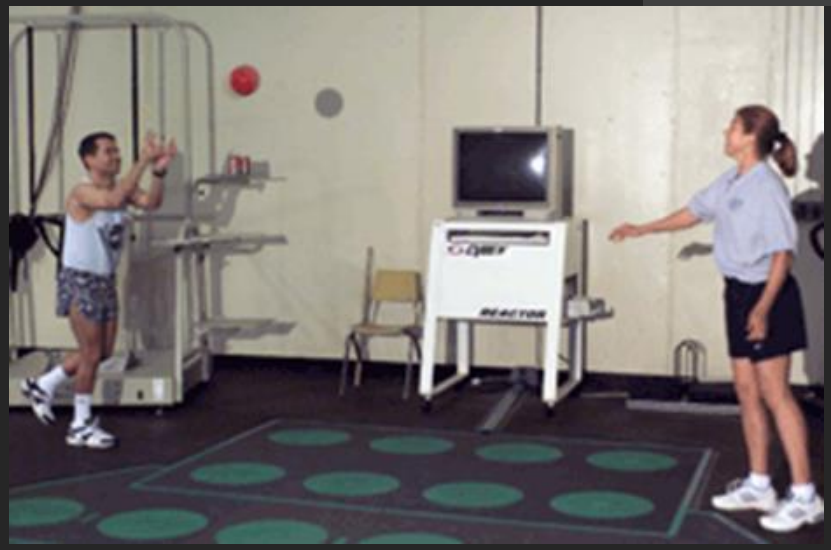
Velo Ergometer (Велотренажер)



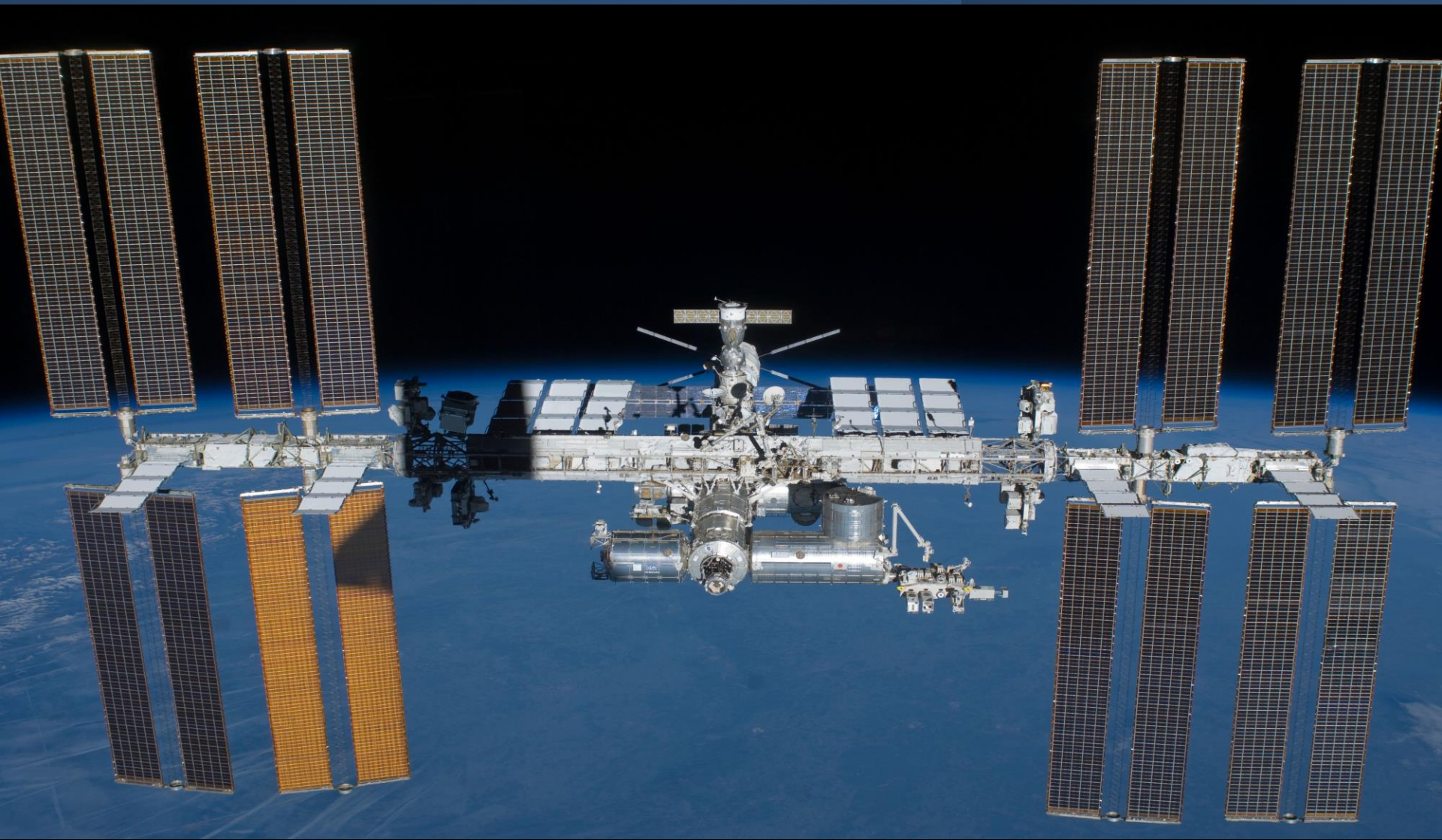


Russian Penguin Suit

Re-Conditioning



International Space Station



ISS Exercise Countermeasure System (CMS)

Resistance Exercise

Muscle Strength & Endurance

Axial & Joint loading

Neurosensory Stimulus

Isometric Testing

Treadmill

Ambulation

Aerobic/Anaerobic Endurance

Skeletal loading

Heel impact

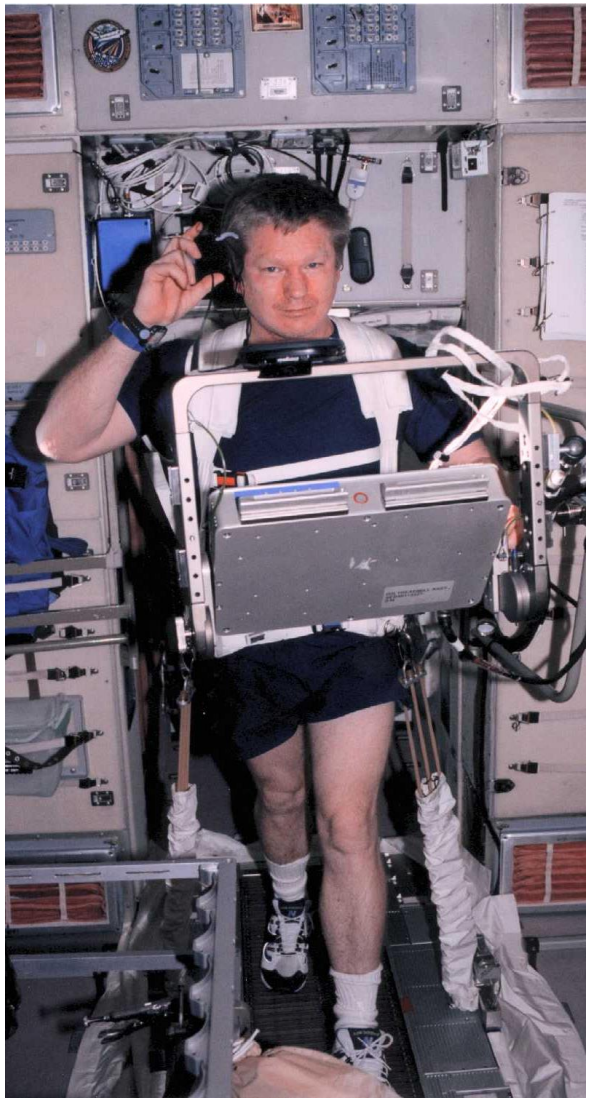
Sensorimotor Stimulus

Cycle Ergometer

Aerobic/Anaerobic Endurance

Fitness Testing

This integrated system supports exercise prescriptions to optimize crew health and performance with **complimentary capabilities** and **limited redundancy** between the modalities.



Treadmill (TVIS)

Treadmill with Vibration Isolation System

Treadmill (T2)

Cycle Ergometer (CEVIS)

Cycle Ergometer with Vibration Isolation System

iRED

Interim Resistive Exercise Device

aRED

Advanced Resistive Exercise Device

Pre-EVA

Training Tools

Nominal In-flight Exercise Plan

2.5 hrs/d; 6 d/wk

Treadmill

- Intensity: 60% to 90% HR_{max}(continuous and interval training); 60-90% BW load; 3-12.3 MPH
- Duration: 30 min
- Frequency: 2 to 6x/wk; ↑ frequency the last month of flight

Cycle

- Intensity: 60% to 90% HR_{max} (continuous and interval training)
- Duration: 30 min
- Frequency: 2 to 4 x/wk

Resistive Exercise

- Intensity: Varies per crewmember and exercise
- Frequency: 5 to 6x/wk upper, lower and core body exercise

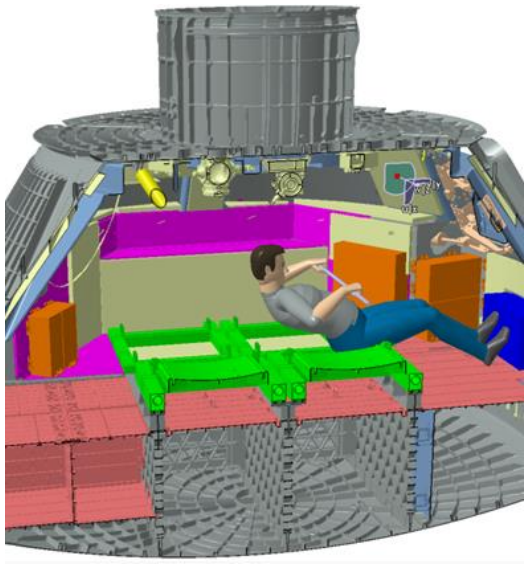
Summary of ISS Outcomes

- All responses are subject to individual variability
- Aerobic capacity dips the first month of flight but recovers
- Skeletal muscle performance trending upward with higher loads
- Bone protection is improving as CM assets and use strategies have matured
  - Requires multiple assets and high intensity prescriptions
    - ARED high intensity loads
    - High intensity interval training improves outcomes
    - Bisphosphonates coupled with exercise
    - Running intervals at higher speeds & improved impact loading on T2

What's next?

Artemis

Orion



Artemis

Exercise in Transit on Orion

Next Steps

- Autonomous Operations
  - Inflight countermeasures using virtual coaching to assure readiness for In-Transit & Terrestrial EVA operations
  - Remote planetary rehabilitation and recovery
- Optimization of vehicles and space suits
  - Supporting human systems on long and variable gravity missions

We are still seeking advanced countermeasure concepts!

DESIGN REQUIREMENTS:

small footprint, low power, resistive & aerobic, autonomous…*highly effective*

WE WILL PUMP YOU UP!
ISS EXPEDITION 21