

National Aeronautics and
Space Administration



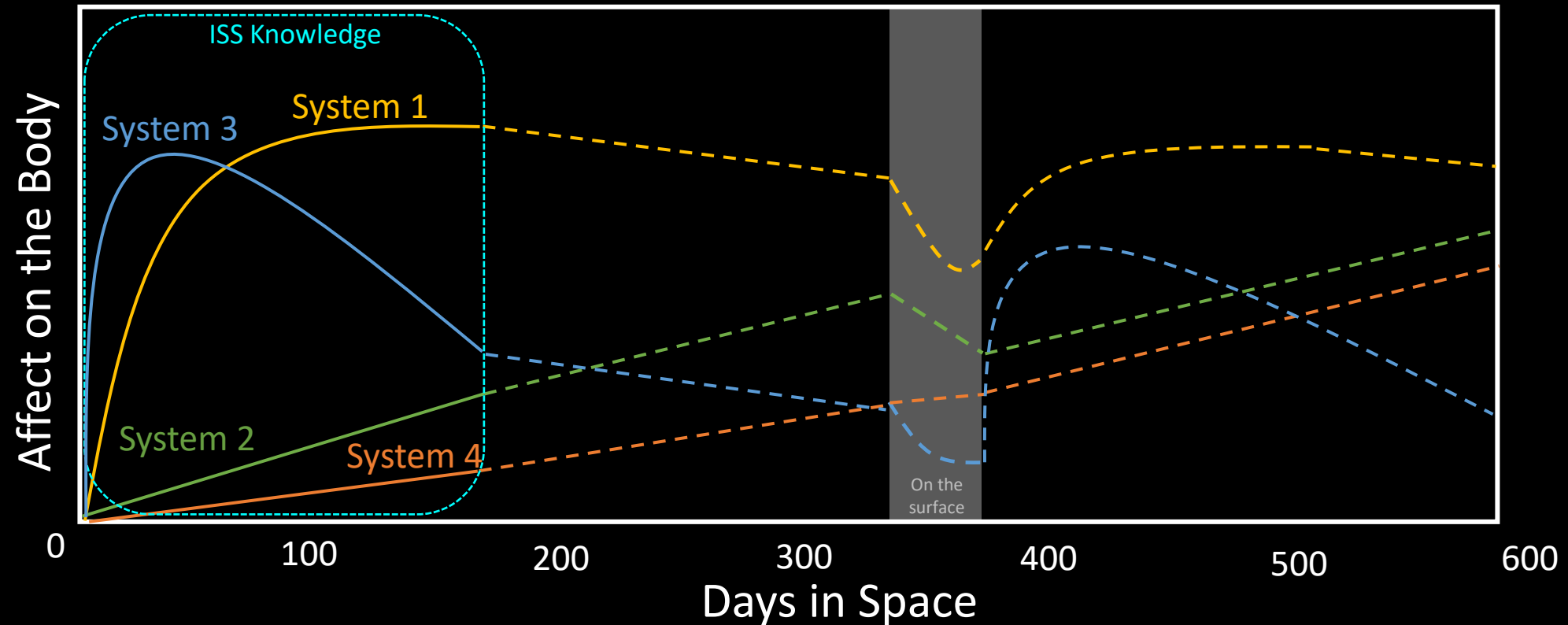
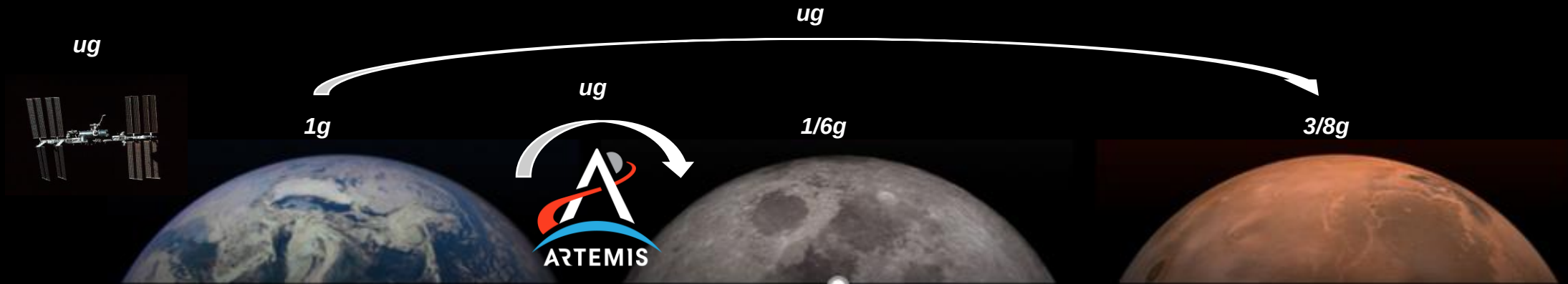
EXPLORE MOON_{to}MARS

Biology Beyond Low Earth Orbit, ASGSR
Microgravity and Partial Gravity Environments
November 9, 2022, Houston, Tx

Becky Brocato, Ph.D.
Human Health Countermeasures
Human Research Program



Notional Physiology to Varied Gravity





Human Health Countermeasures

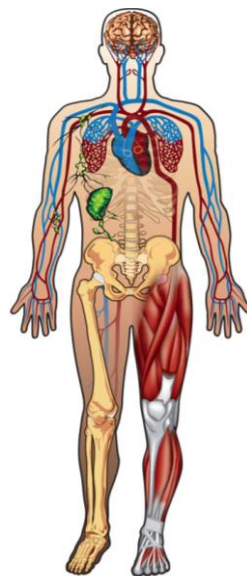


Cardiovascular and Vision

Cardiovascular:
OI, Dysrhythmia, CVD



SANS



Multi-System

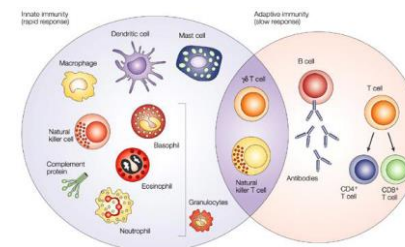
Microhost



Food and Nutrition



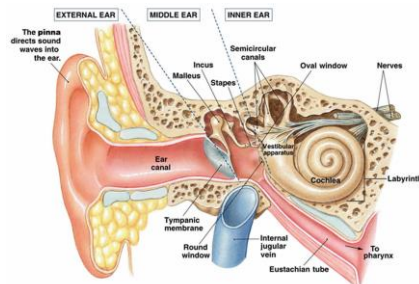
Immune



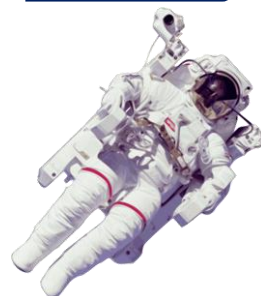
Nature Reviews | Cancer

Exercise and Performance

Sensorimotor



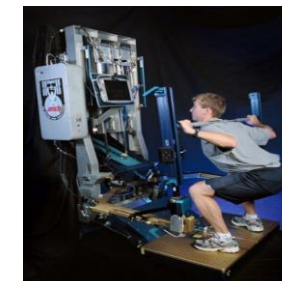
Surface EVA



Bone: Fracture,
Osteoporosis, IVD



Exercise: Muscle, Aerobic



Cardiovascular

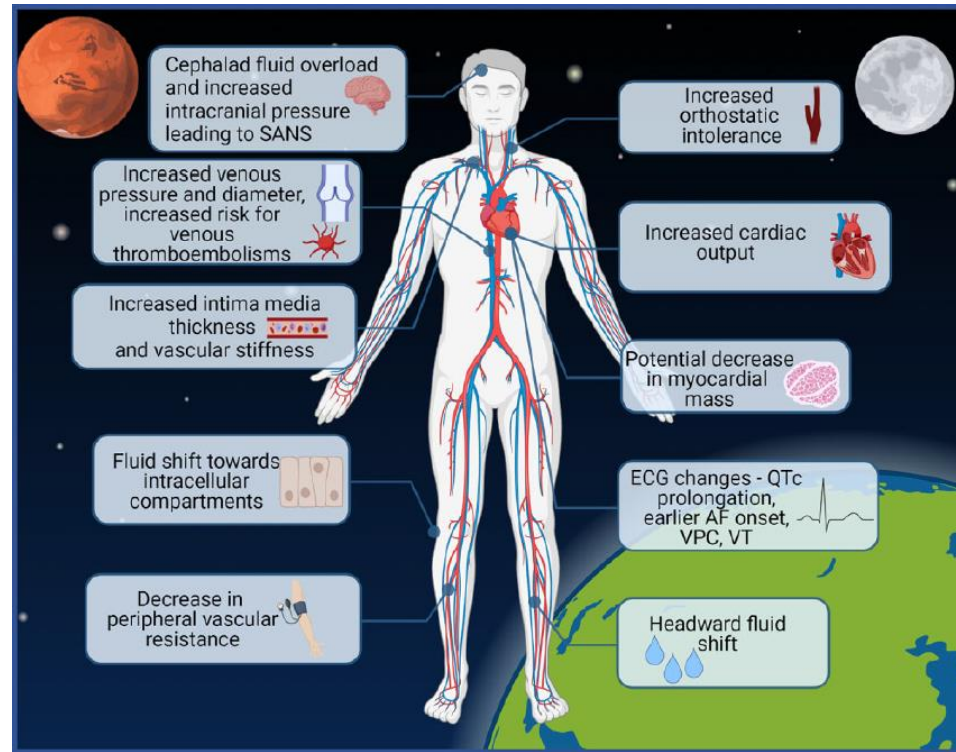


Orthostatic Intolerance

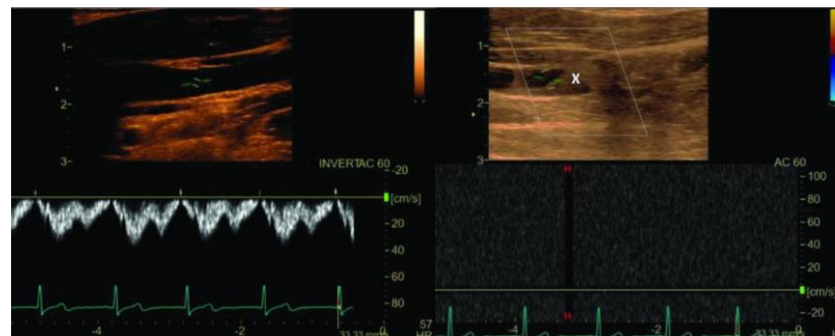
- 20-25% short duration flyers
- 60% long duration flyers
- Likelihood greater in women than men
- Countermeasures:
 - In-flight exercise
 - Recumbent posture
 - Fluid loading
 - Whole body cooling
 - Compression garments

Dysrhythmia

- No clear evidence that spaceflight is associated with increased frequency or complexity of cardiac dysrhythmias
 - Individuals with dysrhythmias prior
 - Not clinically significant



Jirak, et al. 2022, Eur J Prev Cardiol



Marshall-Goebel, et al. 2019, JAMA Netw Open

Cardiovascular Disease

- No epidemiological evidence that spaceflight increases risk of CVD mortality
- Biomarkers of oxidative stress/inflammation are elevated in spaceflight
- Continued monitoring of acute and long-term health
- No long-term health data from long duration crewmembers

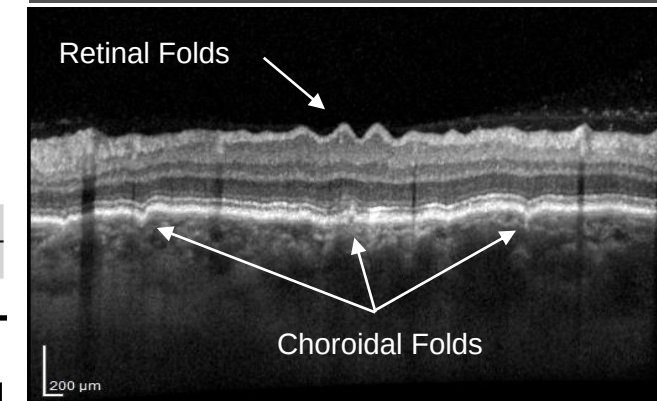
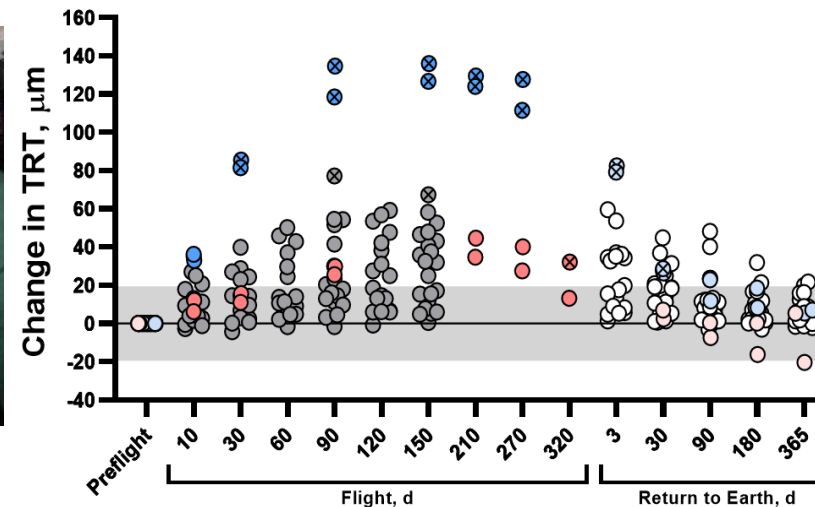
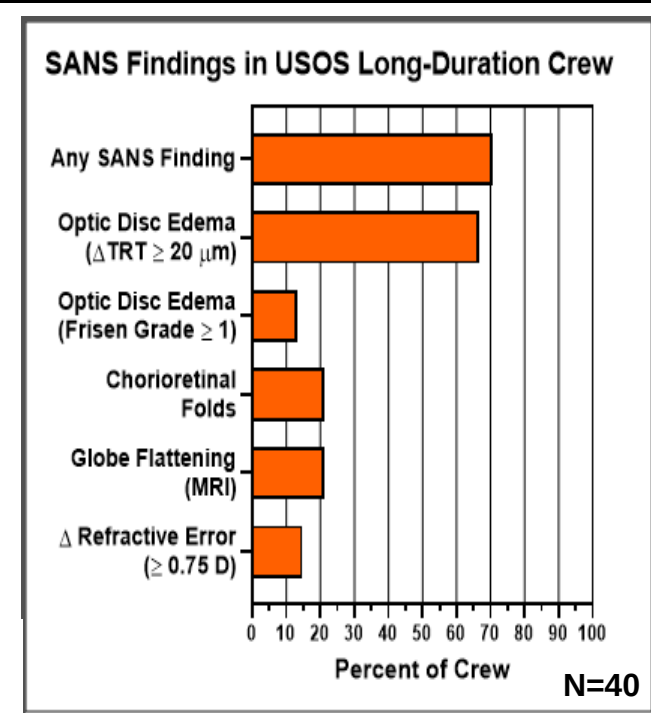
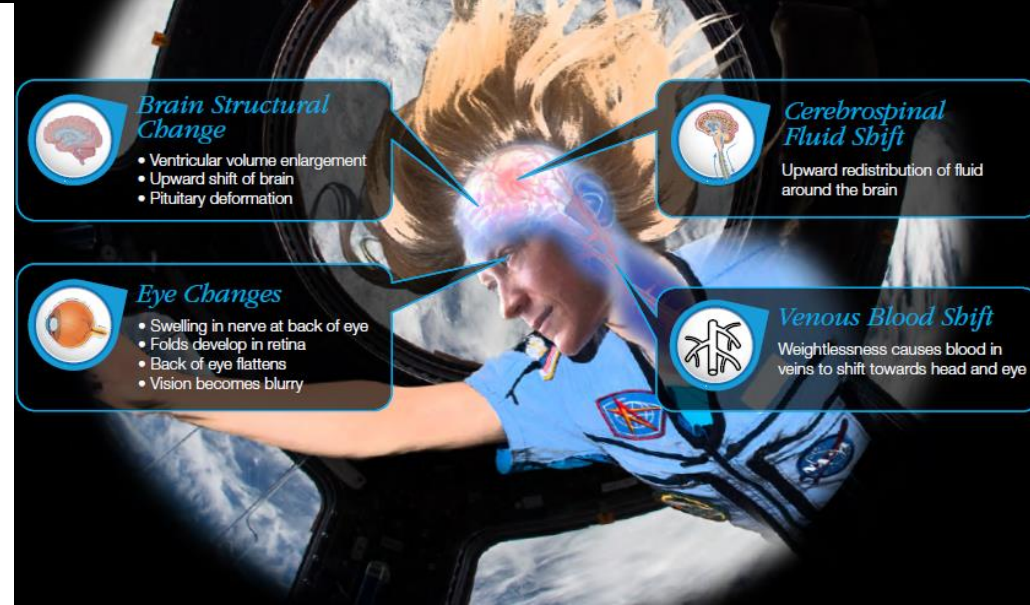
Venous Thromboembolism

- Occlusive IJV thrombus discovered in-flight, a second partial IJV thrombus discovered retroactively
- Hypotheses:
 - Stagnant and retrograde blood flow in IJV

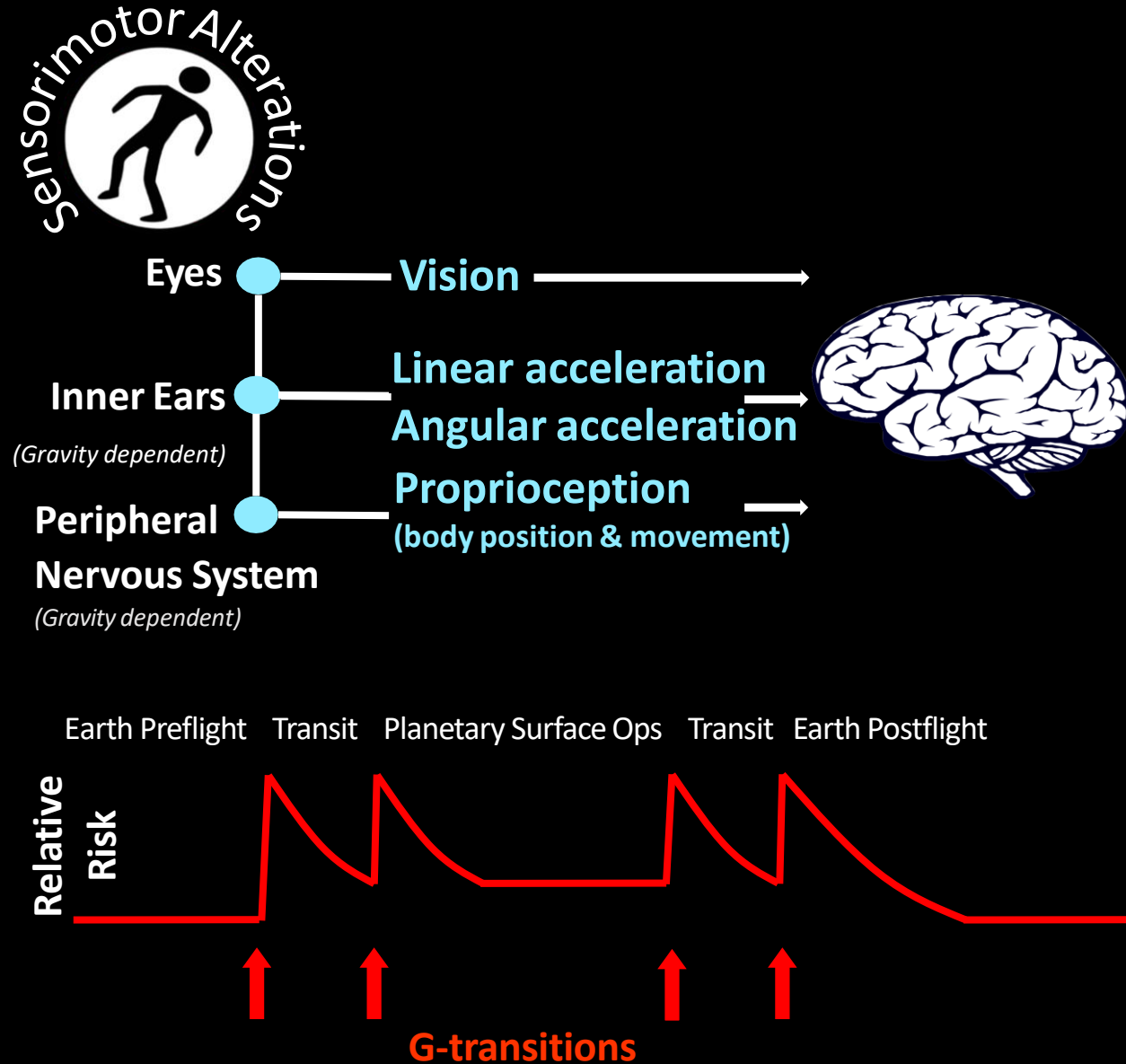
SANS (Spaceflight associated neuro-ocular syndrome)

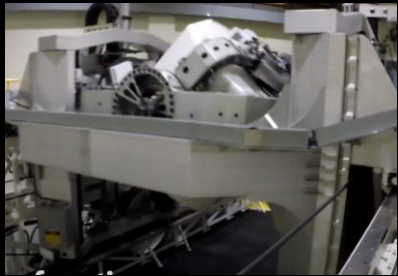


- Ocular and brain changes associated with spaceflight
- 70% of long duration astronauts show one or more signs of SANS
- CMs & CM Research
 - Corrected lenses, in use
 - LBNP, Thigh Cuffs, Vitamin Supplementation research
- Characterization Research
 - Long duration spaceflight
 - Brain structural changes
 - Long-term health



Sensorimotor



Task	Characterization	Countermeasure
 Manual Control	 Lunar Landing Sim Using 6 DOF	 Just-in-Time Training
 First EVA	 Landing Field Assessment	 Sensorimotor Assessments
 Egress	 Kraken Training	 INSCOP & Sensory Aids

Bone Fracture



Bone Strength: fracture risk



Bone Density

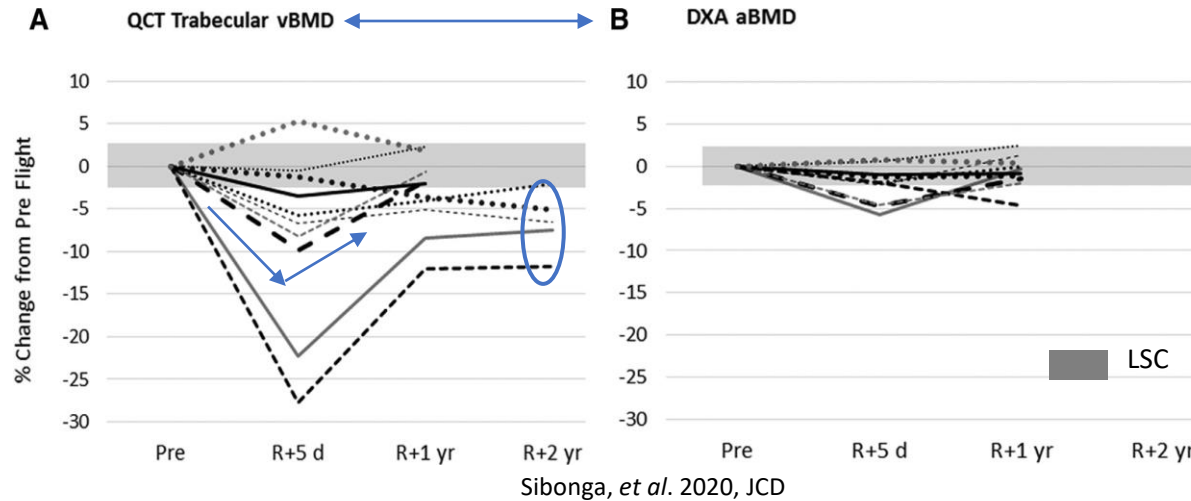
aBMD: DXA
vBMD: QCT



Bone Quality

Turnover: NTX, CTX, BSAP
Microarchitecture
Mineralization
Microdamage
Chemical Composition
Material Properties
Structure/Geometry

Bone Strength is more complex than Density alone



↔ Magnitude of change from QCT to DXA

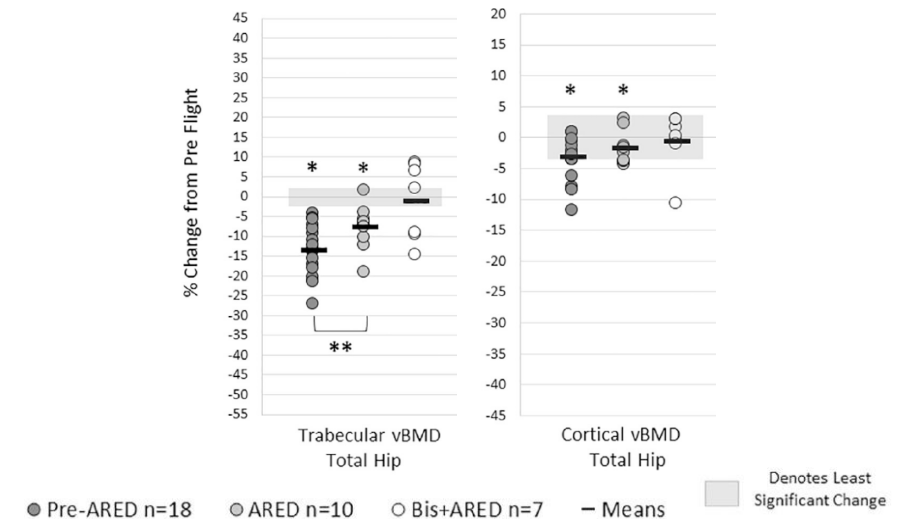
↘ Rate of bone loss and gain

○ Lack of recovery @ R+2yr

Monitoring

- Imaging Modalities
 - Pre/post-flight
 - Inflight?
- Biochemical Assays
 - Decoupling of resorption and formation markers
 - Not skeletal site-specific

Countermeasures



Sibonga, et al. 2019, Bone

Strategy Objectives:

1. Characterize EVA performance and preparedness shortly post-landing on a planetary surface.

Egress risk: combination of sensorimotor, orthostatic intolerance, muscle, aerobic, dynamic loads, and HSIA (CM examples: motion sickness medication, compression garments)

2. Characterize surface EVA performance during exploration missions in partial gravity environments.

CMs to decrements for increased planetary EVA candence (i.e. exercise, nutrition)

3. Characterize impacts of variable pressure exploration suits on EVA performance, including various exploration atmospheres and prebreathe strategies.

Decompression sickness risk: development of prebreathe protocols and DCS models to minimize prebreathe times and estimate risk of DCS (CM example: dive computer)



Muscle/Aerobic



ISS Exercise Prescription

Exercise prescription is the reference for maintaining health and fitness

- Muscle strength
- Aerobic capacity
- Cardiovascular
- Bone
- Immune
- Cognition, Sleep, and Behavioral Health
- Sensorimotor

Challenges for Exploration Missions

- Mission duration
- Available exercise equipment on exploration vehicles
- Crew time devoted to exercise
- Optimize exercise prescription



Current ISS Exercise Devices

ARED



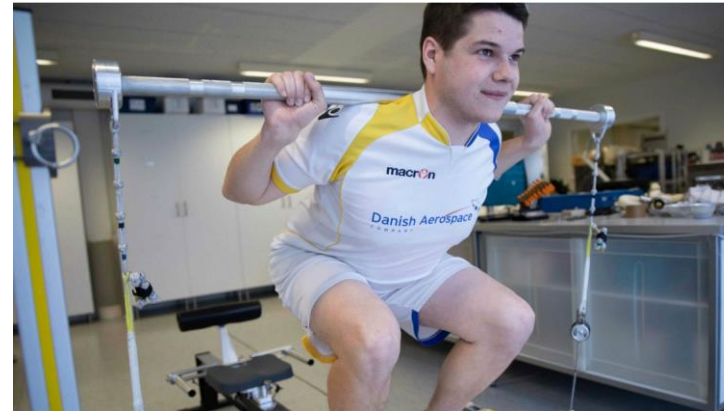
CEVIS



T2



Exploration Exercise



Flywheel



Immune



Spaceflight Immune Dysregulation

- Peripheral leukocyte distribution is relatively normal
- T cell function is reduced, shift in activation threshold
- NK cells disarmed, reduced lytic content
- B cell function unaltered
- Plasma cytokine concentrations are altered
- Reactivation of latent herpesviruses, biomarker of reduced immunity
- Elevated stress hormones and dysregulated circadian rhythms
- Astronauts have some degree of clinical incidence
 - Dermatitis, may have viral etiology
 - Allergy
 - Infections
- Some crew experience persistent symptoms requiring prolonged management

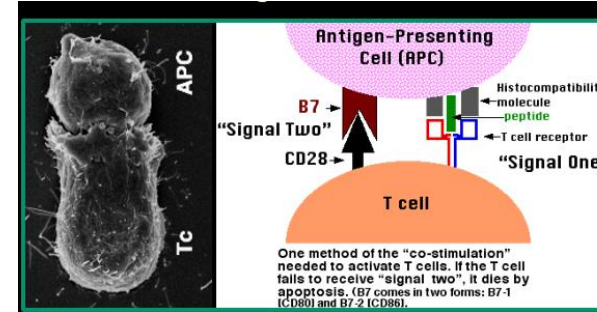
Immune Monitoring

- Virus PCR
- Virus Serology
- WBC/Differential
- Soluble Measures

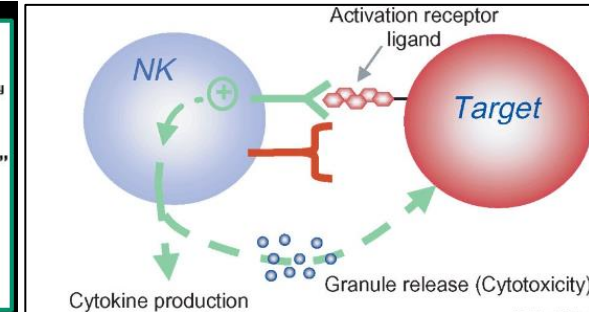
Countermeasures

- Nutrition/Supplementation
- Exercise
- Stress Management
- Personalized Medications

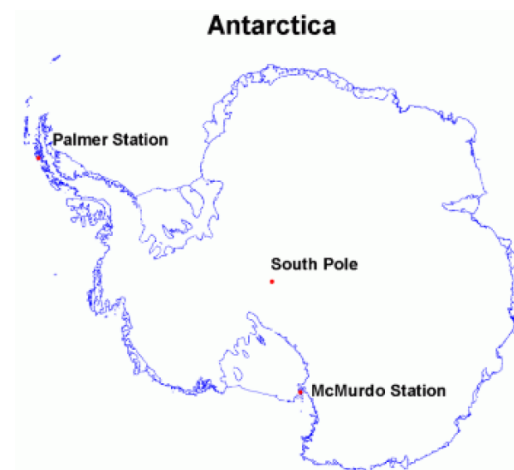
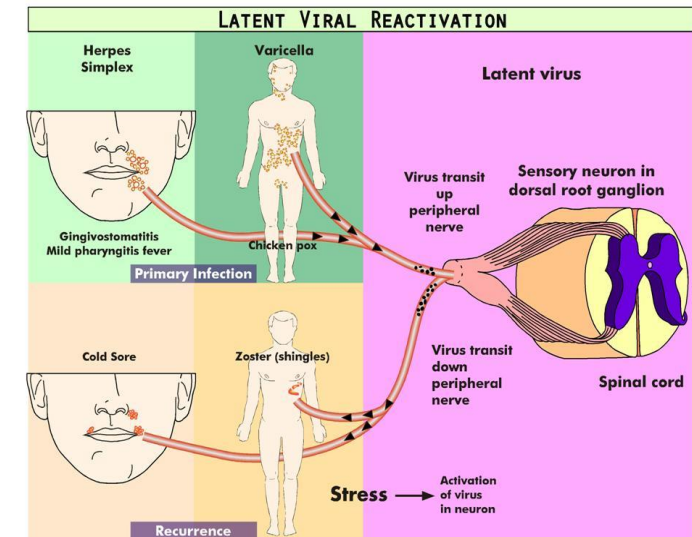
T Cell Function



NK Cell Function



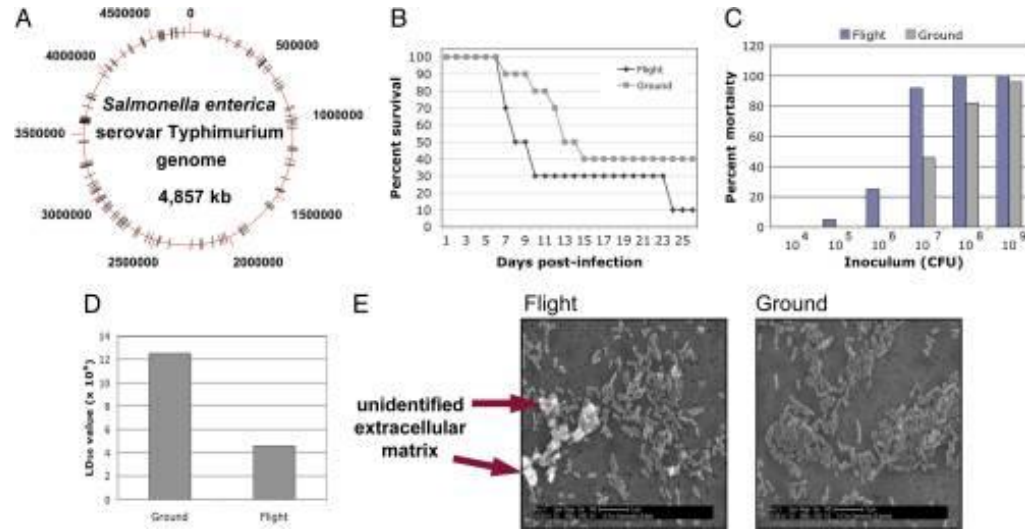
Latent Herpesvirus Reactivation



MicroHost



Evaluation of the effect of spaceflight on microbial profiles

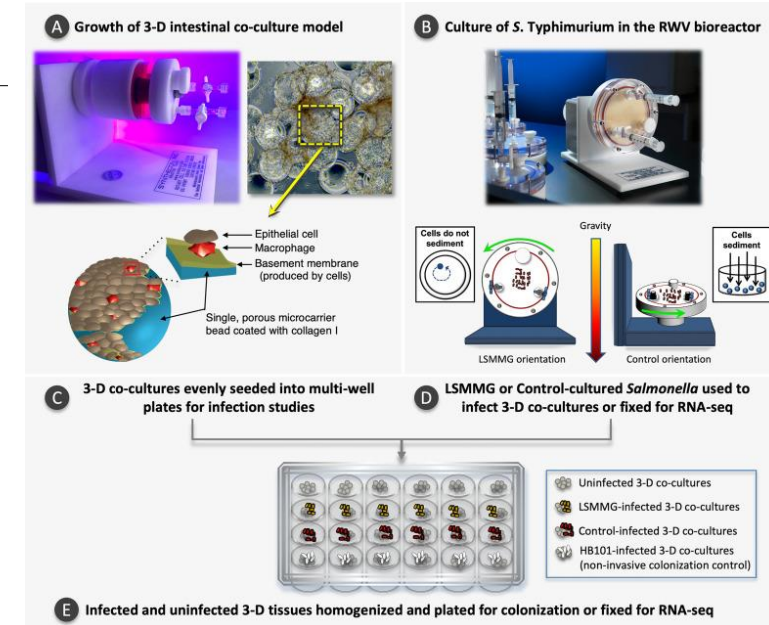


Wilson, *et al.* 2007, PNAS

Understand clinical relevance and outcome



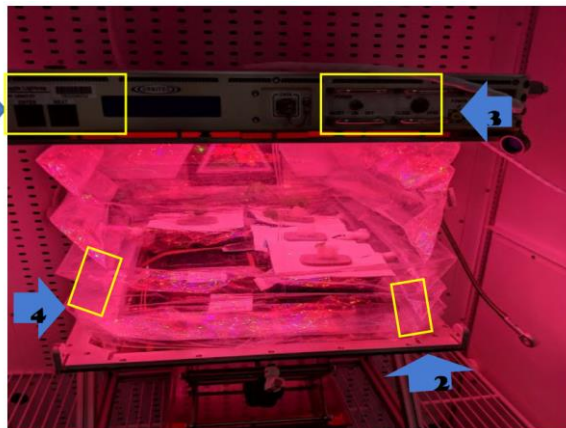
Host Pathogen



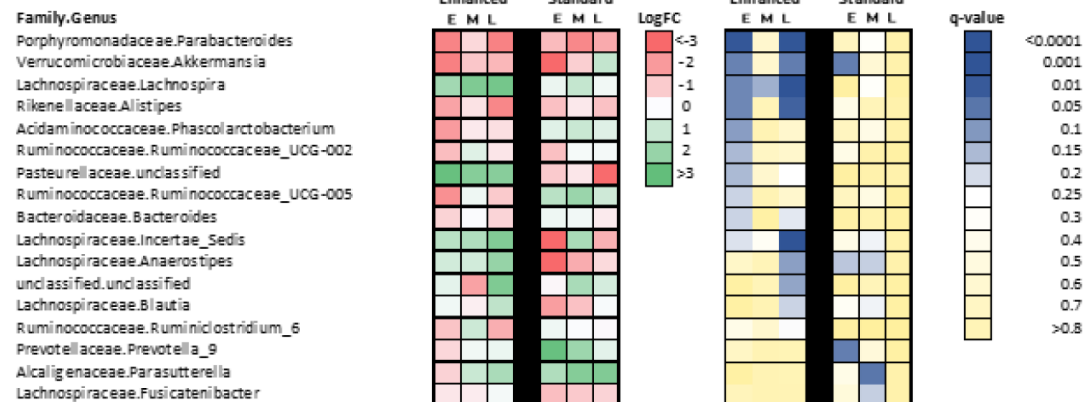
Barrila, *et al.* 2022, Front Cell Infect Microbiol



ISS Clinical Incidence vs. Environmental Monitoring



Vehicle Microbiome: Veggie Monitoring



Human Gut Microbiome: Food Physiology ISS

Food and Nutrition

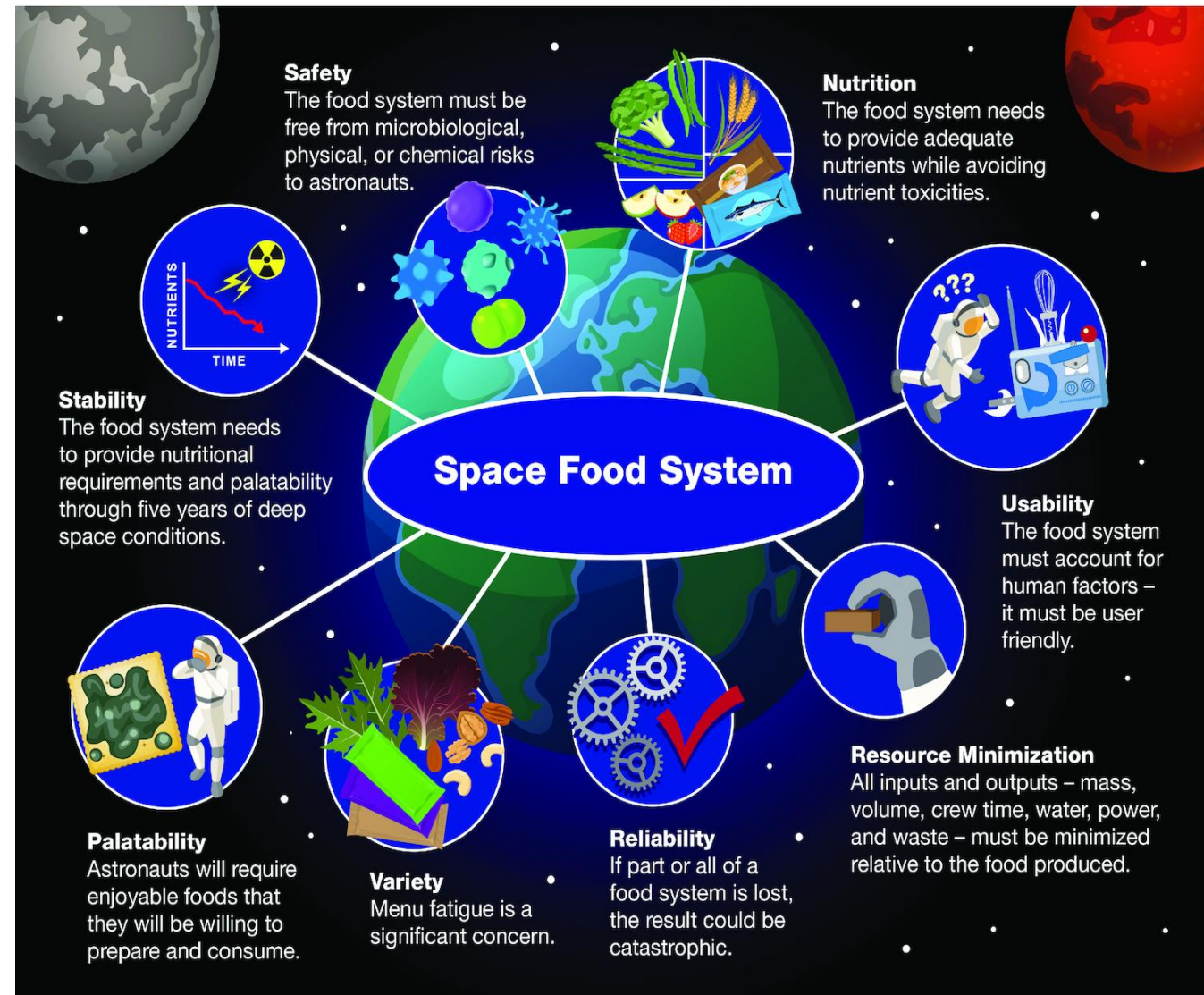


ISS

- Shelf-stable, single-serving food products
- Limited by water, upmass, crew time, food prep capability
- Reformulated 90 foods to reduce crew sodium intake
- Approximately 80% standard foods, 20% preferences foods, plus limited fresh fruits, veggies, semi-shelf stable foods by resupply vehicles

Challenges for Exploration Missions

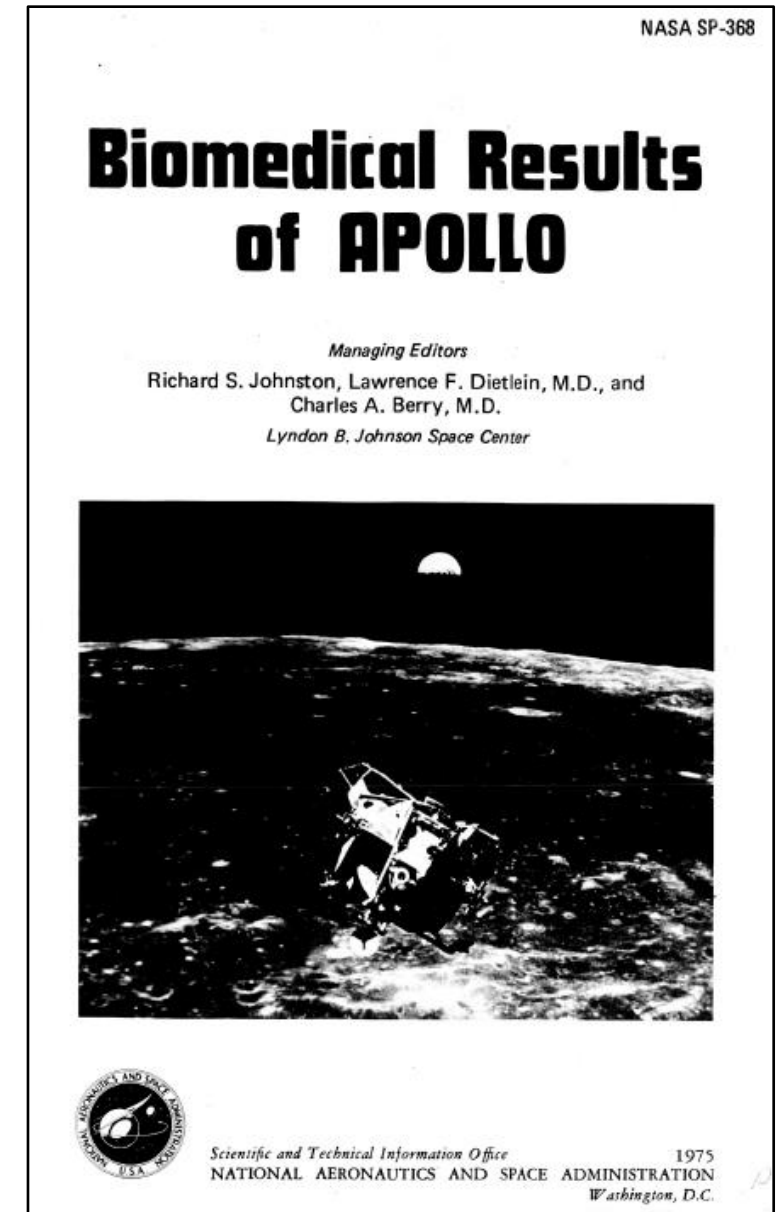
- Food system is a large mass driver
- Lunar Missions:
 - High tempo EVAs, meeting nutritional requirements for energy expenditures
 - Meal replacement bar HERA study resulted in reduced food intake and behavioral implications
- Mars Missions:
 - Shelf-life, stability of nutrients
 - No resupply
 - Regenerative food strategies
 - How to optimize food as a CM for other risks



HRP Research Payloads on Early Artemis



- Limitations of Research on Early Artemis
 - Mass/volume constraints
 - Crew time
 - No cold stowage for biosamples
- Artemis Enabling
 - Lunar OI
 - In-suit Nutrition
 - Bars and Beverages
 - Sensorimotor: motion sickness, assessments
- Artemis Utilization
 - Unknowns beyond LEO (i.e. Immunology Biomarkers, Cardiovascular)
 - Lunar specific risks (i.e. Sensorimotor)
 - Testbed for Mars exploratory missions (i.e. SANS)



ARTEMIS II

First Crewed Test Flight to the Moon Since Apollo

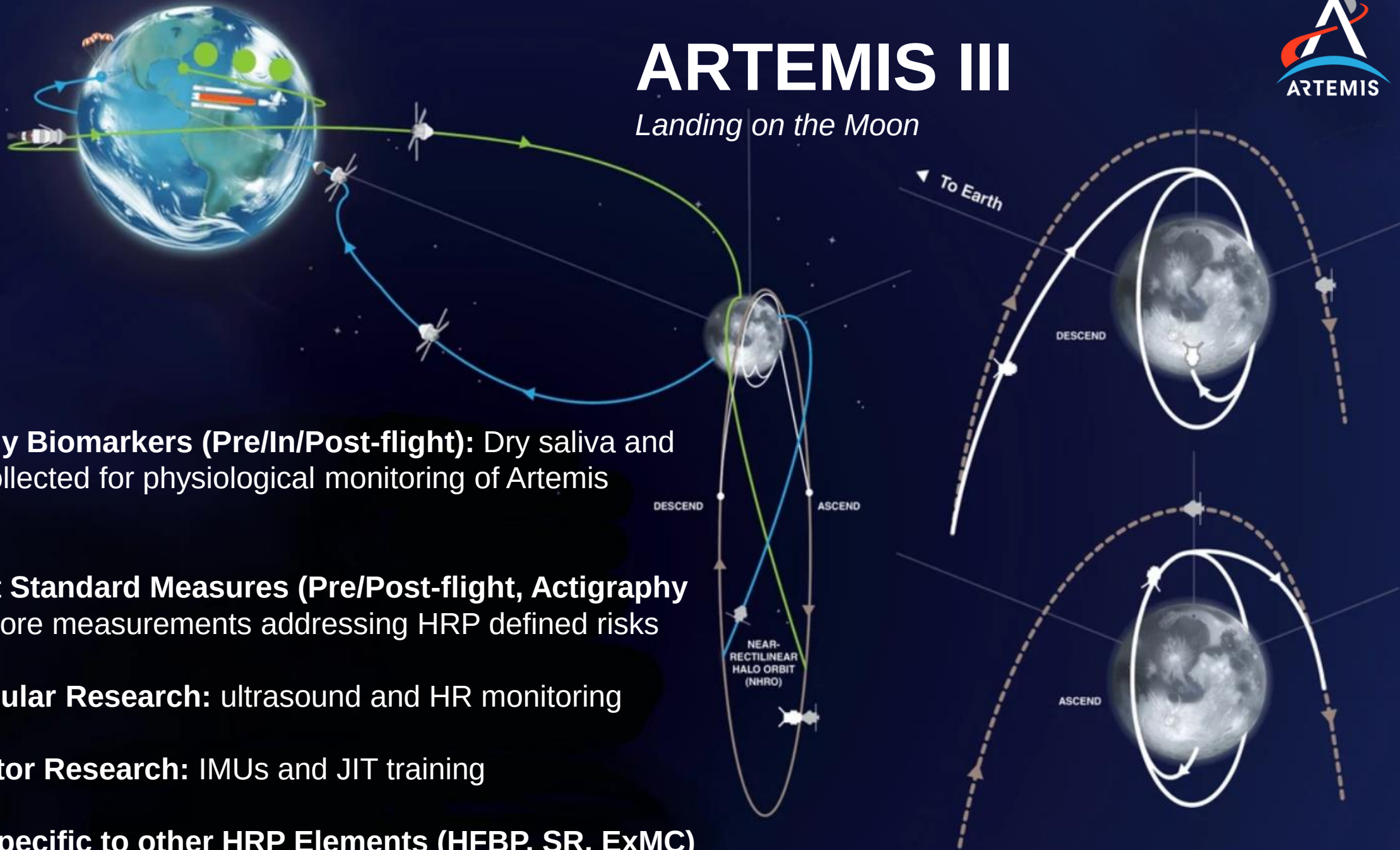
Immunology Biomarkers (Pre/In/Post-flight): Dry saliva and dry blood collected for physiological monitoring of Artemis astronauts

Spaceflight Standard Measures (Pre/Post-flight, Actigraphy In-flight): Core measurements addressing HRP defined risks

Payloads specific to other HRP Elements (HFBP, SR, ExMC)

ARTEMIS III

Landing on the Moon



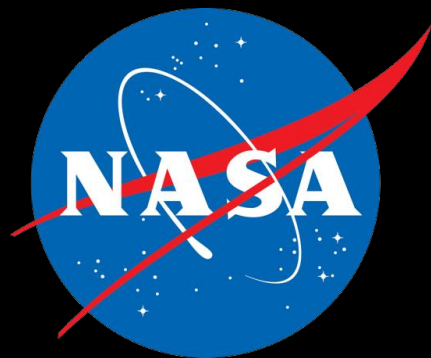
Immunology Biomarkers (Pre/In/Post-flight): Dry saliva and dry blood collected for physiological monitoring of Artemis astronauts

Spaceflight Standard Measures (Pre/Post-flight, Actigraphy In-flight): Core measurements addressing HRP defined risks

Cardiovascular Research: ultrasound and HR monitoring

Sensorimotor Research: IMUs and JIT training

Payloads specific to other HRP Elements (HFBP, SR, ExMC)



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MOON_{to}MARS