



Bridging knowledge gaps with technology

# HUMAN HEALTH RISKS IN SPACE EXPLORATION

Susana (Susi) Zanello, Ph.D.  
Universities Space Research Association (USRA)  
NASA Johnson Space Center (JSC)





# HUMAN EXPLORATION

NASA's Path to Mars



## EARTH RELIANT

MISSION: 6 TO 12 MONTHS  
RETURN TO EARTH: HOURS



Mastery fundamentals aboard the International Space Station

U.S. companies provide access to low-Earth orbit

## PROVING GROUND

MISSION: 1 TO 12 MONTHS  
RETURN TO EARTH: DAYS

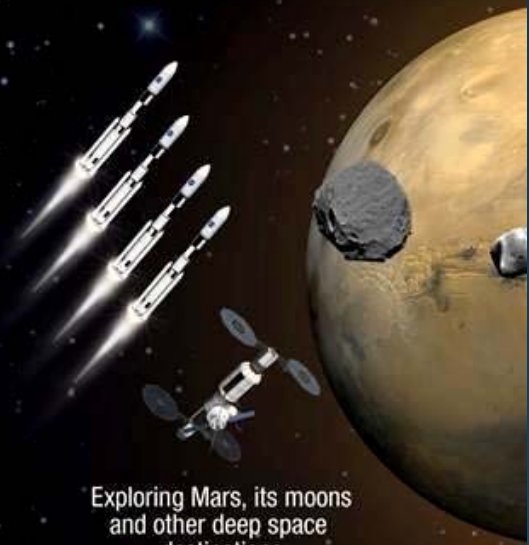


Expanding capabilities by visiting an asteroid redirected to a lunar distant retrograde orbit

Traveling beyond low-Earth orbit with the Space Launch System rocket and Orion spacecraft

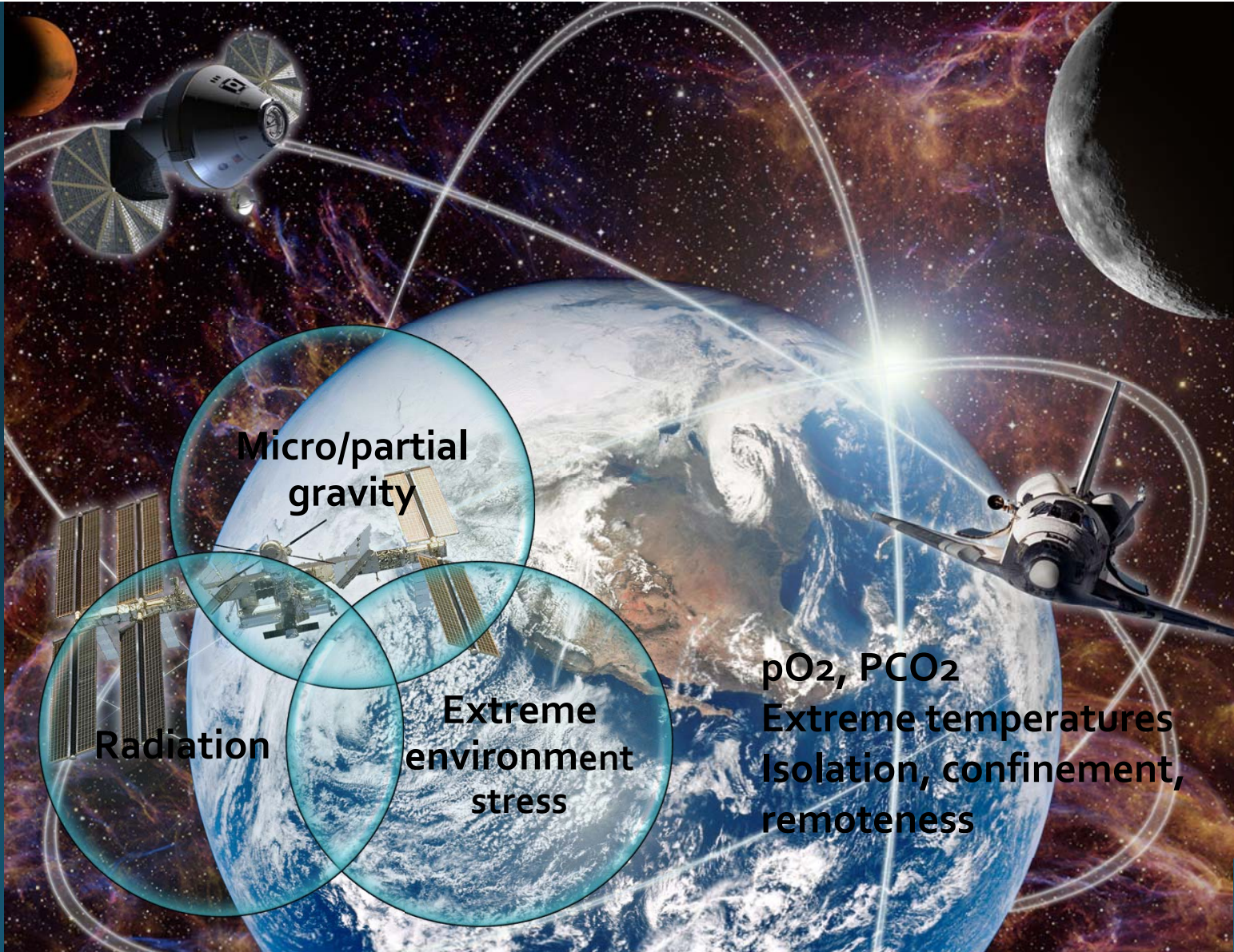
## MARS READY

MISSION: 2 TO 3 YEARS  
RETURN TO EARTH: MONTHS



Exploring Mars, its moons and other deep space destinations





**Micro/partial  
gravity**

**Radiation**

**Extreme  
environment  
stress**

**pO<sub>2</sub>, PCO<sub>2</sub>  
Extreme temperatures  
Isolation, confinement,  
remoteness**

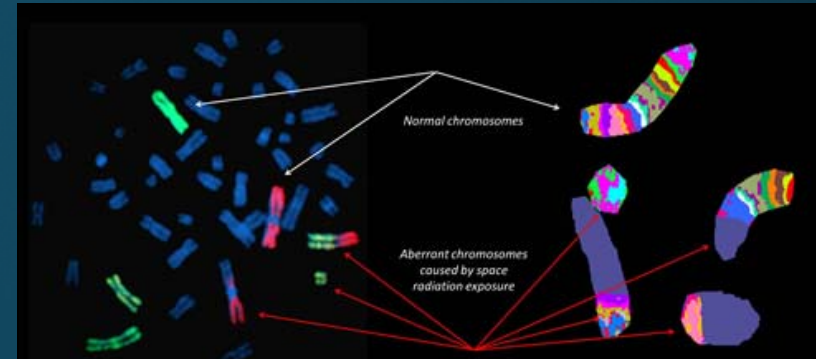


# Human Research Roadmap

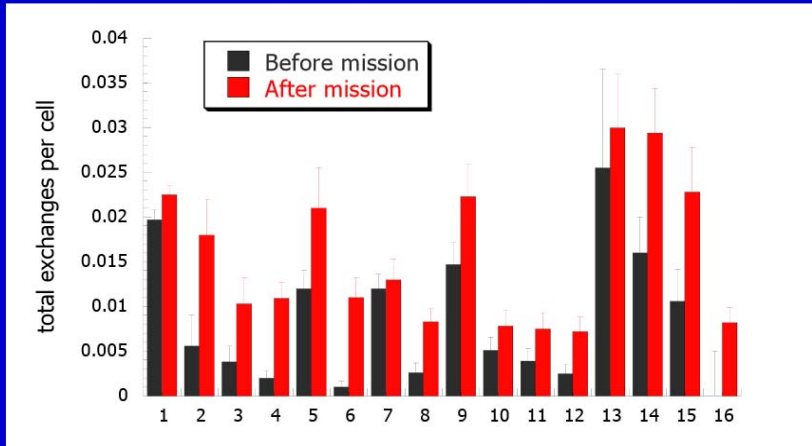
- The NASA Human Research Program (HRP) uses an Integrated Research Plan to identify the approach and research activities planned to address these risks
- <http://humanresearchroadmap.nasa.gov/>



# Space Radiation



## International Space Station Astronaut Biodosimetry



Total exchanges increased post-mission in all cases

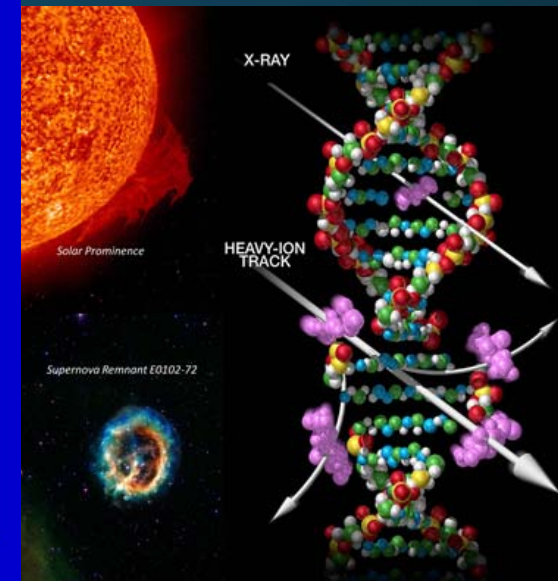
## Categories of Radiation Risk

Four categories of risk of concern to NASA:

- **Carcinogenesis (morbidity and mortality risk)**
- **Acute and Late Central Nervous System (CNS) risks**
  - ✓ immediate or late functional changes
- **Chronic & Degenerative Tissue Risks**
  - ✓ cataracts, heart-disease, etc.
- **Acute Radiation Risks** – sickness or death

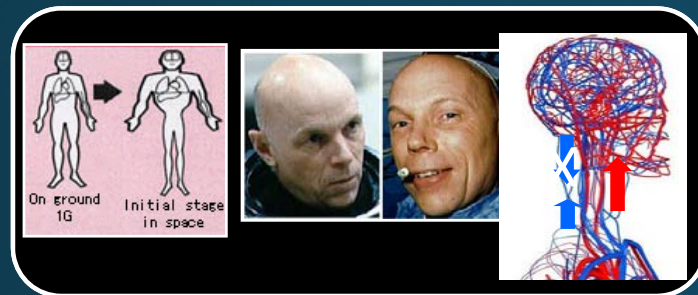
Differences in biological damage of heavy nuclei in space with x-rays, limits Earth-based data on health effects for space applications

- New knowledge on risks must be obtained
- Confounds biomarker development and interpretation

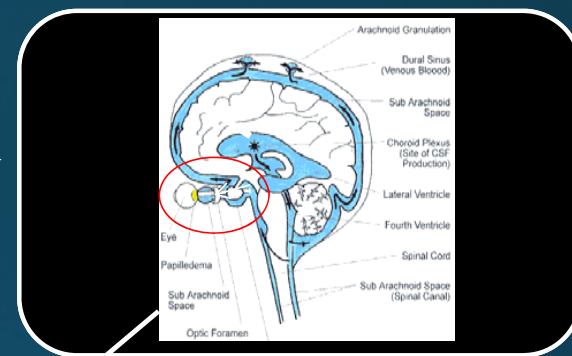


# Visual Impairment and Intracranial Pressure (VIIP) Risk: Proposed Pathophysiology

## 1. Weightlessness-induced headward fluid shift



## 2. Fluid shift increases intracranial pressure (ICP)



## 3. Elevated ICP & fluid shift transmitted to the eye

**Hyperopic Shifts**  
Up to +1.75 diopters

**Increased Optic Nerve Sheath Diameter**

**Choroidal Folds**  
Ridges in back of eye

**Optic Disc Edema (Swelling)**

**Globe Flattening**

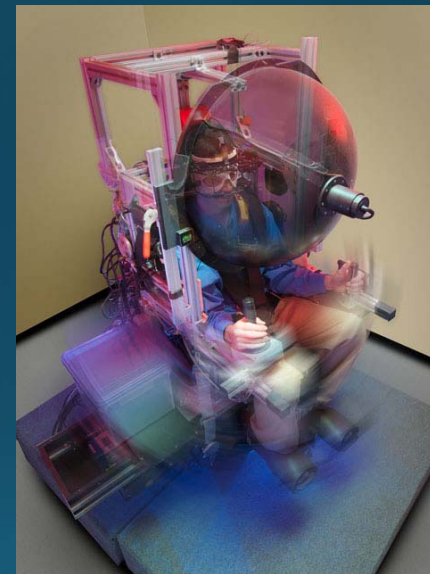
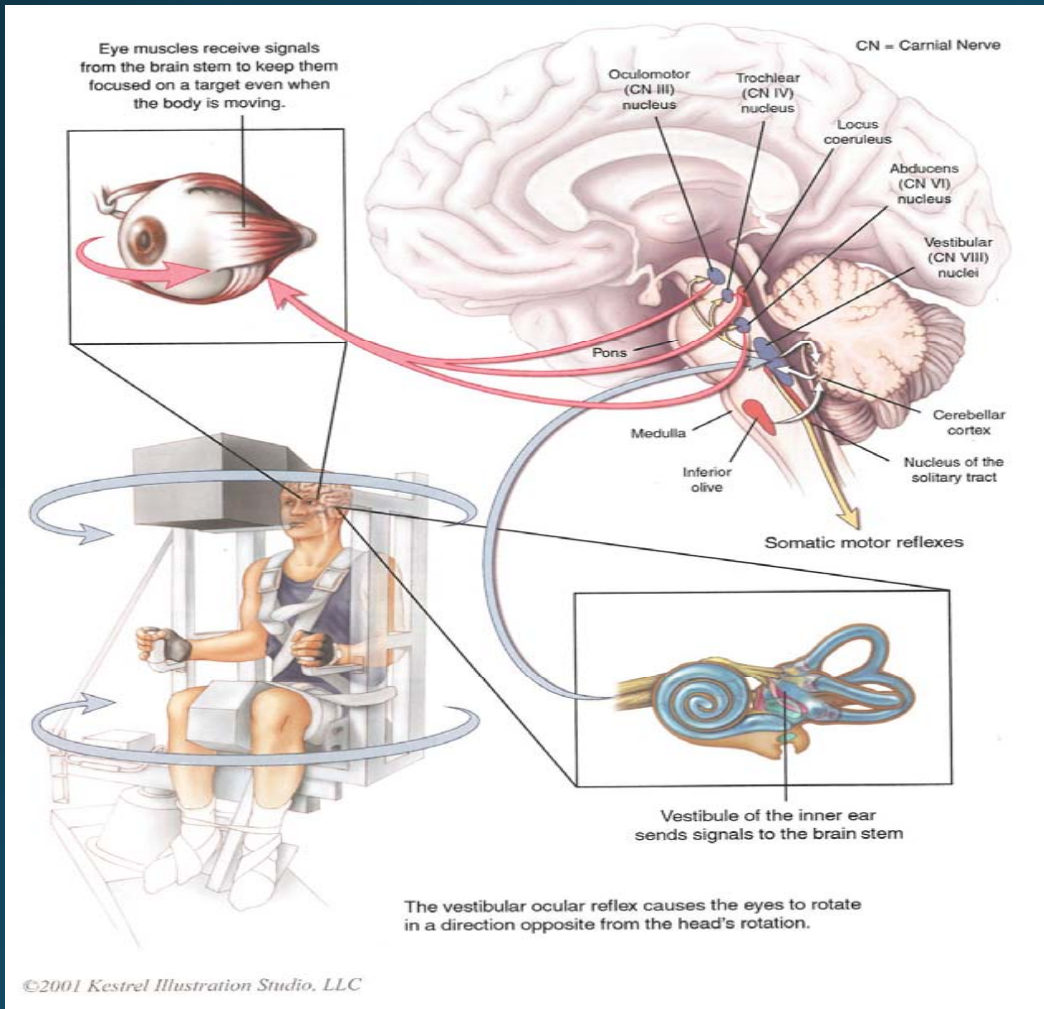
**+ICP**

Courtesy Christian Otto, MD, HRP VIIP Project Scientist, July, 2014



# Neurovestibular/Sensorimotor Perturbations

- Space motion sickness
- Spatial disorientation
- Lunar, Mars and post Earth return balance and locomotion problems
- Sensorimotor Training Programs

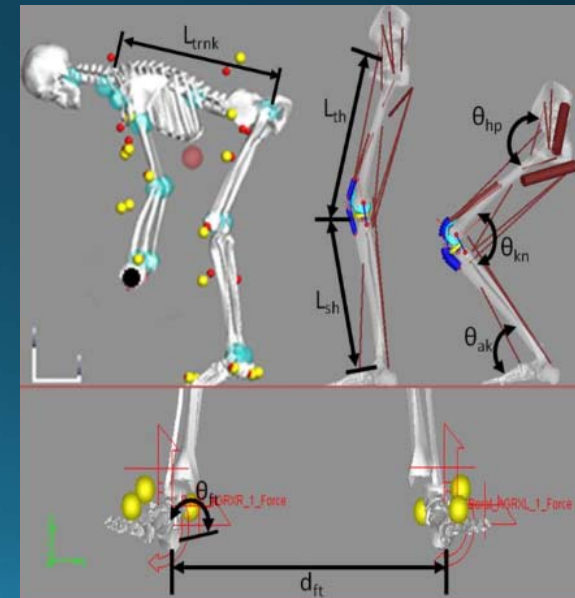
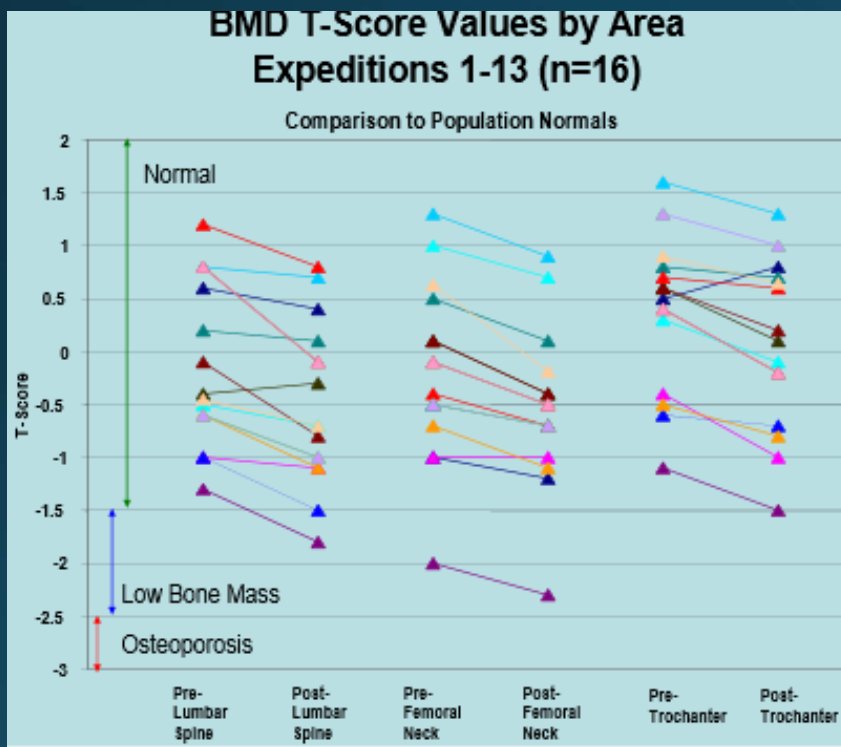


**The Balance System:  
Vestibular  
Ocular Reflex**



# Risk of bone fracture and early onset of osteoporosis

- Bone atrophy occurs due to space travel.
- DXA-measured areal BMD has been shown to be an incomplete indicator of whole bone strength.
- Knowledge regarding changes in bone geometry and microarchitecture is incomplete.
- The relative contribution of microarchitecture and geometry to bone strength is not known but the literature indicates that it could be substantial.
- Due to the multiple contributors to bone strength, the full impact of spaceflight on whole bone strength is unknown.
- The state of bone loading for different mission scenarios is unknown



## EXERCISE PHYSIOLOGY



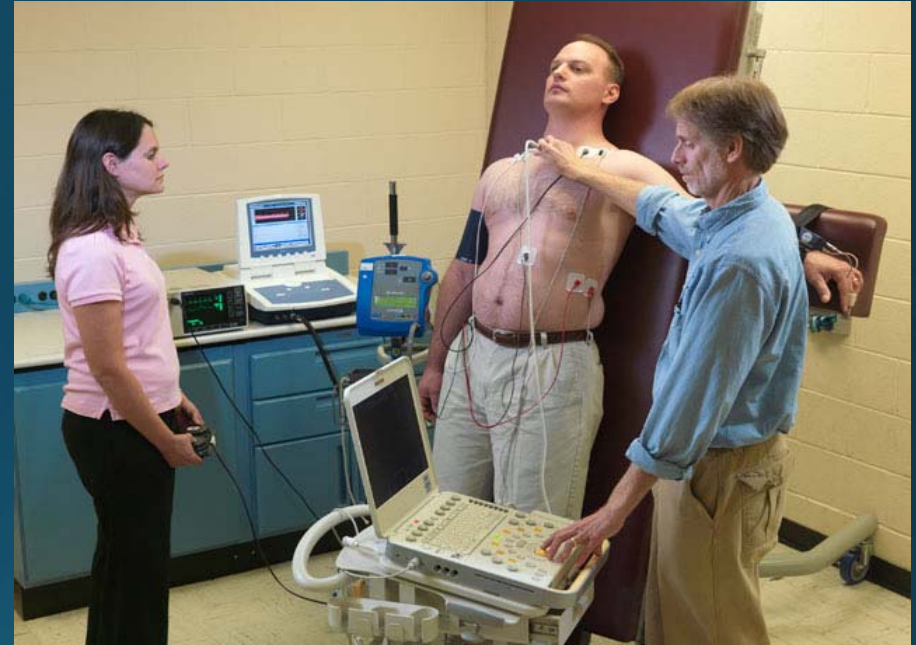
- ✓ Risk of Impaired Performance Due to Reduced Muscle Mass, Strength and Endurance:

Reduced mass, strength, and endurance in-flight



Crew may be unable to perform mission tasks

## CARDIOVASCULAR

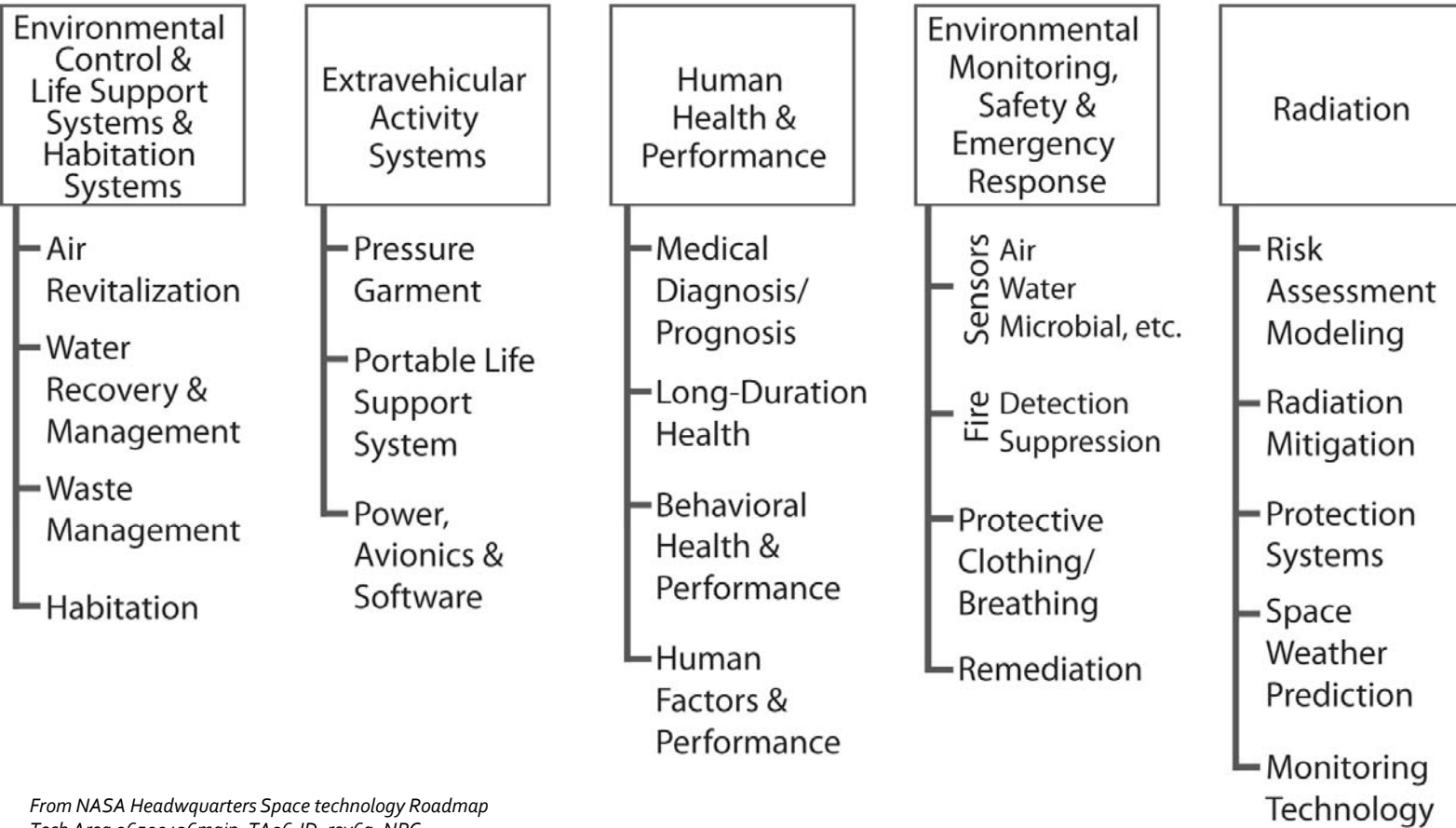


- ✓ Risk Of Cardiovascular Disease and Other Degenerative Tissue Effects From Radiation Exposure
- ✓ Risk of Cardiac Rhythm Problems
- ✓ Risk of Orthostatic Intolerance During Re-Exposure to Gravity



# TECHNOLOGY AREA NEEDS

## Human Health, Life Support & Habitation Systems

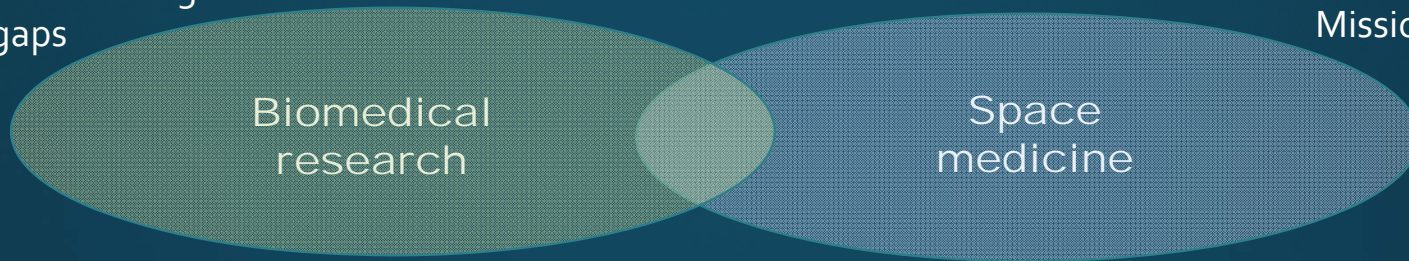


From NASA Headquarters Space technology Roadmap  
Tech Area 06500436main\_TA06-ID\_rev6a\_NRC

# Key Technologies

Increase knowledge  
Close gaps

Operations  
Occupational health  
Mission success



Pharmacokinetics

iPSC- In situ drug delivery

Cell/tissue/animal models

Sensorimotor and exercise countermeasures equipment

Non-exercise countermeasures including artificial gravity

Genomic screening and health status

Biomedical sensors/scanners

Inflight sample analysis

Integrated Biomedical informatics

Non-invasive ICP

Disease and therapeutic monitoring

Autonomous medical decision, simulation and training

Sterilization/surgical methods

Drug delivery/packaging

Non-invasive renal stone treatment



## Crosscutting areas

### **Human Health and Countermeasures**

*Focuses on understanding, characterizing, and counteracting the body's adaptation to microgravity, enabling healthy astronauts to accomplish mission objectives and return to normal life following a mission.*

### **Autonomous Medical Care:**

*The capability to provide medical care during a mission with little or no real-time support from Earth.*

### **Behavioral Health and Performance (BHP):**

*Focuses on maintaining the psychosocial and psycho-physiological functions of the crew throughout space flight missions and providing an optimal set of countermeasures.*

### **Advanced Human Support Technologies (AHST):**

*Focuses on developing efficient, reliable and autonomous technologies and systems to support human habitation in spacecraft and planetary dwellings.*

## Discipline Teams

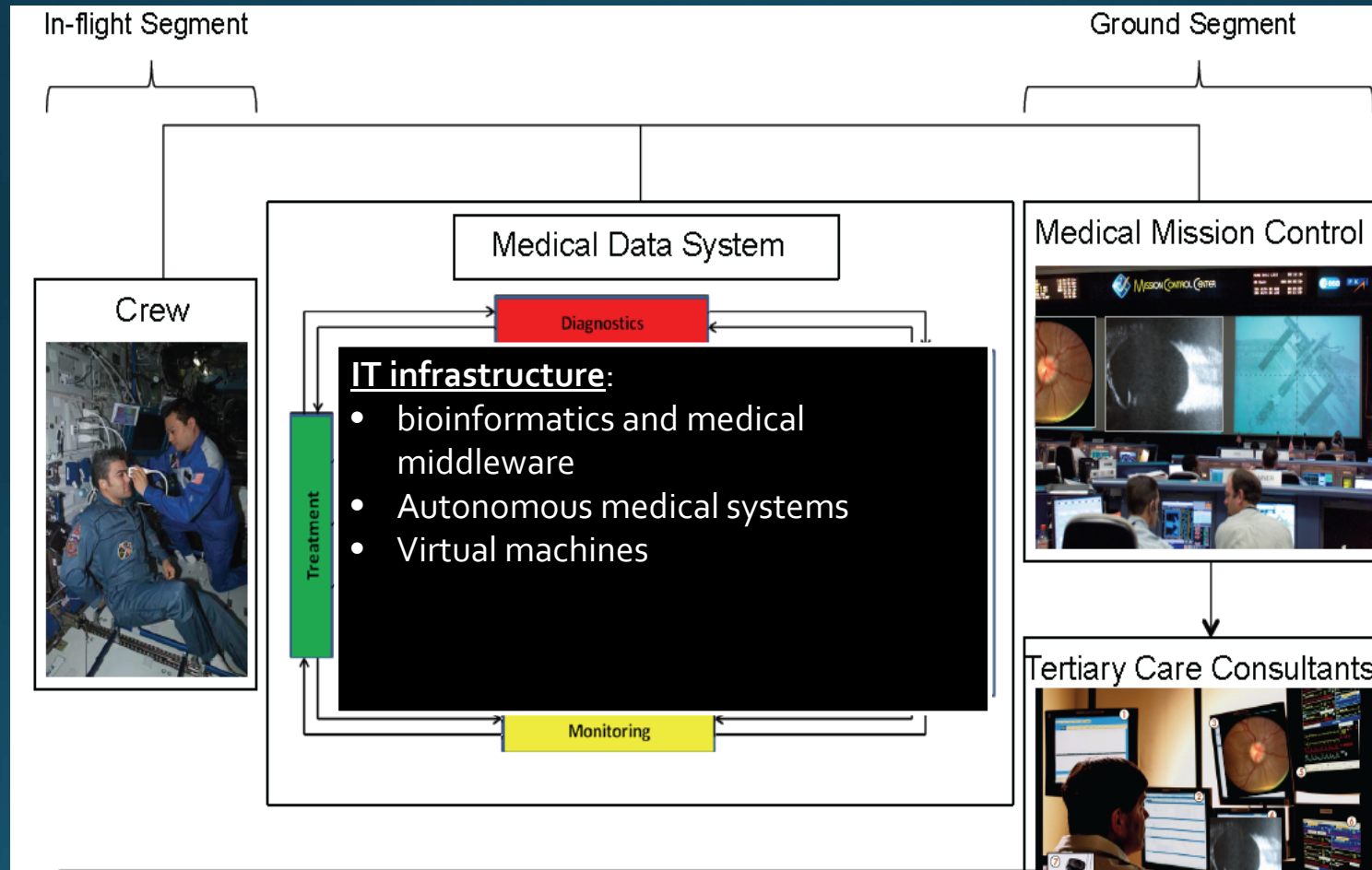
Bone Loss  
Cardiovascular Alterations  
Environmental Health  
Immunology & Infection  
Skeletal Muscle Alterations  
Sensory-Motor Adaptation  
Nutrition  
VIIP

Clinical capabilities (space medicine)

Behavioral Health & Performance and Space  
Human Factors (Cognitive)

Advanced Environmental Monitoring & Control  
Advanced Extravehicular Activity  
Advanced Food Technology  
Advanced Life Support  
Space Human Factors Engineering

# EXPLORATION MEDICAL SYSTEMS



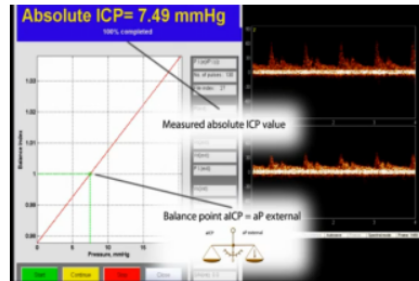


# VIIP SYNDROME AND NON-INVASIVE ICP MEASUREMENT

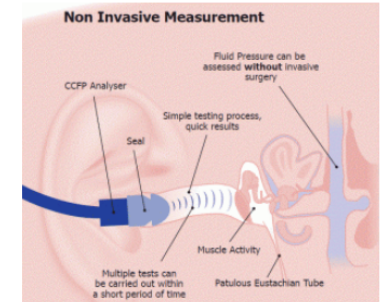


Visual and ocular tests on ISS

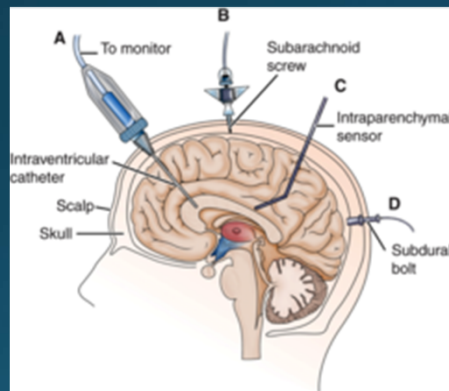
## Vittamed 205 Monitor



## Cochlear and Cerebral Fluid Pressure (CCFP) Analyzer



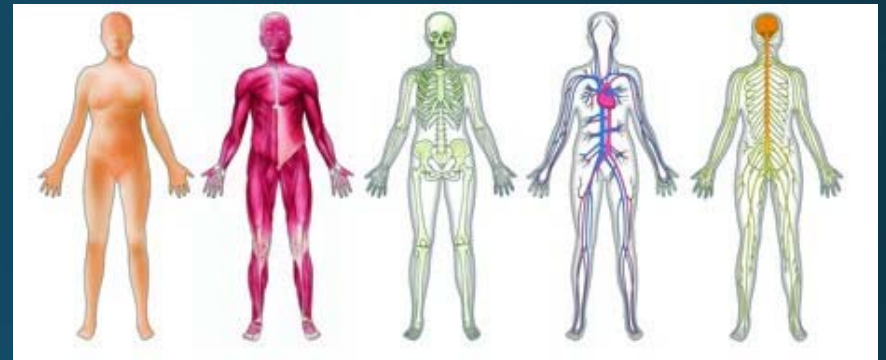
Current non-invasive ICP measurement technologies under evaluation



Intracranial pressure (ICP) measurement is invasive

## SCREENING TECHNOLOGIES

- Currently screening done for physical and psychological conditions
- Biomarker screening and health status monitoring for anticipated medical conditions at all systems levels and individual susceptibilities to environmental stressors and disease
- Pre-flight and in-flight personalized medicine and pharmacogenomics for better diagnosis, treatment and prognosis
- Based on more sensitive and specific biomarker tests originating from medical research/industry (pharma and companion diagnostics)



# SCREENING/MONITORING TECHNOLOGIES

## New Paradigm For Multi-modal Multiplex Diagnostics

- Quantitative
- Save Time
- Broad Dynamic Range
- Mid/High Multiplex

## Breadth of Applications

- Infectious Disease
  - Pathogen Detection
  - Viral Load
- Disease, health status, screening
  - Methylation, SNP, CNV
- Non-Clinical Fields of Use
  - Microbial Detection-Food

Qualitative

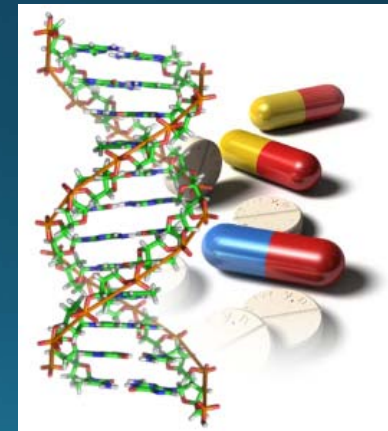
Quantitative

SNP

mRNA

MicroRNA

Multi-Modal

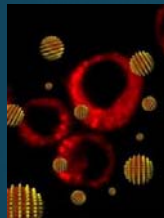




# PHARMACOLOGY: Concern of Clinically Relevant Unpredicted Effects of Medication



**DRUG DELIVERY**



**DRUG PACKAGING**

- Easy dispensing
- Longer shelf life



**PHAMACOKINETICS:** time course of drug absorption, distribution, metabolism and excretion.

**PHARMACODYNAMICS:** relationship between drug concentration at the site of action and the resulting effect

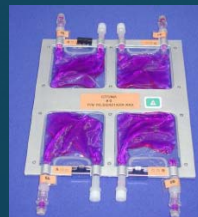


# MODELS



Microorganism culture (BioServe)

## Cell culture

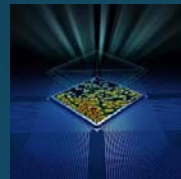


Cell culture system (Wyle)

## Tissue culture



Bioreactor



Human body on a chip

## Plant/Animal models



Biomass production system (Orbitec)

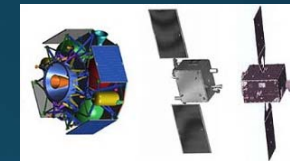


Animal Enclosure Module (AEM)

**Biosentinels**  
*('biological instrument', an organism that can help us understand constraints to a certain environment.*



ISS



Micro-satellites

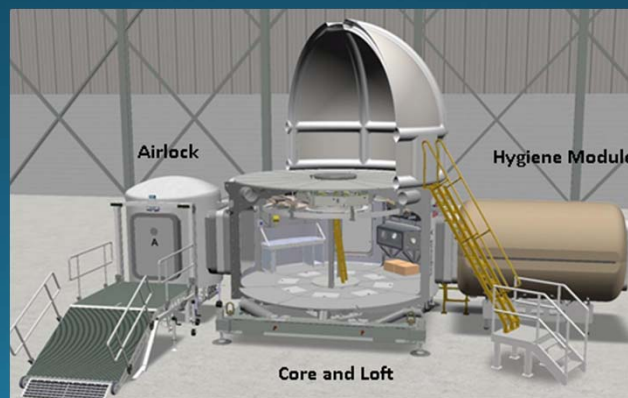


Commercial/International collaborations (Russian Bion)

## Examples of ISS Implementation Partners

# HUMAN FLIGHT ANALOGS

- A ground analog creates a situation that produces effects on the human body similar to those experienced in spaceflight and space exploration
  - ✓ Physiological
  - ✓ Cognitive/behavioral
- Not all experiments can be done in flight
- Resources are limited (time, dollars)
- Takes significantly longer to complete studies (multiple flights needed to achieve required n)
- Allows for selection of best candidate countermeasures before using them in flight
- Saves time and money as studies can be completed more quickly and less expensively on the ground.





# HEAD DOWN TILT BED REST

- 6° Head-down Tilt
  - serves as a model for studying the physiological changes that occur during spaceflight **under controlled conditions**
  - provides a ground-based platform for comparison to spaceflight;
  - provides a mechanism for testing countermeasures prior to being used in flight.
  - Excellent ground-based analog for bone, muscle and cardiovascular systems.

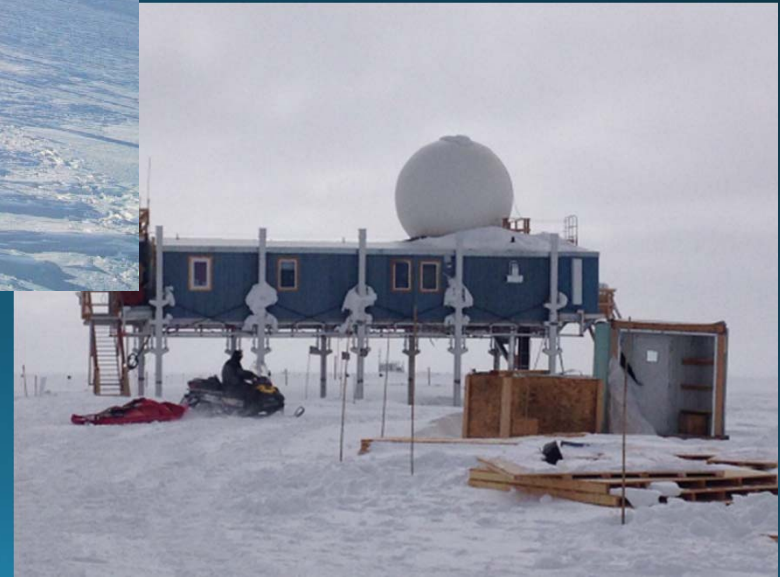
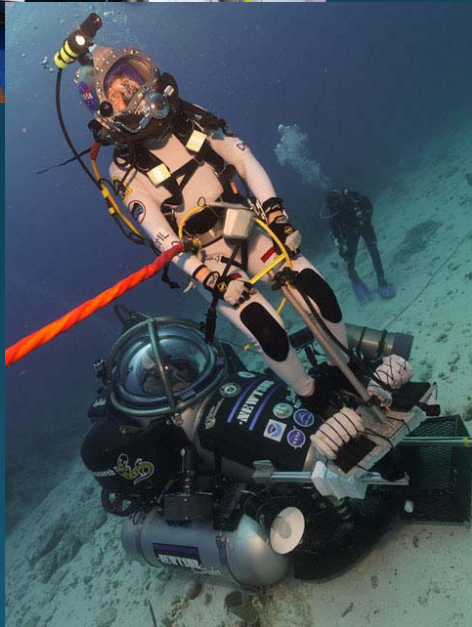
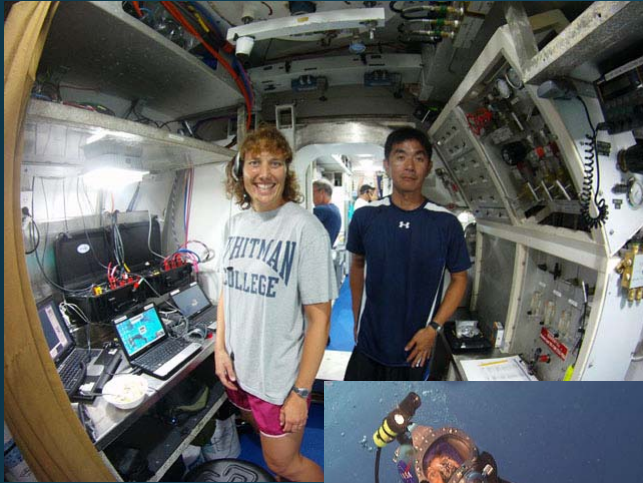


DLR Institute of Aerospace Medicine  
:enhivab, Cologne, Germany



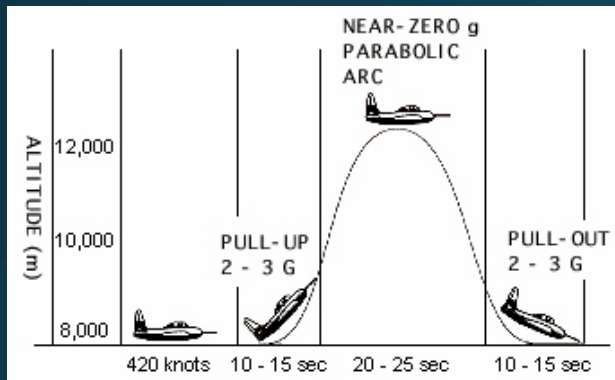
NASA Bed Rest  
Facility,  
Galveston TX

# NEEMO AND POLAR ENVIRONMENTS





# PARABOLIC FLIGHTS



<https://flightopportunities.nasa.gov/about/program/>





THANK YOU

QUESTIONS?

