Bridging knowledge gaps with technology

HUMAN HEALTH RISKS IN SPACE EXPLORATION

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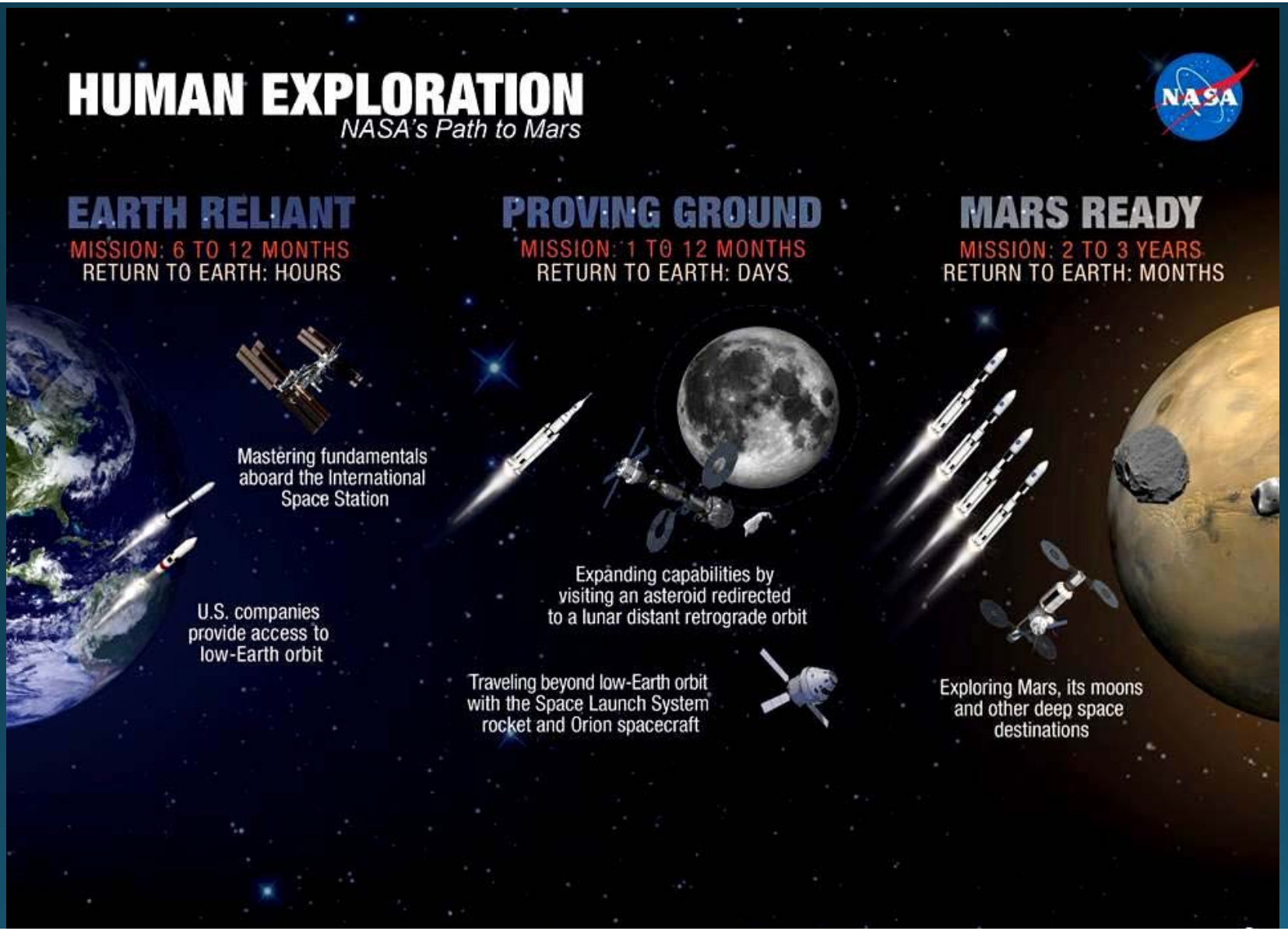
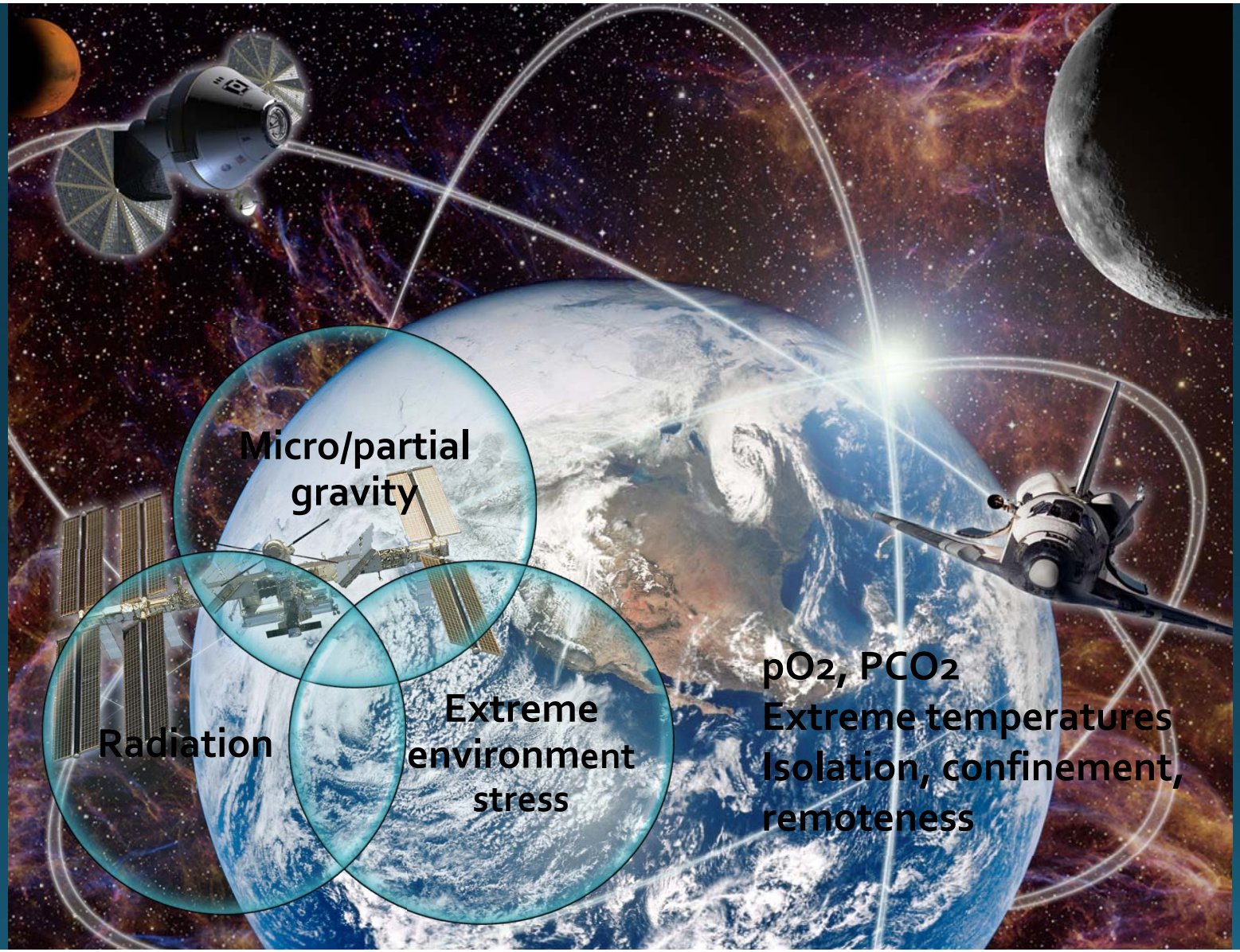
NASA

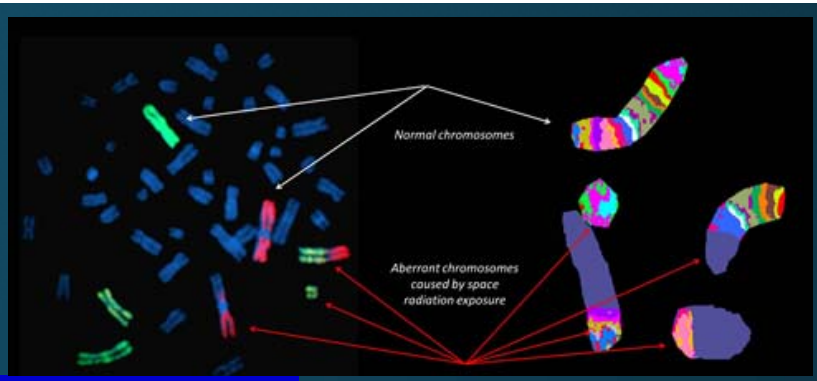

HUMAN EXPLORATION
NASA's Path to Mars
NASA
EARTH RELIANT
MISSION: 6 TO 12 MONTHS
RETURN TO EARTH: HOURS
PROVING GROUND
MISSION: 1 TO 12 MONTHS
RETURN TO EARTH: DAYS
MARS READY
MISSION: 2 TO 3 YEARS
RETURN TO EARTH: MONTHS
Mastering fundamentals aboard the International Space Station
U.S. companies provide access to low-Earth orbit
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
Exploring Mars, its moons and other deep space destinations


Micro/partial gravity
Radiation
Extreme environment stress
pO2, PCO2
Extreme temperatures
Isolation, confinement, remoteness

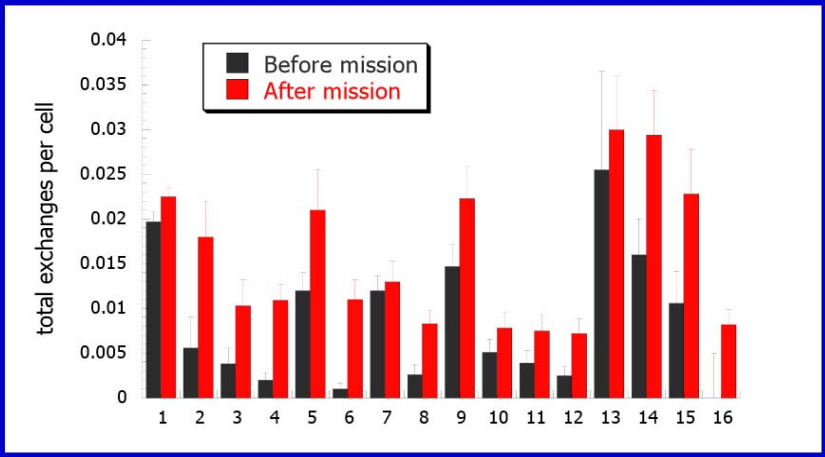
Human Research Roadmap

- 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

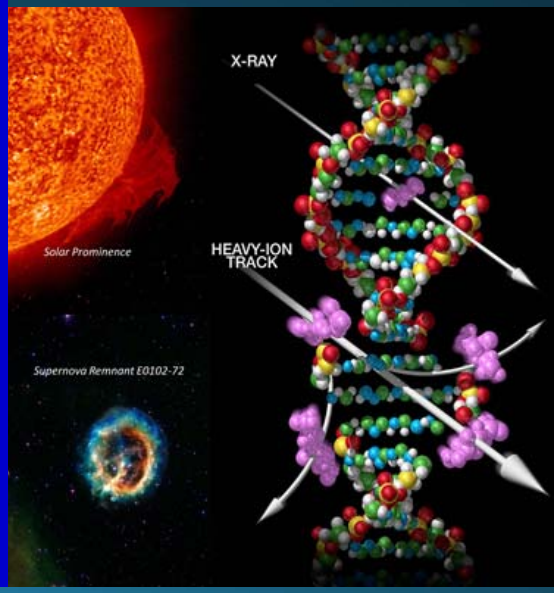
Categories of Radiation Risk

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

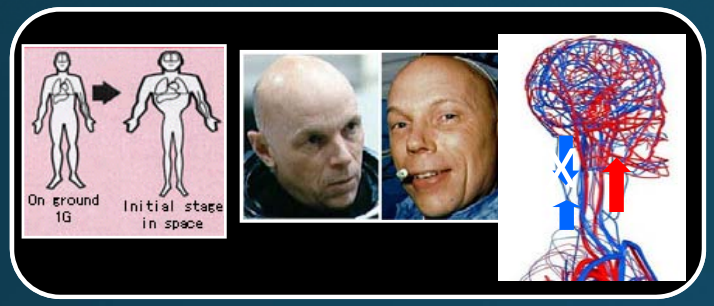
Differences in biological damage of heavy nuclei in space with x-rays, limits Earth-based data on health effects for space applications

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

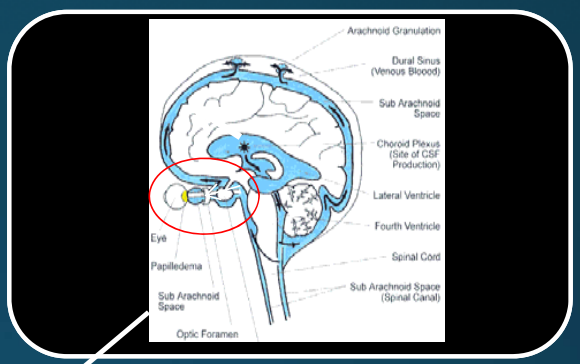


Visual Impairment and Intracranial Pressure (VIIP) Risk: Proposed Pathophysiology

1. Weightlessness-induced headward fluid shift

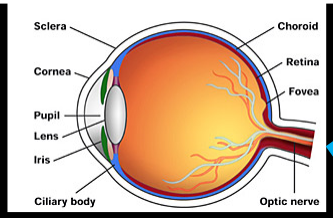


2. Fluid shift increases intracranial pressure (ICP)



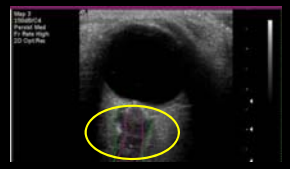
3. Elevated ICP & fluid shift transmitted to the eye

Hyperopic Shifts
Up to +1.75 diopters

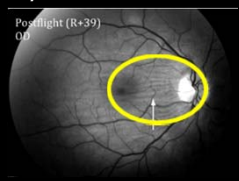


+ICP

Increased Optic Nerve Sheath Diameter

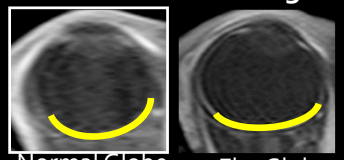


Choroidal Folds
Ridges in back of eye



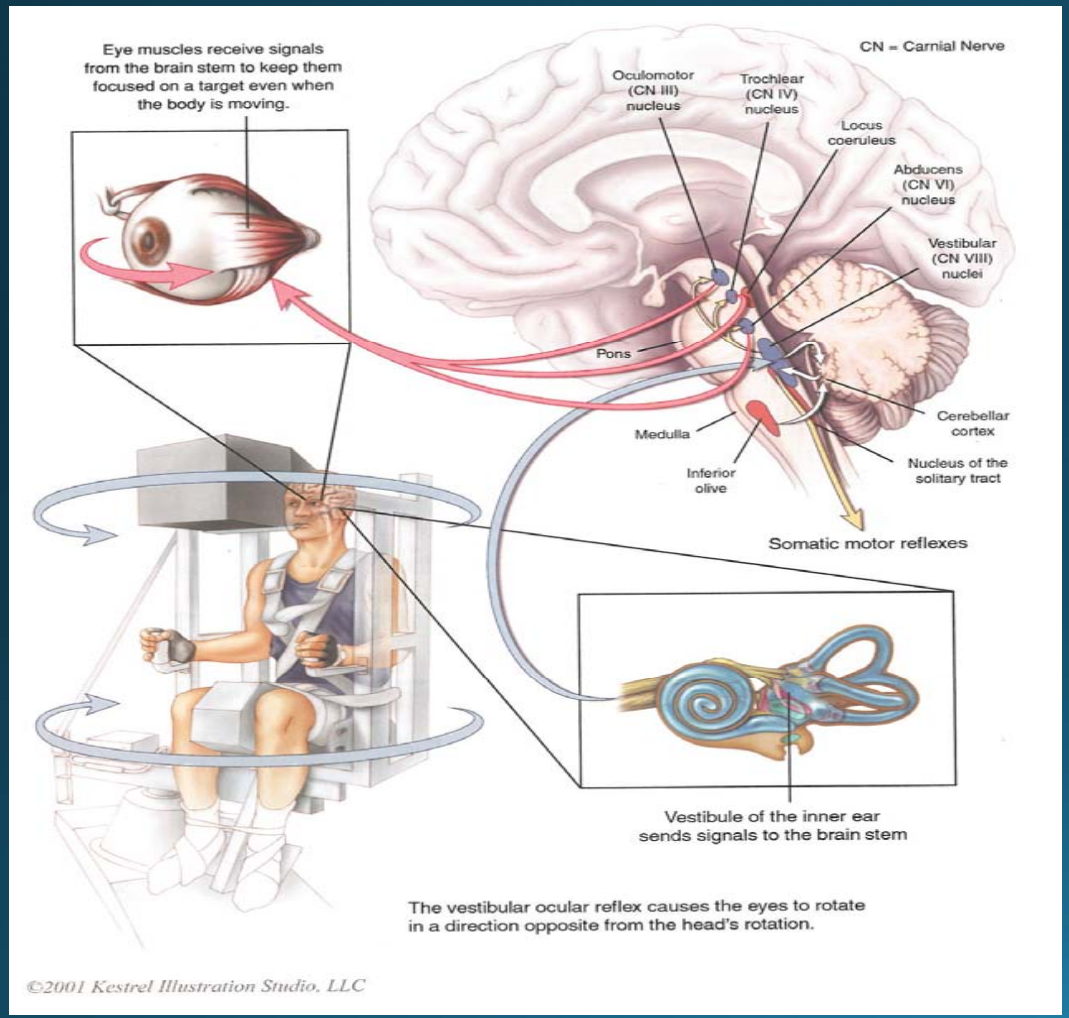
Optic Disc Edema
(Swelling)

Globe Flattening

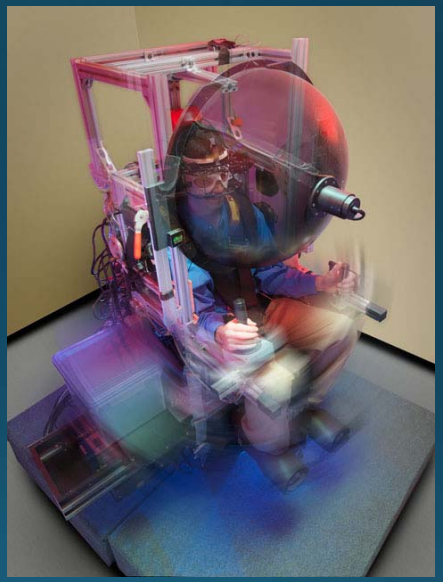


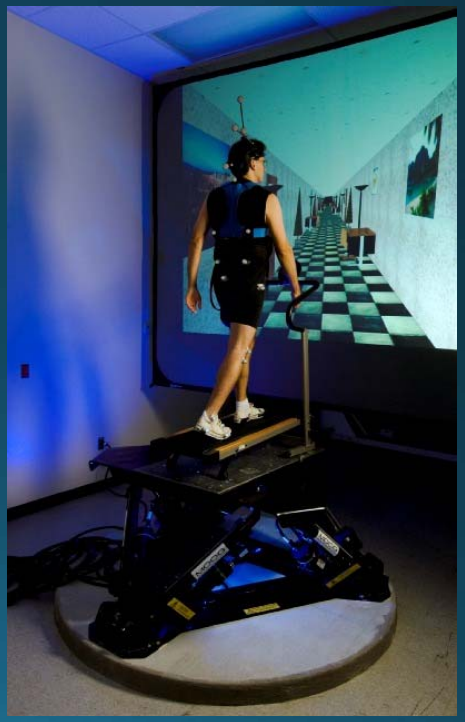
Courtesy Christian Otto, MD, HRP VIIP Project Scientist, July. 2014

Neurovestibular/Sensorimotor Perturbations



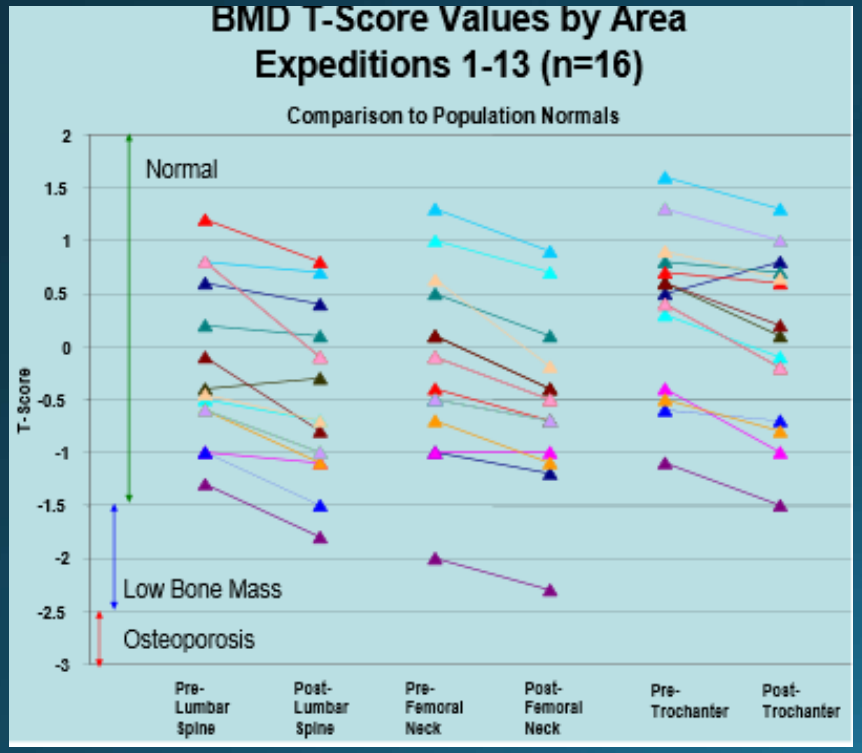
- Space motion sicknes
- Spatial disorientation
- Lunar, Mars and post Earth return balance and locomotion problems
- Sensorimotor Training Programs





The Balance System: Vestibular Ocular Reflex

Risk of bone fracture and early onset of osteoroporosis



- Bone atrophy occurs due to space travel.
- DXA-measured areal BMD has been shown to be

an incomplete indicator of whole bone strength.

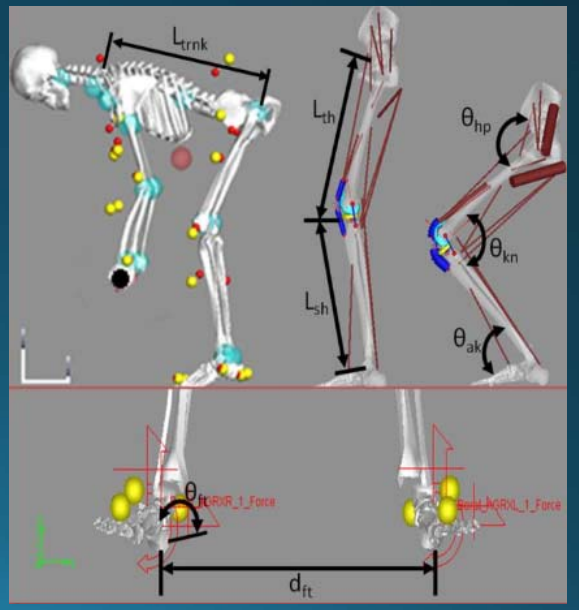
- Knowledge regarding changes

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

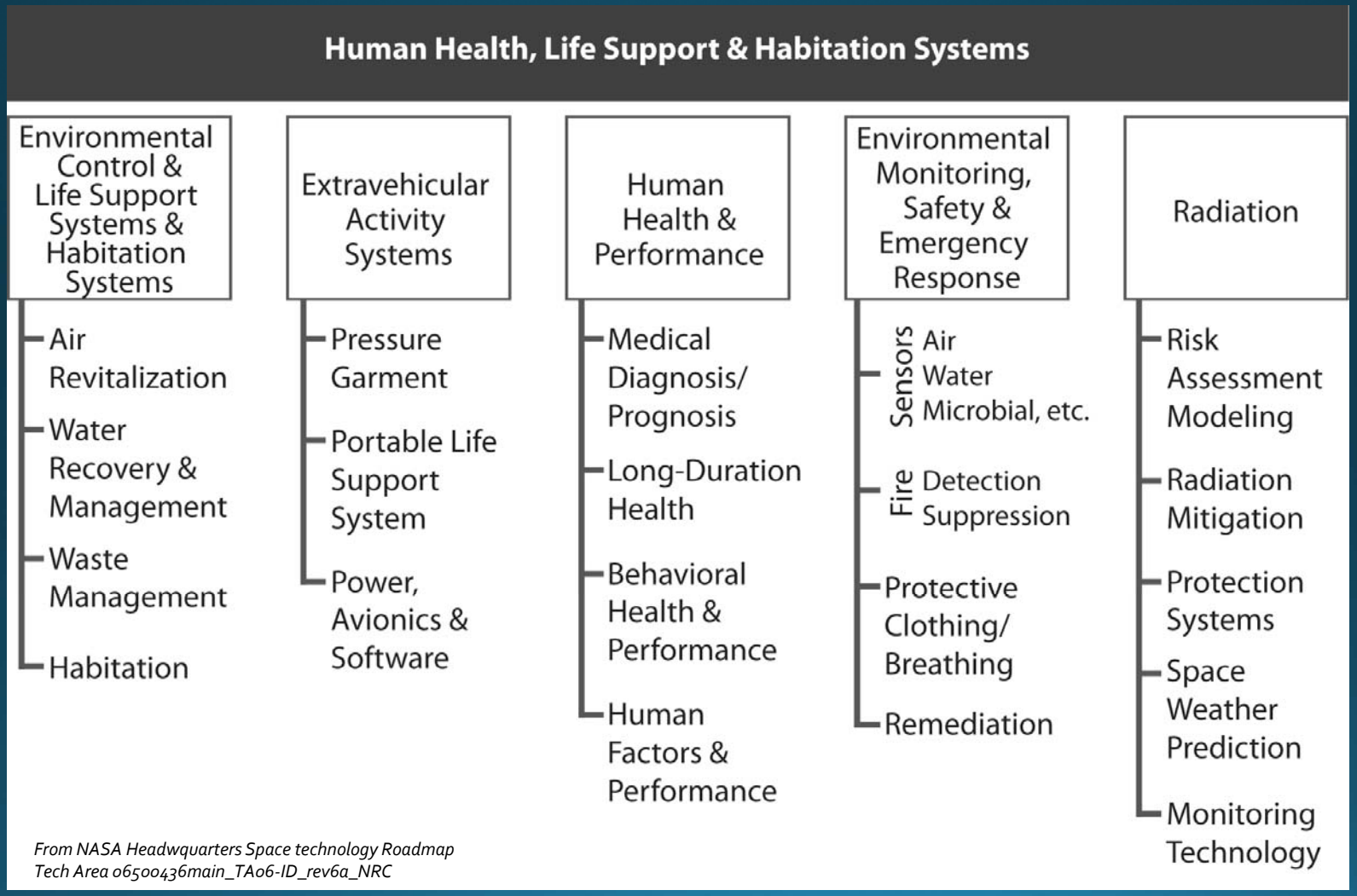
  ⇩

  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

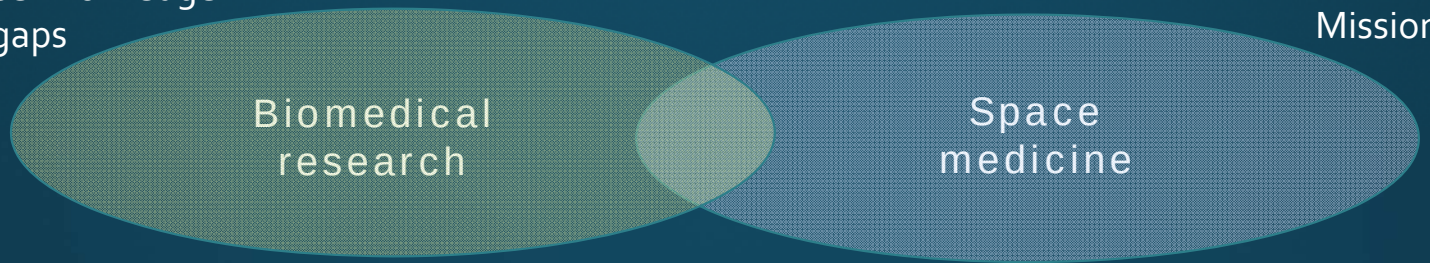
TECHNOLOGY AREA NEEDS



From NASA Headwquarters Space technology Roadmap
Tech Area 0650o436main_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

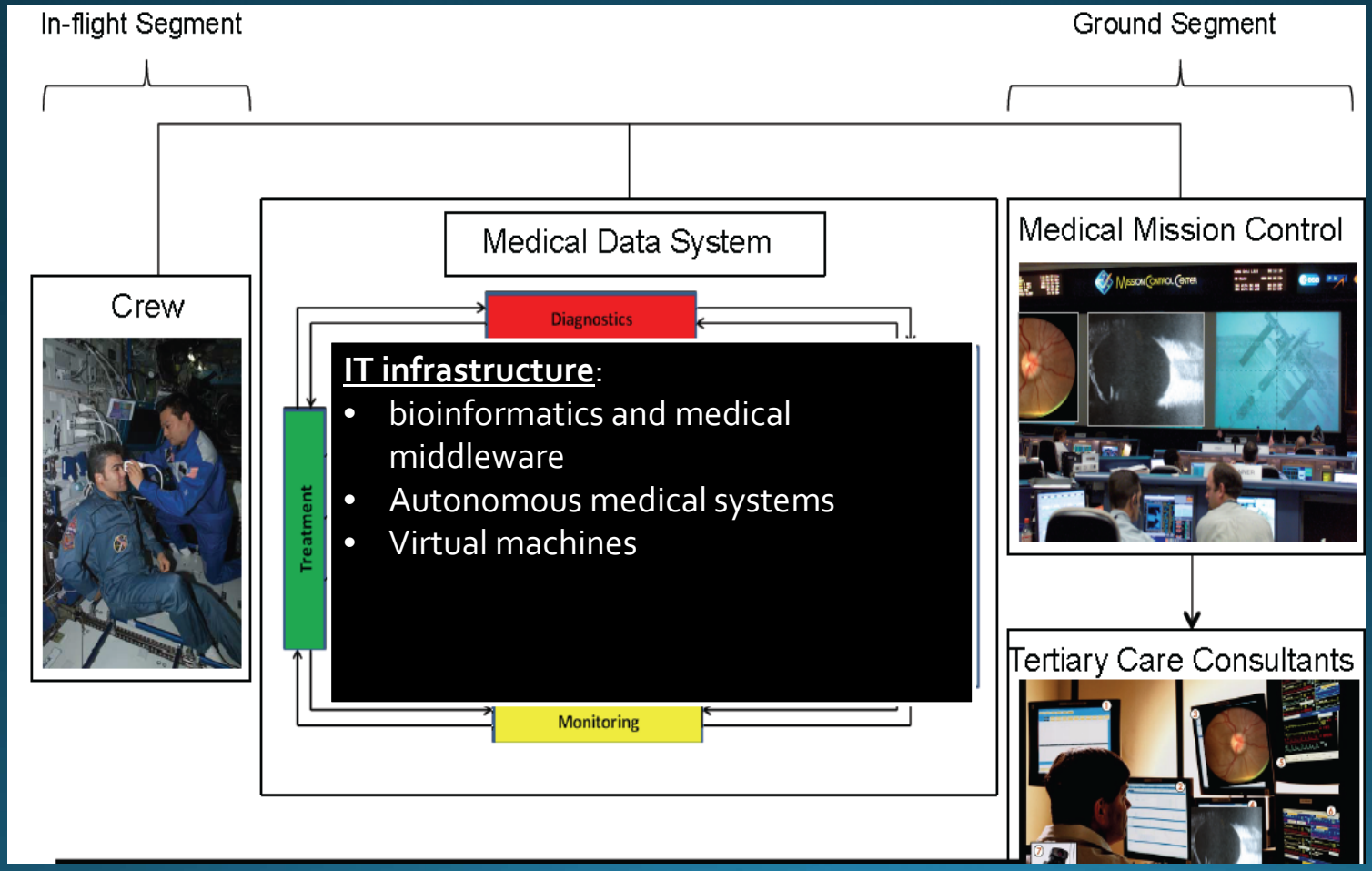
Bone Loss
Cardiovascular Alterations
Environmental Health
Immunology & Infection
Skeletal Muscle Alterations
Sensory-Motor Adaptation
Nutrition
VIIP

Clinical capabilities (space medicine)

Behavioral Health & Performance and Space
Human Factors (Cognitive)

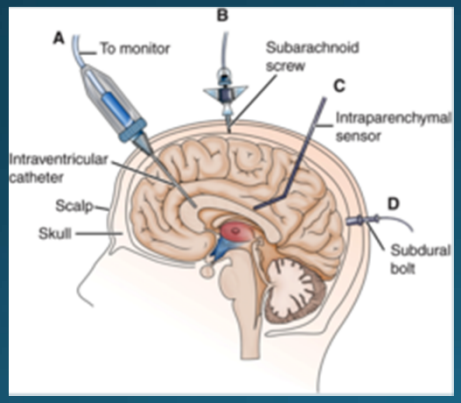
Advanced Environmental Monitoring & Control
Advanced Extravehicular Activity
Advanced Food Technology
Advanced Life Support
Space Human Factors Engineering

EXPLORATION MEDICAL SYSTEMS



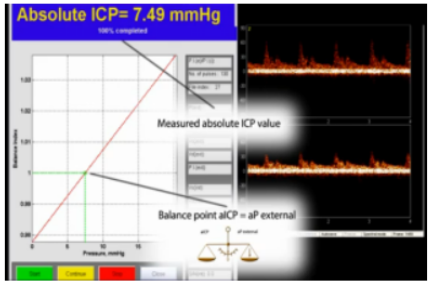
VIIP SYNDROME AND NON-INVASIVE ICP MEASUREMENT

Visual and ocular tests on ISS

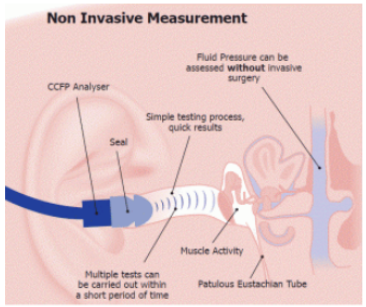


Intracranial pressure (ICP) measurement is invasive

Vittamed 205 Monitor



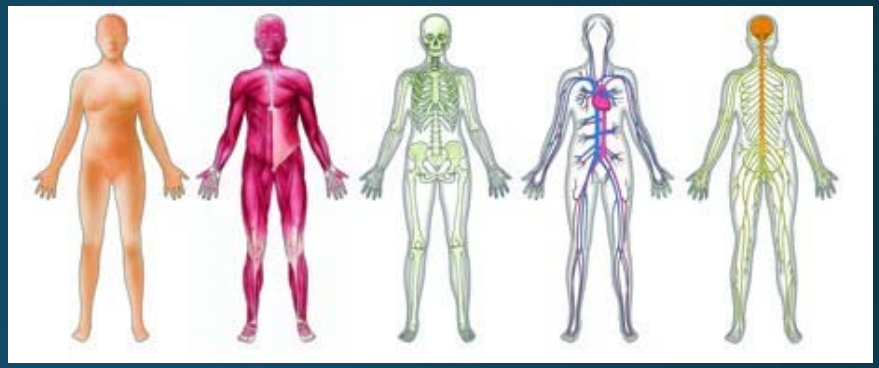
Cochlear and Cerebral Fluid Pressure (CCFP) Analyzer



Current non-invasive ICP measurement technologies under evaluation

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

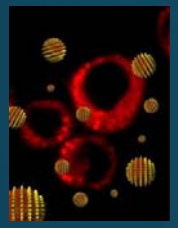
mRNA

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

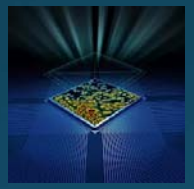
Microorganism culture (BioServe)

Cell culture system (Wyle)

Cell culture

Tissue culture

Bioreactor



Human body on a chip

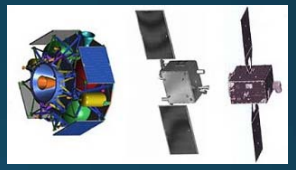
Plant/Animal models

Biomass production system (Orbitec)

Animal Enclosure Module (AEM)

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

ISS



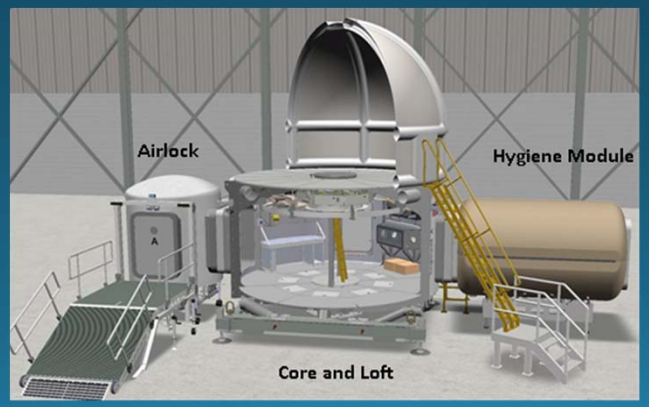
Micro-satellites

Commercial/ International collaborations (Russian Bion)

Examples of ISS Implementation Partners

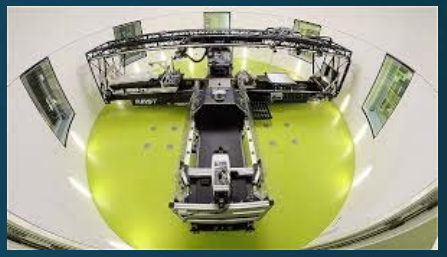
HUMAN FLIGHT ANALOGS

- 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

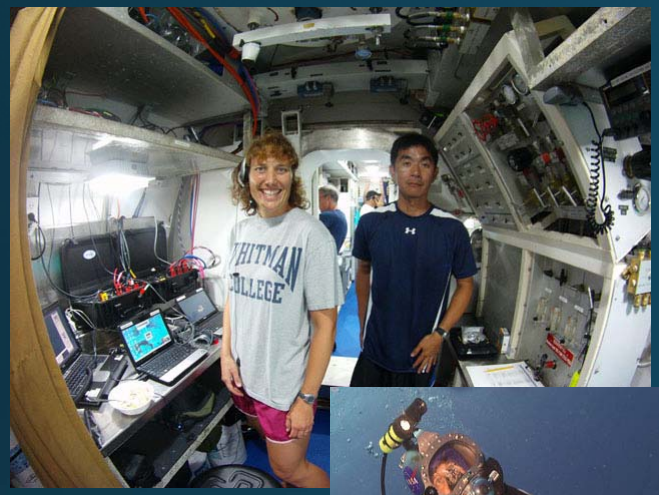
- 6º Head-down Tilt
  - serves as a model for studying the physiological changes that occur during spaceflight **under controlled conditions**
  - provides a ground-based platform for comparison to spaceflight;
  - provides a mechanism for testing countermeasures prior to being used in flight.
  - Excellent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

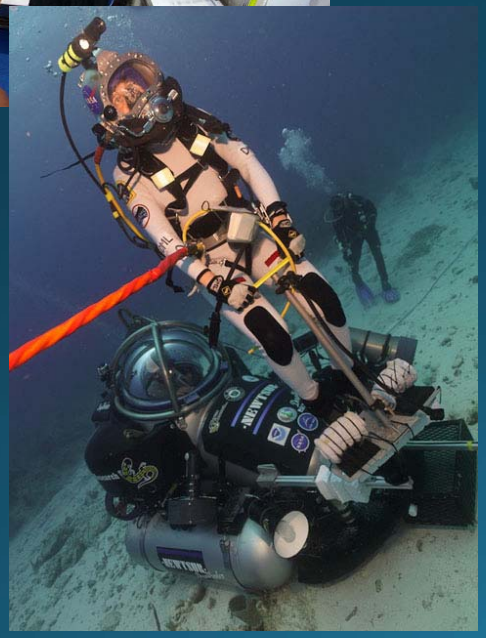


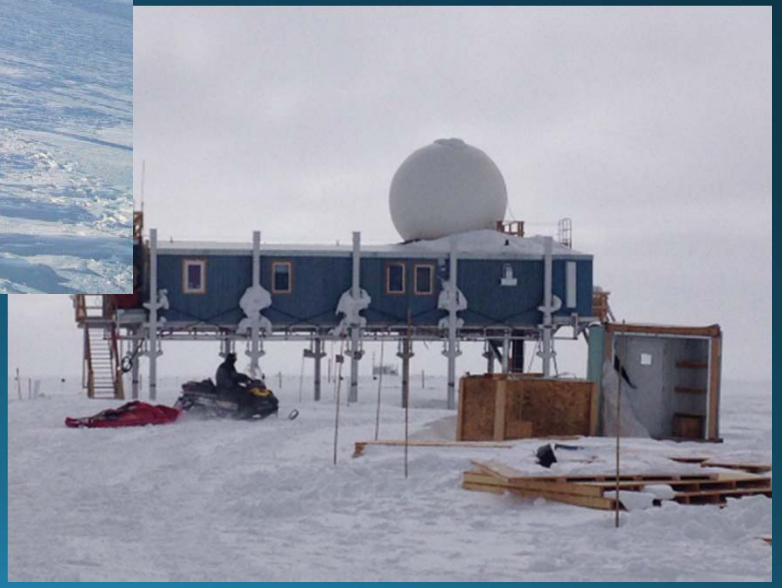
DLR Institute of Aerospace Medicine :enhivab, Cologne, Germany

NASA Bed Rest Facility, Galveston TX

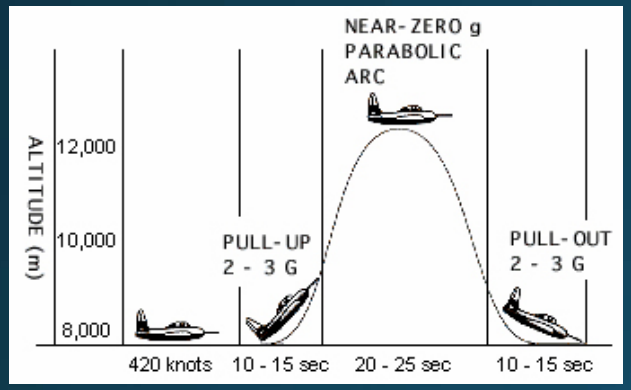
NEEMO AND POLAR ENVIRONMENTS







PARABOLIC FLIGHTS



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

THANK YOU

QUESTIONS?