

National Aeronautics and Space Administration



Physiological Health Protection in Space

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Exploring Further

NASA is embarking on a new era of space exploration in which humans will travel deeper into the solar system than ever before. The International Space Station is the centerpiece for space operations. Serving as a test bed for research and new technologies, the space station is a steppingstone toward future exploration destinations. The commercial industry will transport cargo and eventually crew to the space station while NASA focuses on developing the Orion Multi-Purpose Crew Vehicle, Space Launch System, and advanced exploration systems that will enable a sustainable human presence to destinations such as the moon, near-Earth asteroids and Mars.

To learn more, visit <http://www.nasa.gov/exploration>.

The Future of American Human SPACEFLIGHT

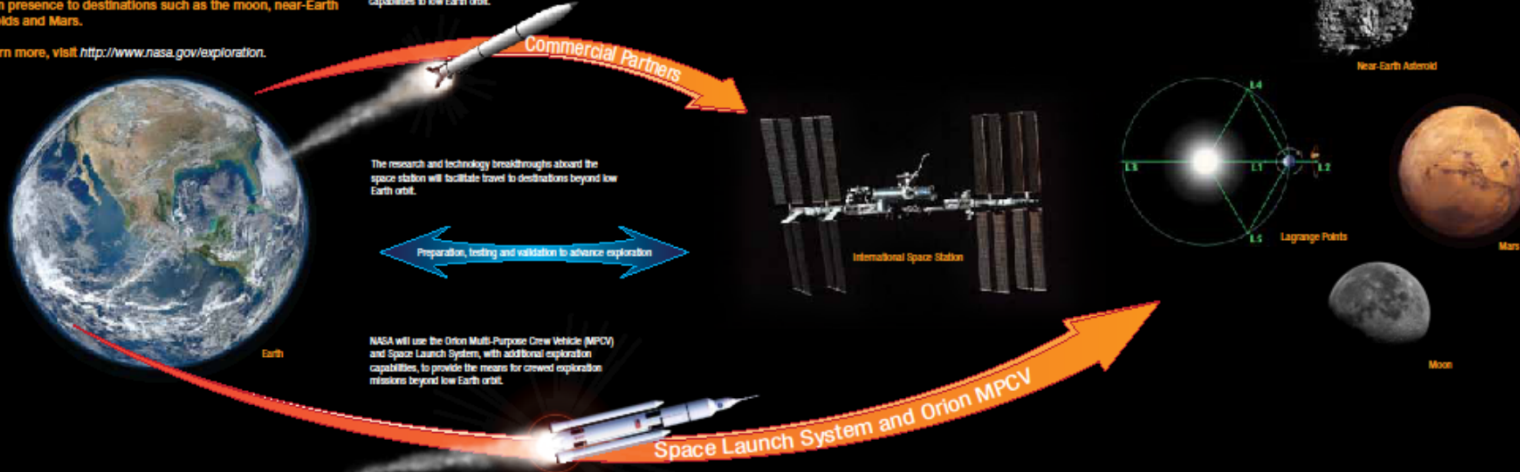
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Following NASA's innovative partnership activities and investments in U.S. commercial launch capabilities, the agency has purchased cargo transportation services to and from the Space Station and will continue to partner in the development of crew transportation capabilities to low Earth orbit.

"This is the next chapter that we can write together here at NASA. We will partner with industry. We will invest in cutting-edge research and technology. We will set far-reaching milestones and provide the resources to reach those milestones. And step by step, we will push the boundaries not only of where we can go but what we can do..."

— President Barack Obama



Destinations

Lagrange Points

Lagrange Points are microgravity destinations beyond low Earth orbit that provide opportunities for construction, testing and repair of complex in-space systems. These points in space can serve as a gateway to reaching multiple destinations in our solar system.

Near-Earth Asteroids

These near-Earth objects may provide answers to some of humankind's most compelling questions, such as these: How did the solar system form? Where did Earth's water and other organic materials come from?

Moon

Earth's nearest neighbor provides significant opportunities for commercial and international collaboration and has critical resources needed to sustain human explorers.

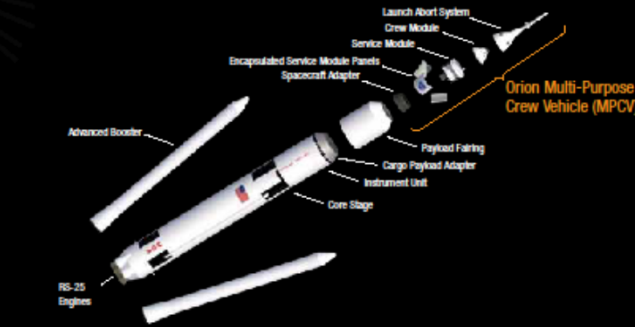
Mars

Mars provides the best opportunity to demonstrate that humans can live for extended — even permanent — stays beyond low Earth orbit. The technology and space systems required to transport and sustain explorers on Mars will expand scientific knowledge and drive technological innovation.

Commercial Spaceflight Development

NASA is investing financial and technical resources to stimulate efforts within the commercial industry to develop and demonstrate cargo and crew space transportation capabilities to and from low Earth orbit.

Cargo Partners	Commercial Company	Spacecraft	Launch Vehicle
	Space Exploration Technologies (SpaceX)	Dragon (Cargo)	Falcon 9
	Orbital Sciences Corporation (Orbital)	Cygnus	Antares
Funded Crew Partners	Commercial Company	Spacecraft	Launch Vehicle
	Blue Origin	Crew Transportation System	Initial — Atlas V Final — Open Reusable Booster System
	Sierra Nevada Corporation	Dream Chaser	Atlas V
	SpaceX	Dragon (Crew)	Falcon 9
	The Boeing Company	Crew Space Transportation (CST)-100	Initial — Atlas V



Human Spaceflight Capabilities

NASA is developing next-generation spaceflight technology to explore multiple destinations throughout the solar system. New technology systems include the following:



Launch Vehicle	Saturn V	Space Shuttle	Space Launch System
Years	1967–1973	1981–2011	Initial LRI Capability: First uncrewed launch planned for 2017 Evolved LRI Capability: To be determined
Height	111 m (363 ft)	56 m (184 ft) (Orbiter 122 ft)	97 m (318 ft) → 115 m (376 ft)
LRI Capability to Low Earth Orbit	118 metric tons	28 metric tons (to 28.2° inclination)	70 metric tons → 130 metric tons
Crew Capsule/Capacity	Apollo Spacecraft	Orbiter	Orion MPCV Cargo Configuration Shows



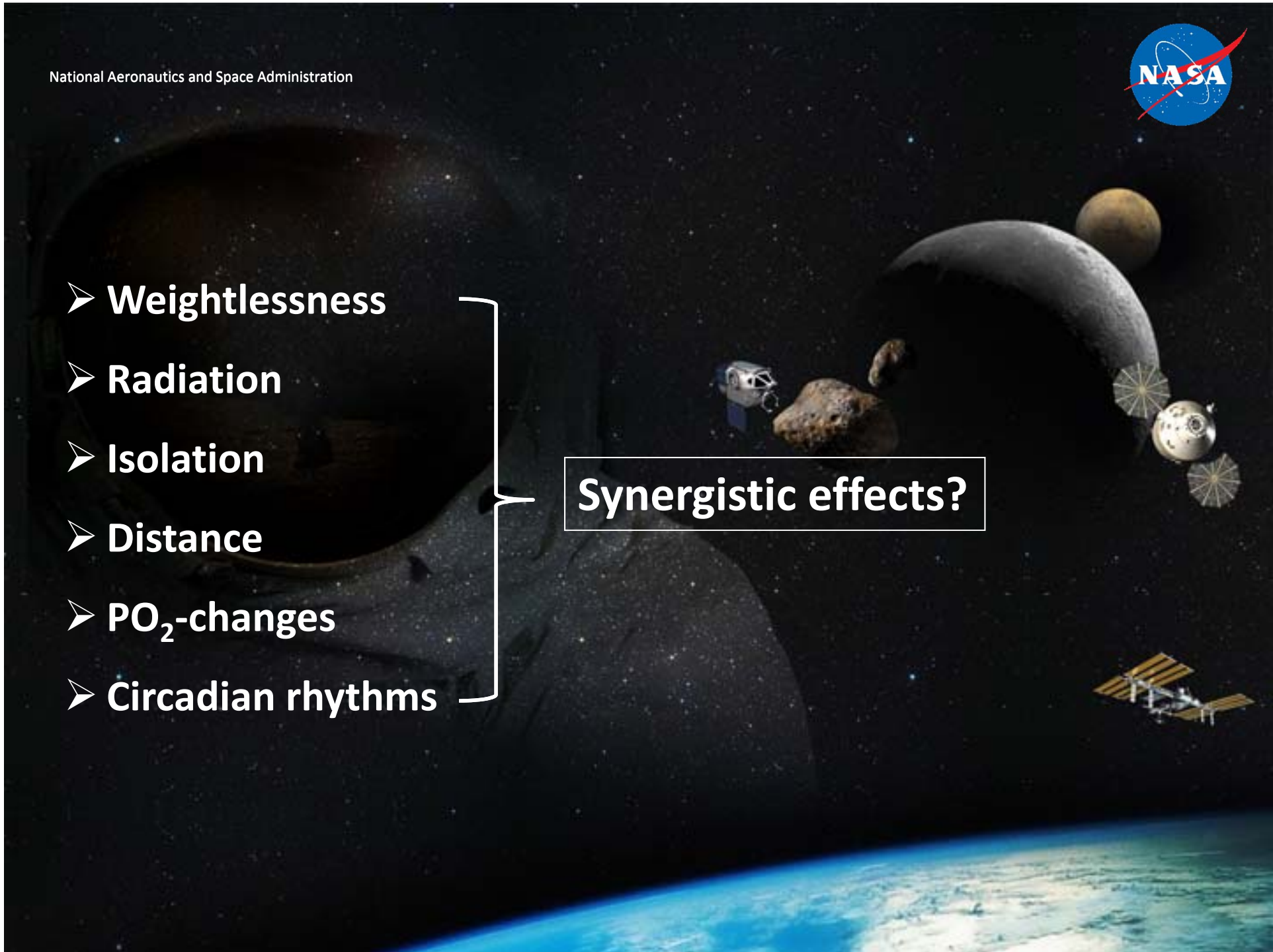
- **Weightlessness**
- **Radiation**
- **Isolation**
- **Distance**
- **PO₂-changes**
- **Circadian rhythms**



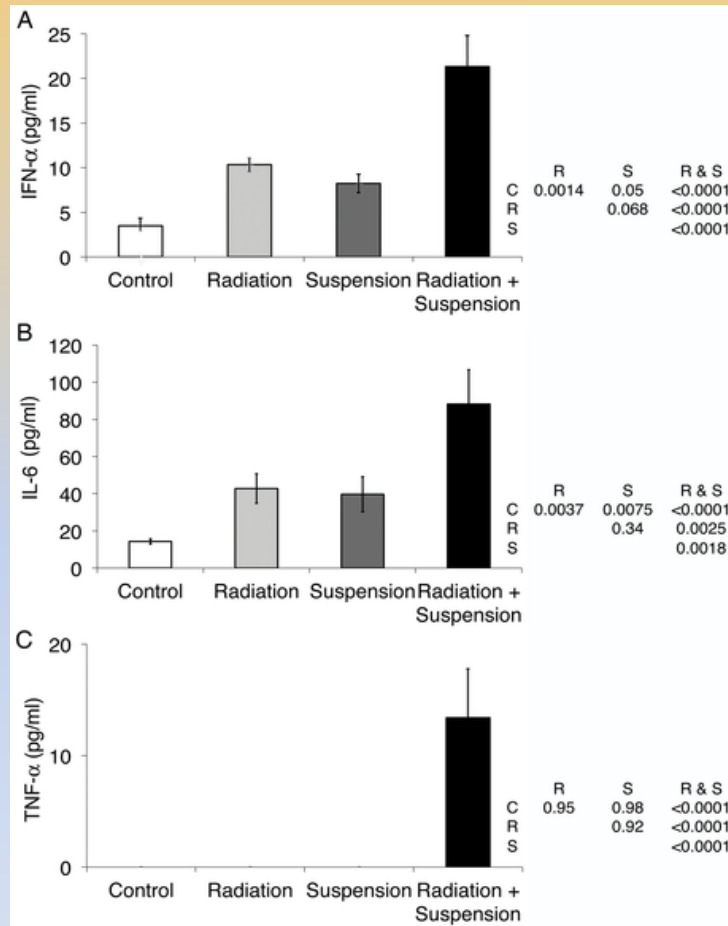


- **Weightlessness**
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Synergistic effects?



Example



An example of synergistic effects of 0 G-simulation and radiation (2 Gy)

Zhou Y, Ni H, Li M, Sanzari JK, et al. (2012) PLoS ONE 7(9): e44329. doi:10.1371/journal.pone.0044329

<http://www.plosone.org/article/info:doi/10.1371/journal.pone.0044329>

Present platform in LEO

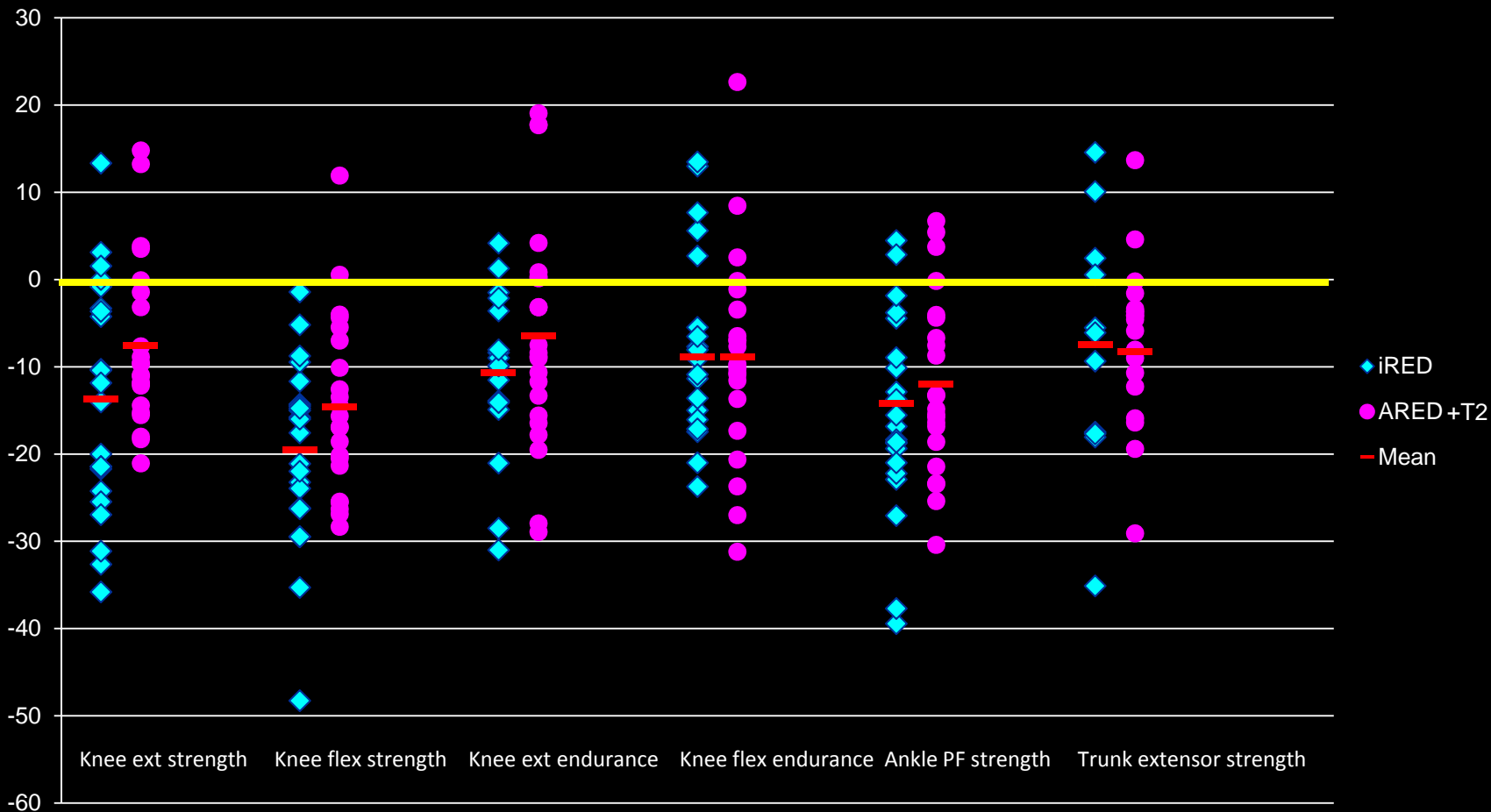






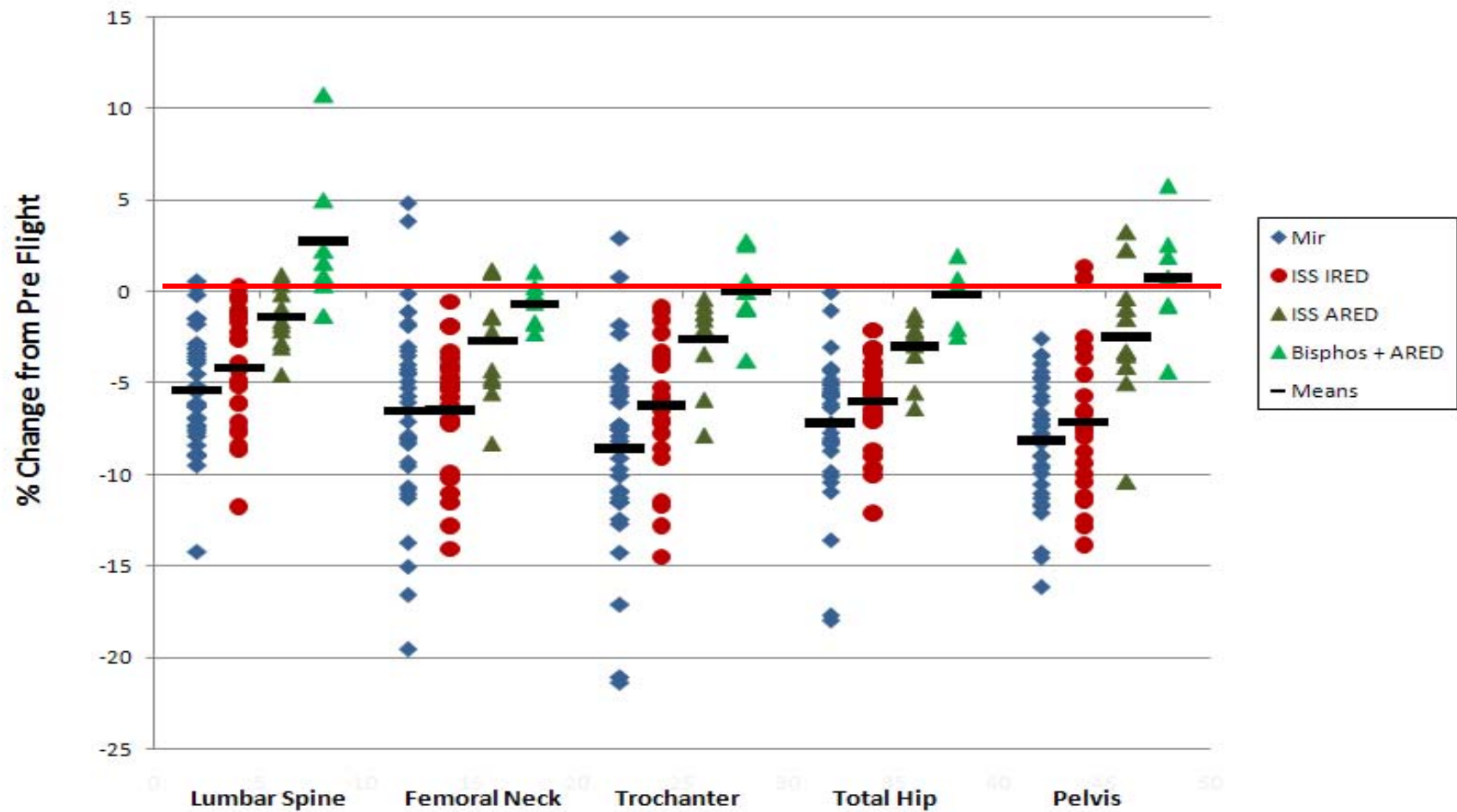
Muscle Function

Exp 1-32 (IRED n=22 ARED+T2 n=25)



% Change in DXA BMD after Long-Duration Mir and ISS Missions

Mir n=35; ISS IRED n=24; ISS ARED n=11; Bisphos + ARED n=7



1217

* Updated data since 2010 Bone Summit

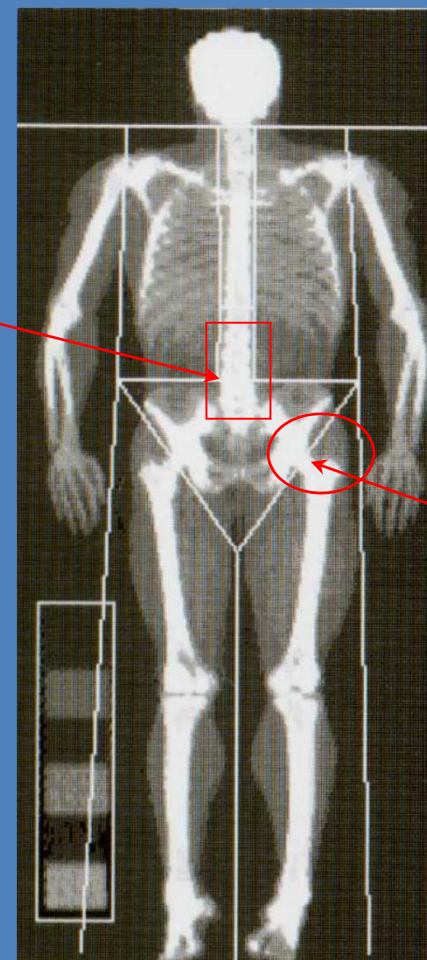
DXA: BMD losses are regional and rapid



Areal BMD g/cm ²	%/Month Change \pm SD
Lumbar Spine	-1.06 \pm 0.63*
Femoral Neck	-1.15 \pm 0.84*
Trochanter	-1.56 \pm 0.99*
Total Body	-0.35 \pm 0.25*
Pelvis	-1.35 \pm 0.54*
Arm	-0.04 \pm 0.88
Leg	-0.34 \pm 0.33*
*p<0.01, n=16-18	

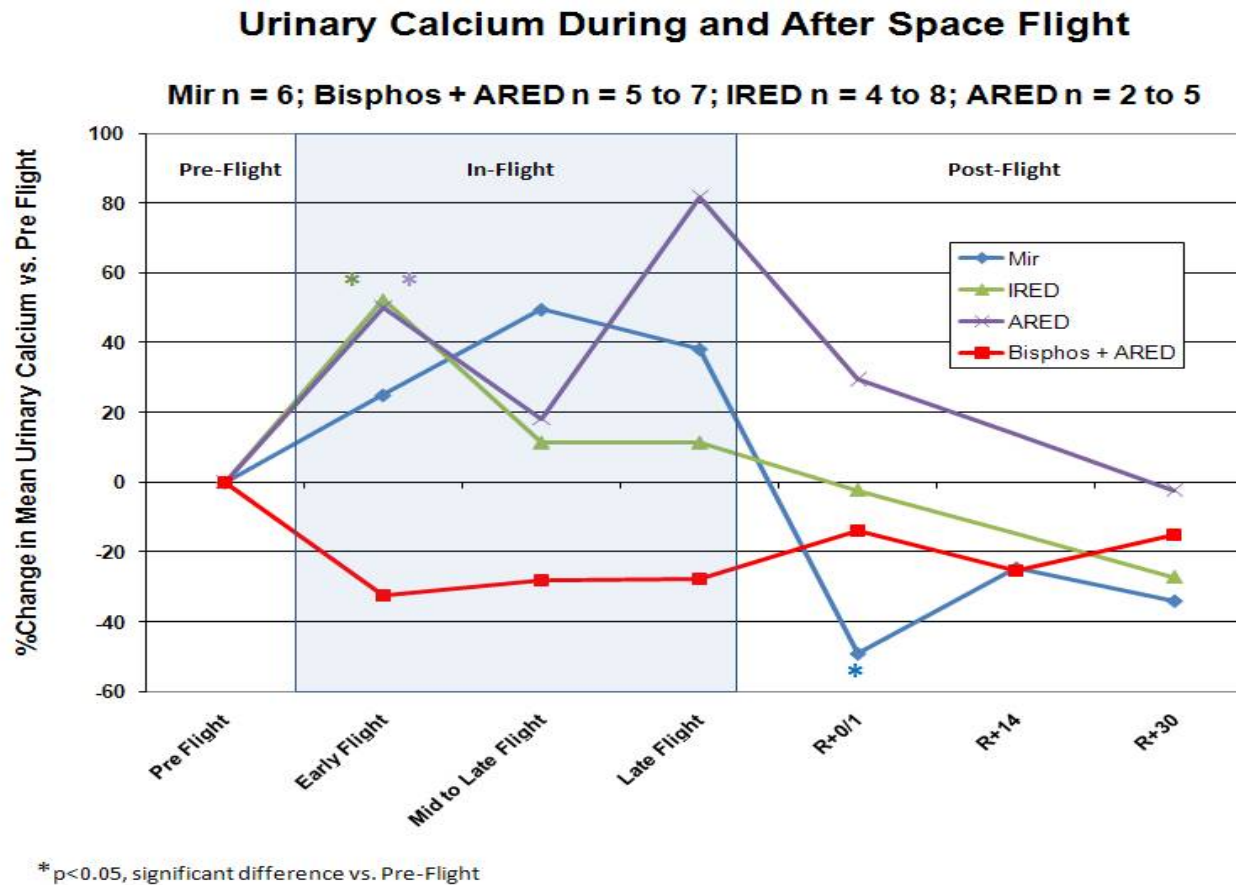
Whole Body
0.3% / month

Lumbar Spine
1% / month



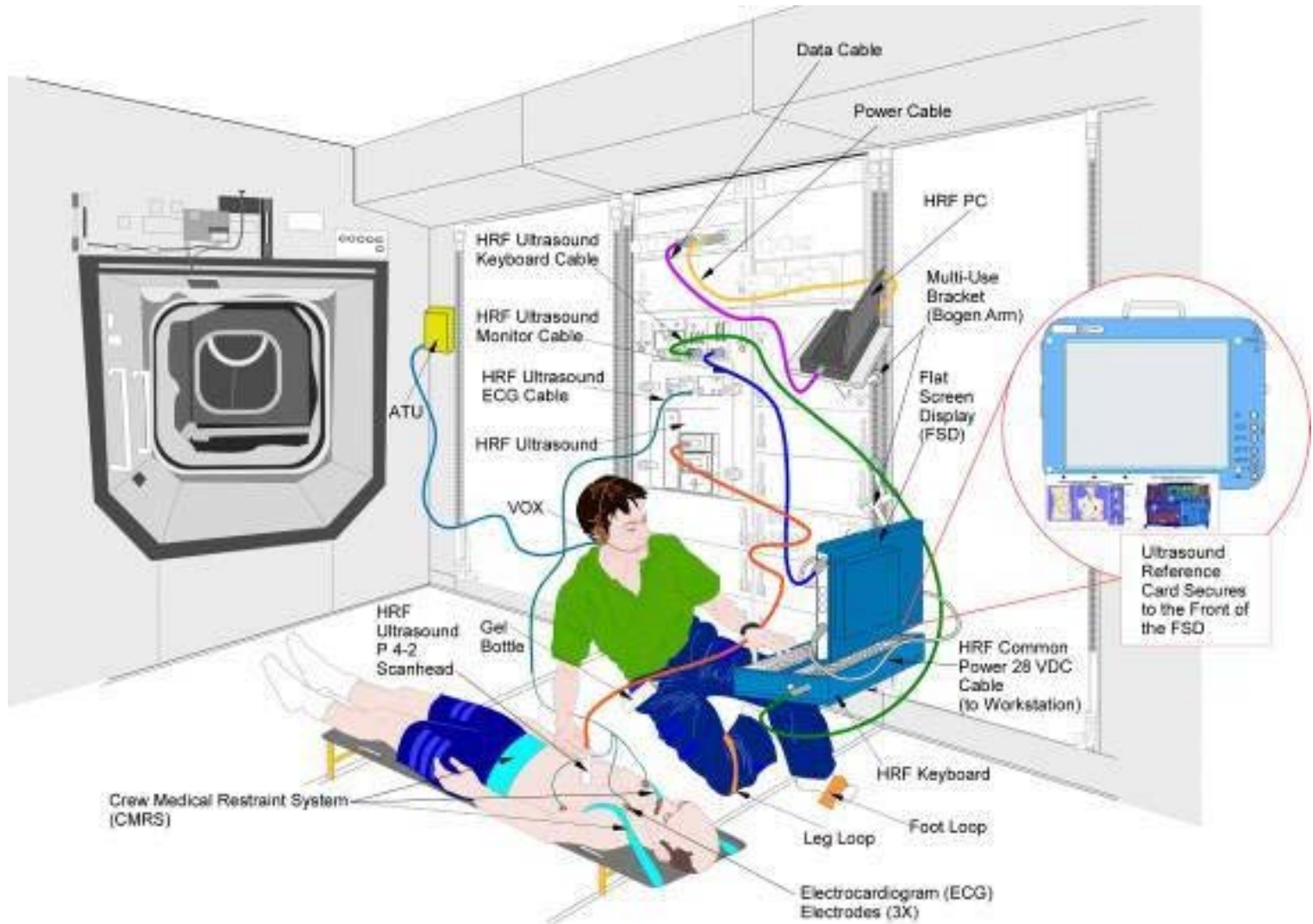
Hip
1.5% / month

Bisphosphonates as a Countermeasure to Spaceflight Effects - mitigates of urinary calcium excretion



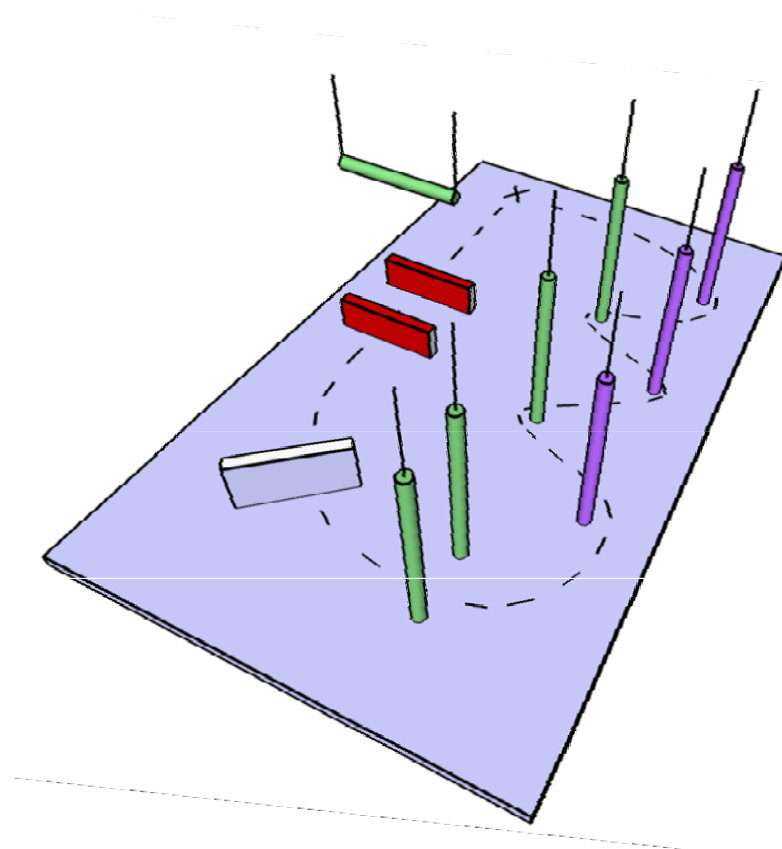
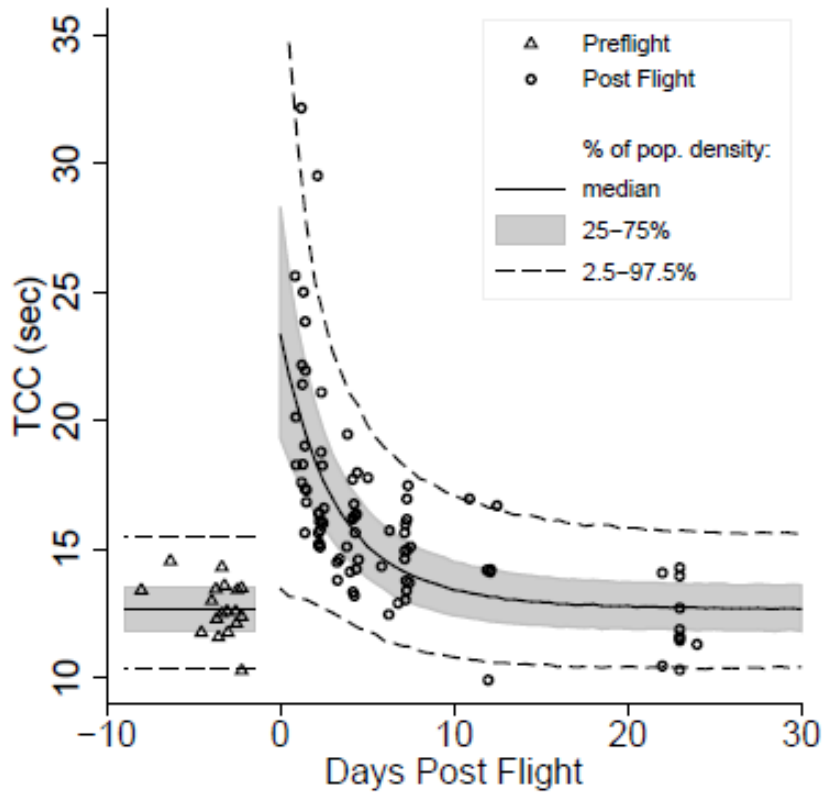
Slide courtesy of Dr. A. LeBlanc

'Integrated Cardiovascular'





Time to Complete Course

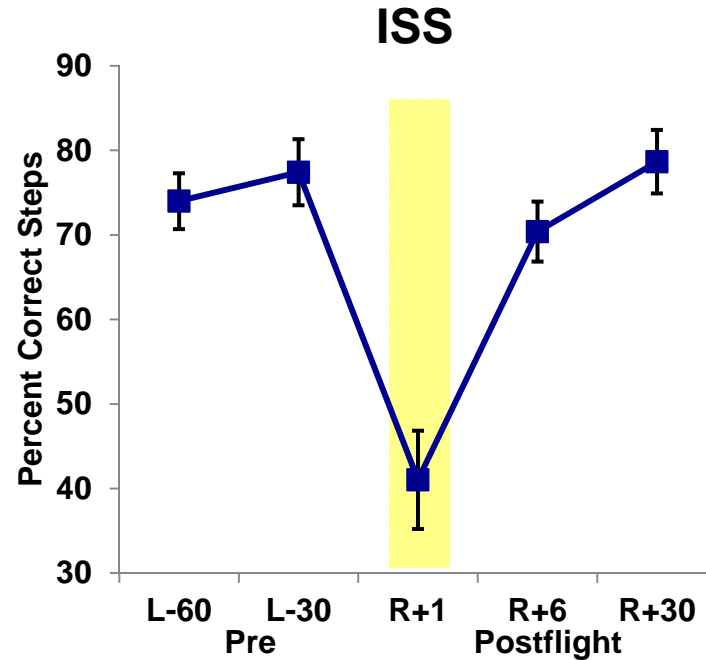
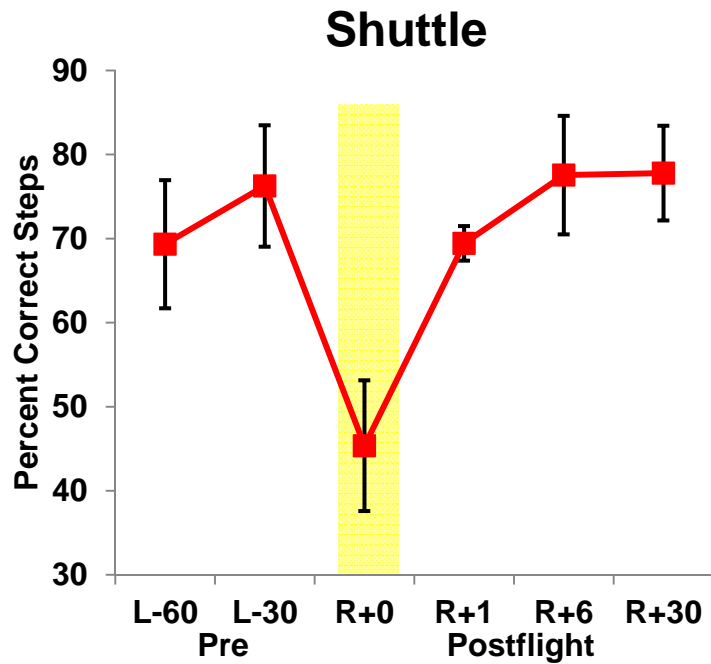


Recovery of functional mobility to 95% of preflight level took 15 days.

N = 18

Mulavara AP, Feiveson A, Feidler J, Cohen HS, Peters BT, Miller CA, Brady R, Bloomberg JJ. Experimental Brain Research. 202(3): 649-59. 2010.

Tandem Walk Test



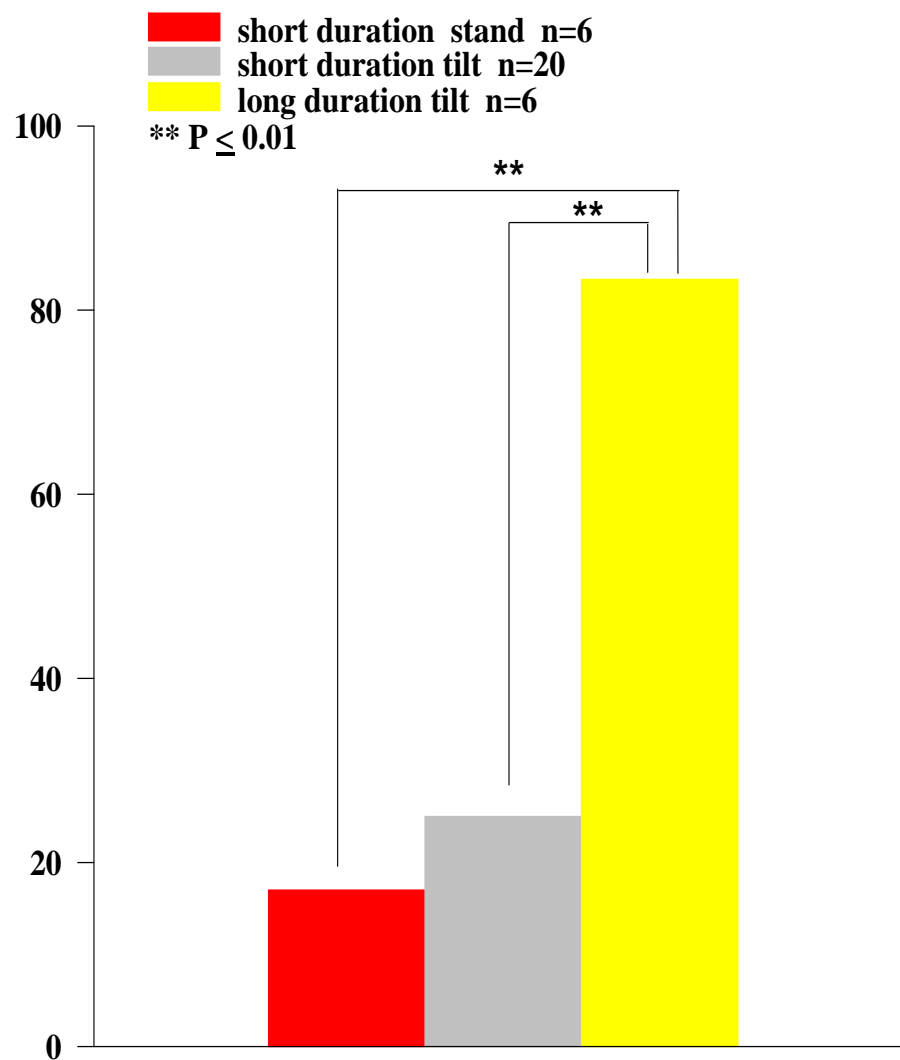
Incorrect Steps:

sidestepped, opened eyes,
or paused for more than
three seconds between steps





Incidence of Presyncope
on Landing Day, %



Meck et al.,
*Psychosomatic
Medicine*, 63:865-873,
2001



Orthostatic Intolerance

- Mitigated by:
 - Oral salt and fluid loading
 - Antigravity garment
 - Additional clinical i.v fluid treatment



VIIP Syndrome

Fluid shift induced vision and intracranial pressure changes!



Example of cephalad fluid shift



Preflight press briefing



FD-2

Integrated Visual Impairment/Intracranial Pressure Project

Risk Background - Symptoms

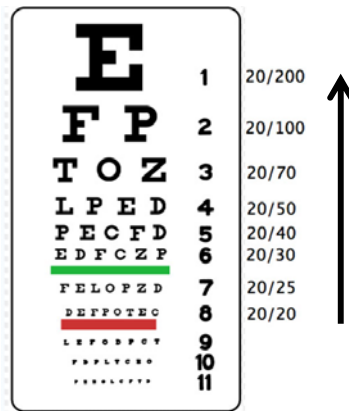


Background:

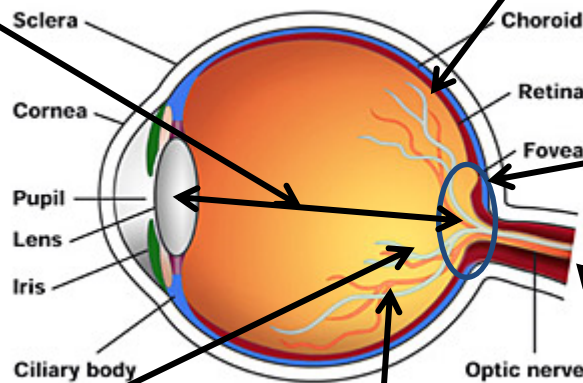
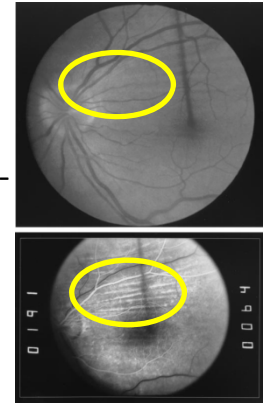
- 8 known “clinical cases” (of 34 long duration crew) members
 - Each with different degrees of symptoms
 - Elevated measures of **Intracranial Pressure (ICP)** post flight

•Hyperopic Shifts

-Up to +1.75 diopters



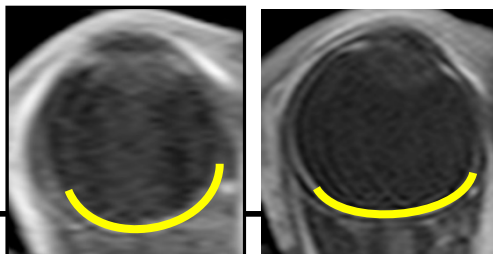
•**Choroidal Folds** - parallel grooves in the posterior pole



•**Optic Disc Edema (swelling)**



•Globe Flattening



Normal Globe

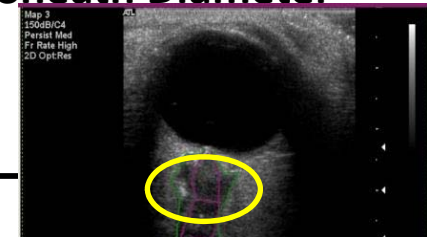
Flatten Globe

MRI Orbital Image showing globe flattening

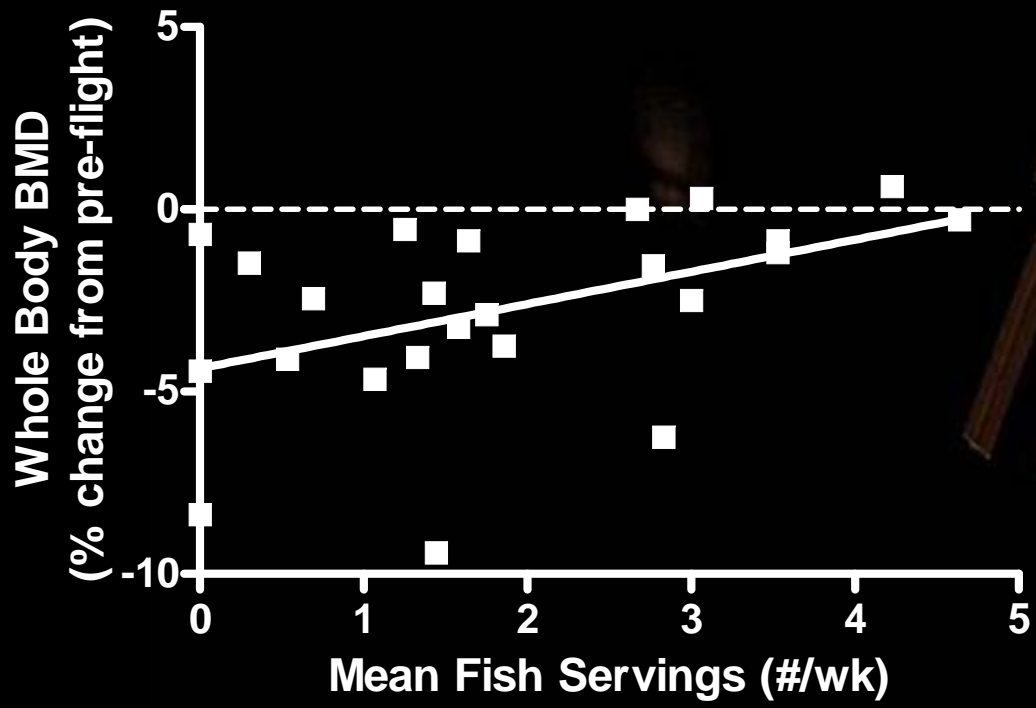
•**Altered Blood flow**
•“cotton wool” spots



•**Increased Optic Nerve Sheath Diameter**

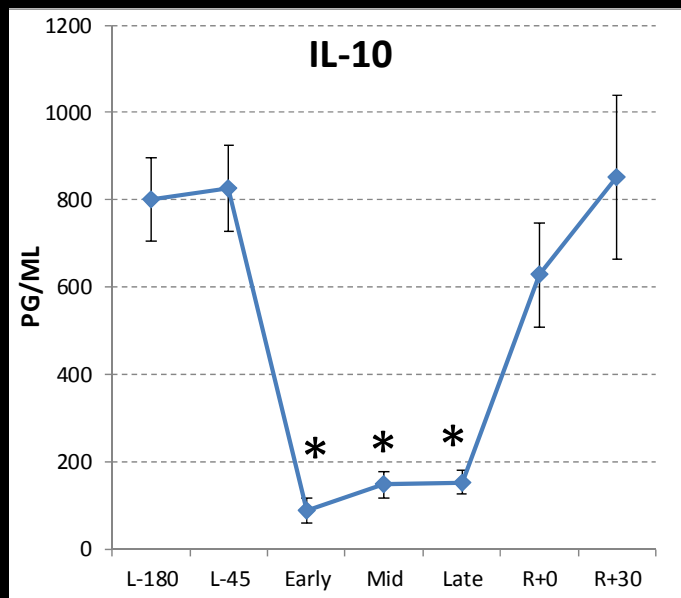


no pre-existing tone, would probably first a...
... however slight, in bodily structure...
... of so, whether the variations are transi...
... accordance with the laws which prevail with...
... and, are the variations the result, as far...
... as to judge, of the same general cause...
... the same general laws, as in the case of an...
... in correlation, the liberated effect...
... connect to similar relationships...
... of reduplication of part...
... of the animal's resources to a...
... of sight also necessary to a...
... of sight.

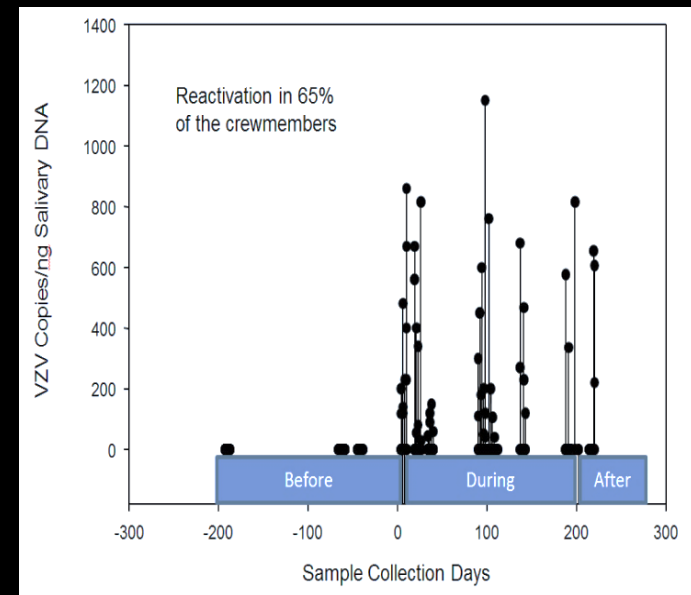


Immunity is Altered During Long-duration Spaceflight onboard ISS

Cytokine Production Profiles



Latent Herpesvirus Reactivation



Future approach

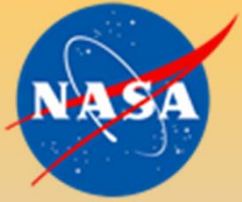
IPCS:

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Integrated
Physiological
Countermeasure
Suite

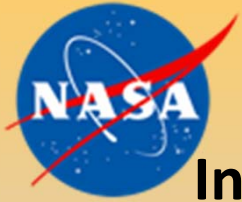
Based on ISS Research



Integrated Physiological Countermeasure Suite

Pre-flight

- Establish healthy life style: Exercise, food intake
- Develop individualized CM-protection programs: Computer modeling, G-transition training



Integrated Physiological Countermeasure Suite

In-flight

Monitoring

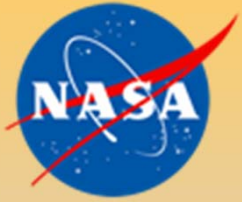
- Immune/OSaD-biomarkers (Lab analysis of urine, blood, saliva)
- Cardiovascular, VIIP, muscle/bone (ultrasound, ECG, BP, OCT, CCFP/TCD, vision, cognition)

Training & Prevention

- Sensory-motor adaptation: Computer programs , vestibular (galvanic) stimulation
- Exercise prescriptions: Aerobic and resistive
- EVA pre-breathing
- Functional food items: Omega-3, anti-oxidants, low salt and iron
- Anti-osteoporotic medications: Bisphosphonates, anabolics, ACE-inhibitors

Treatment and prevention

- Anti-VIIP bracelets (+/- dynamic exercise) and/or medication
- Anti-motion sickness & anti-inflammatory medications (medication stability monitoring)
- Anti-orthostatic pre-landing fluid and salt ingestion



Integrated Physiological Countermeasure Suite

Planetary landing

- Anti-orthostatic garment and fluid/salt treatment
- G-transition medication, vestibular (galvanic) stimulation



Integrated Physiological Countermeasure Suite

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Planetary landing:

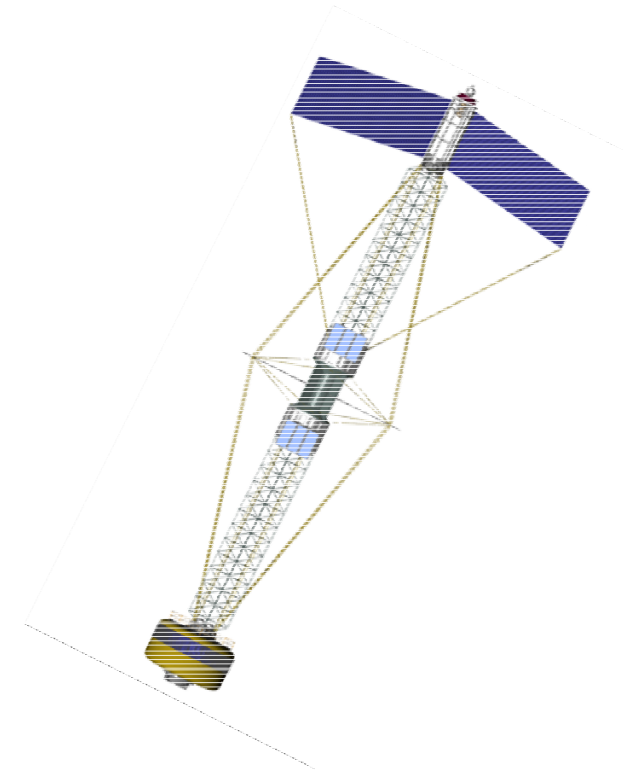
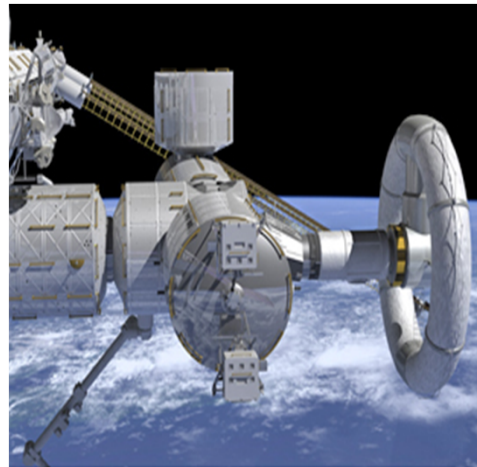
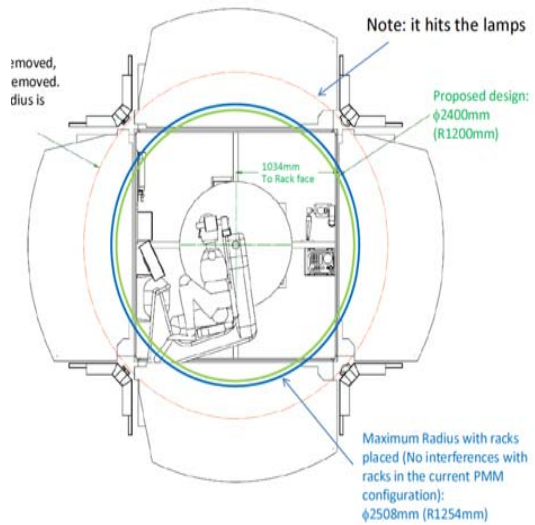
- Anti-orthostatic garment and fluid/salt treatment
- G-transition medication, vestibular (galvanic) stimulation

But -

But – why not bring gravity?



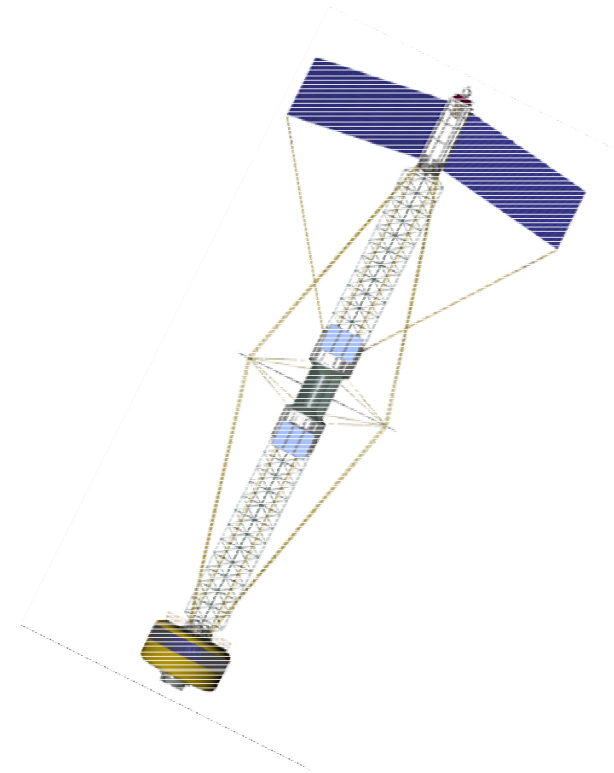
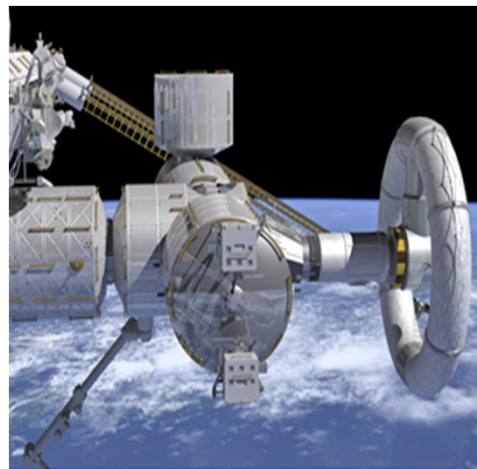
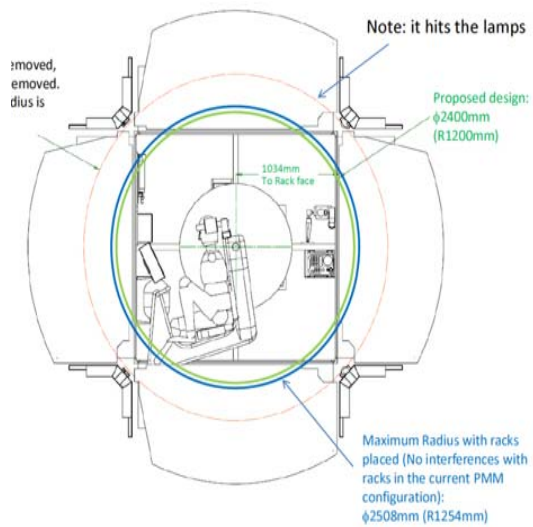
Artificial Gravity



Spinning:



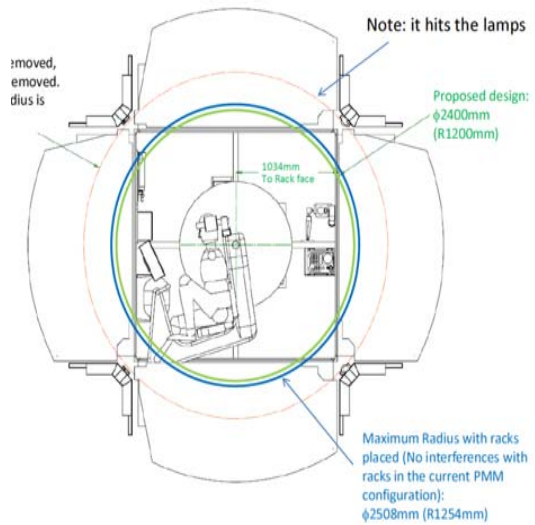
Artificial Gravity



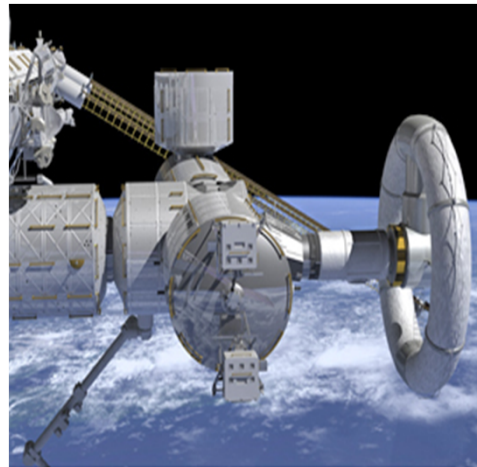
Spinning:
Inside



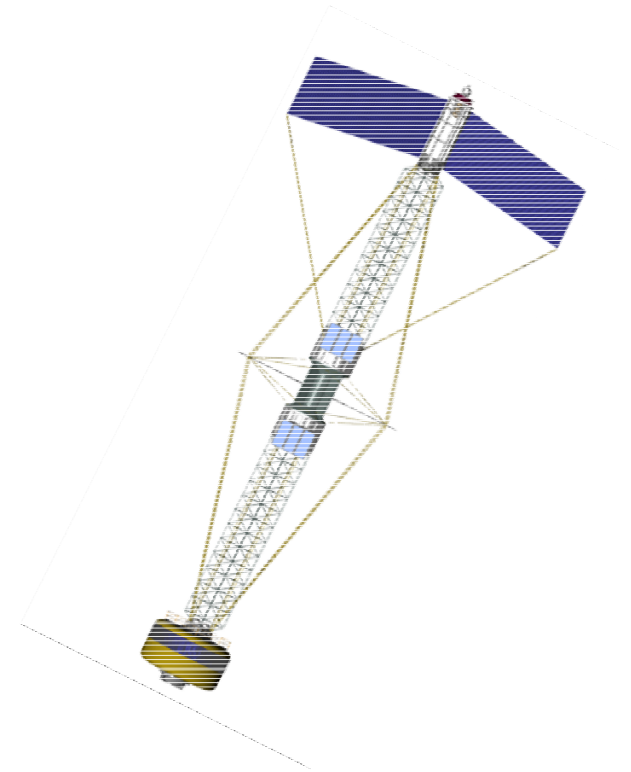
Artificial Gravity



Spinning:
Inside

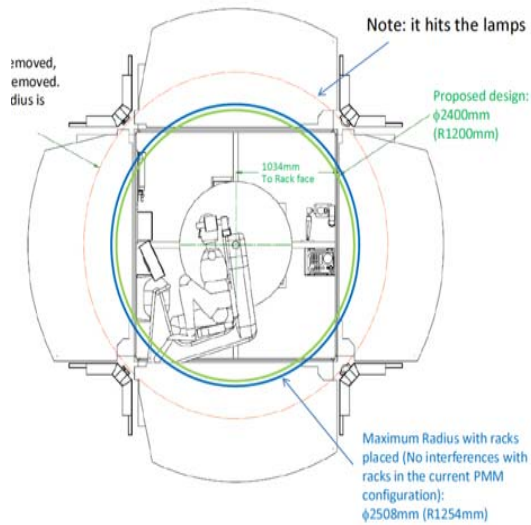


Part of

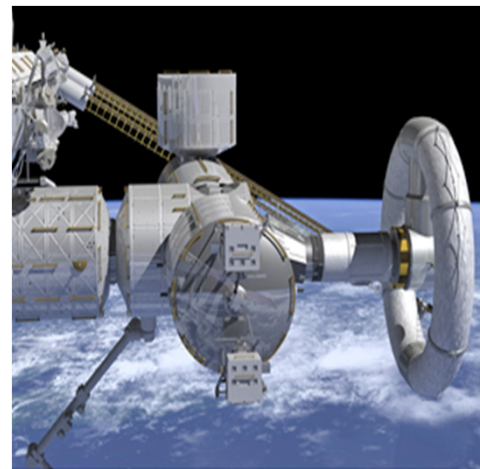




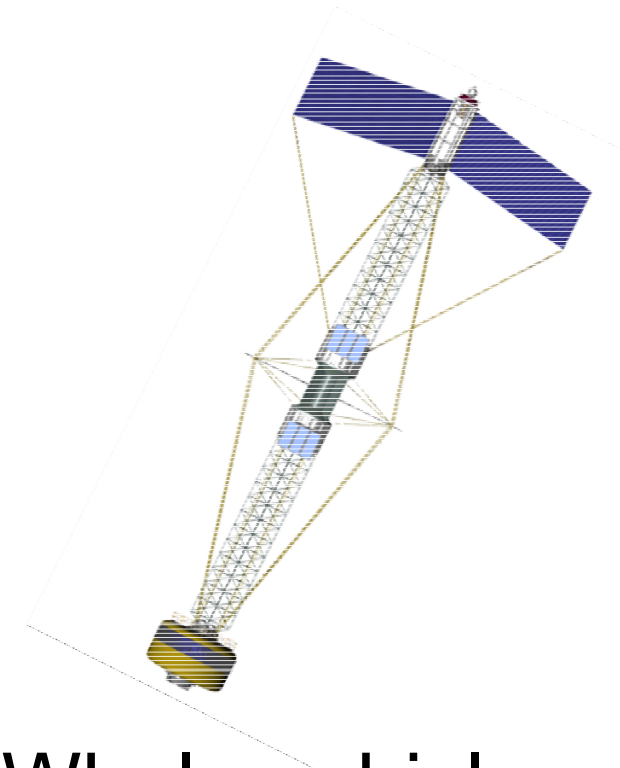
Artificial Gravity



Spinning:
Inside



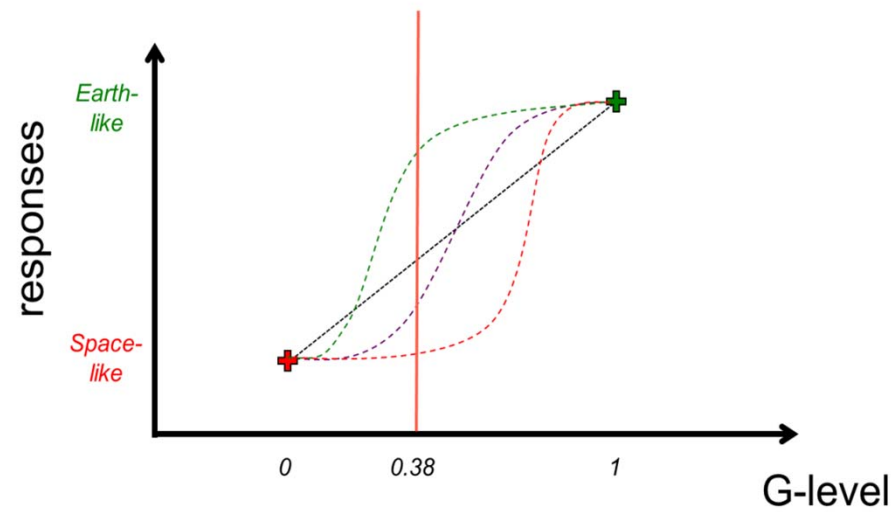
Part of



Whole vehicle



Physiological Responses to Hypogravity?



We don't know:

- The minimum artificial gravity level?
- The protection of Martian gravity?



Thank
you!