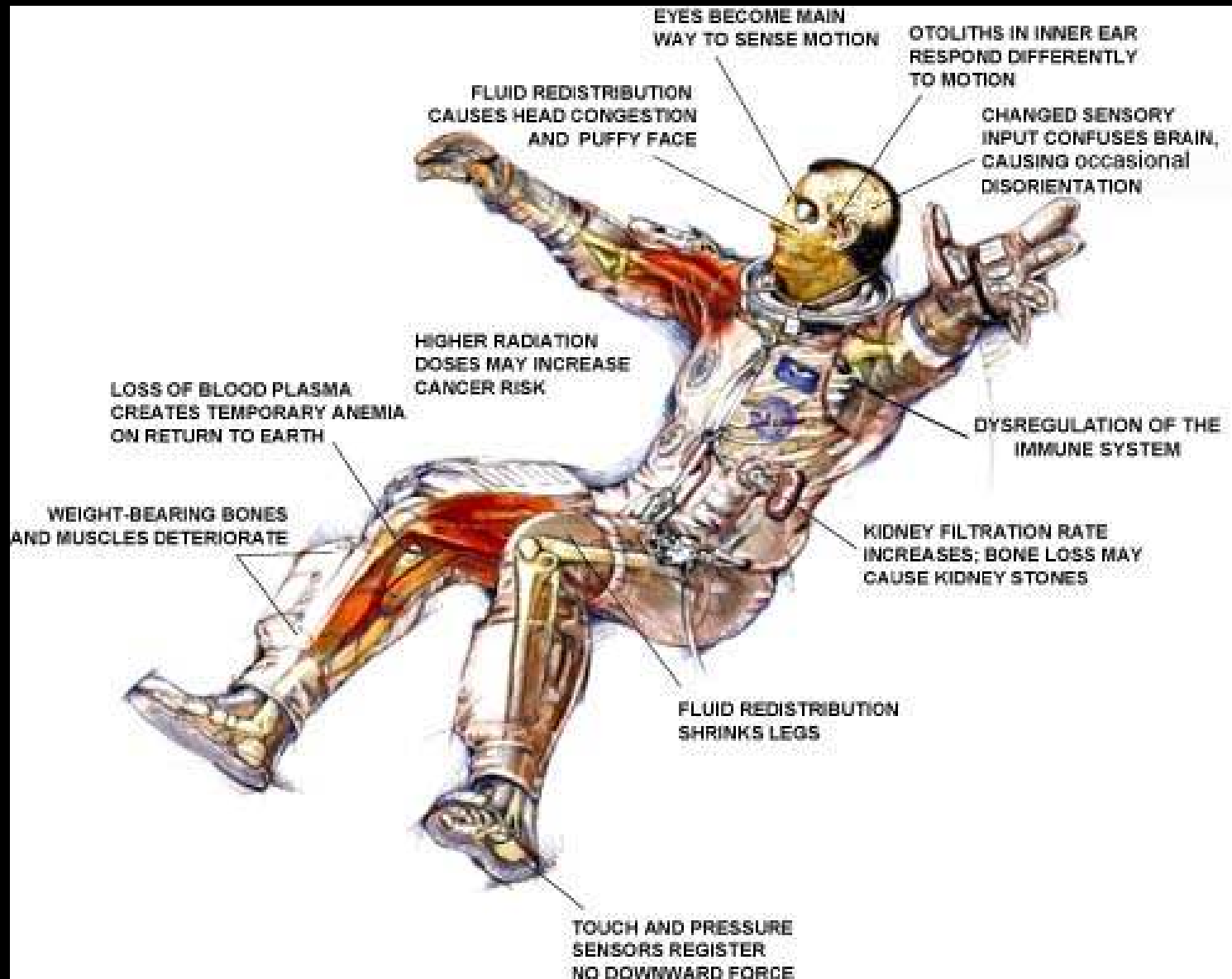


Medical Concerns for Exploration Class Space Missions



Brian Crucian, Ph.D.
September 20, 2011

Microgravity Effects on the Human Body



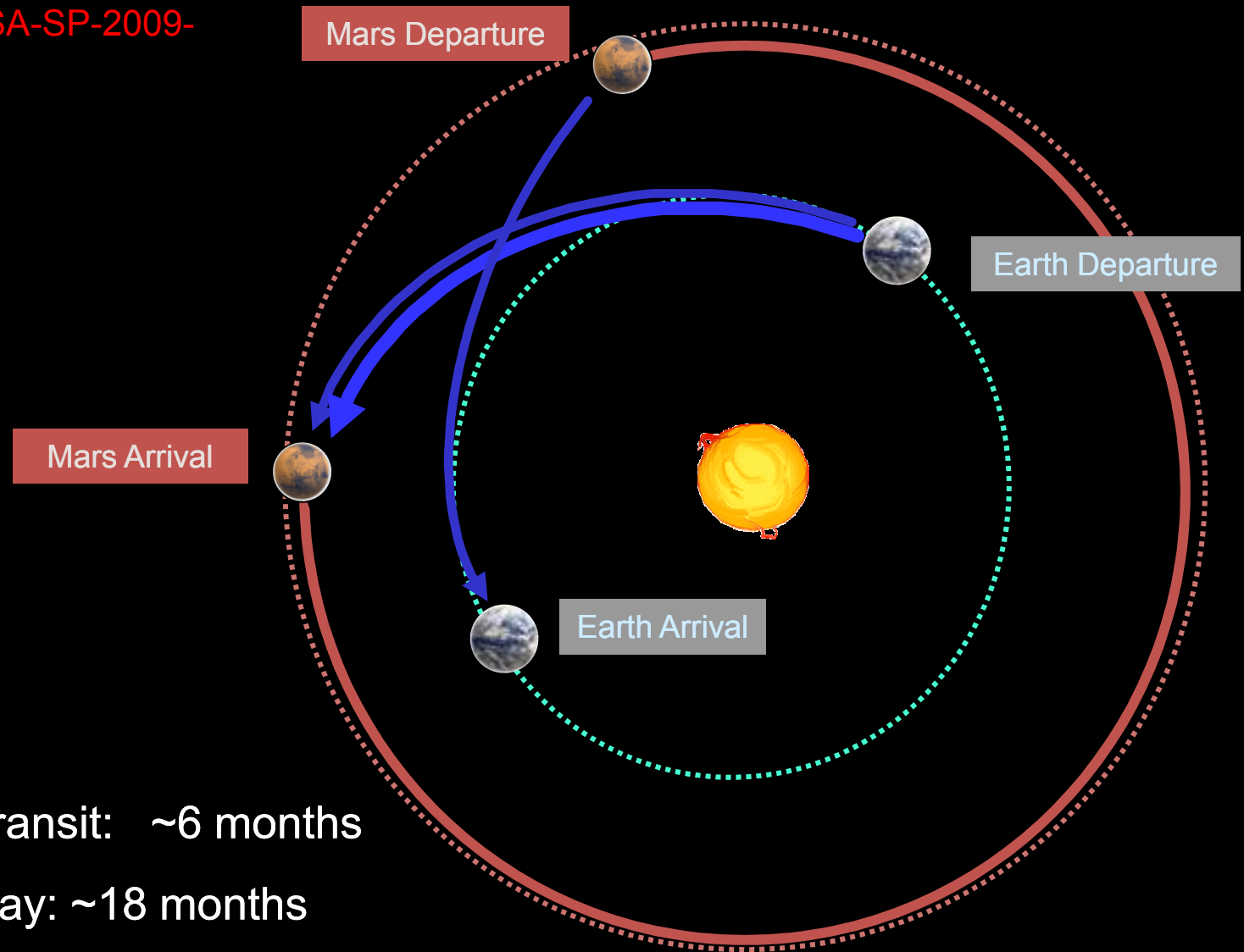
Life Sciences Research Laboratories (Bldg. 37)

- Immunology Laboratory
- Nutrition Laboratory
- Radiation Laboratory
- Microbiology Laboratory
- Neurovestibular Laboratory
- Clinical Laboratory
- Muscle Laboratory
- Bone Laboratory
- Toxicology Laboratory
- Cardiology Laboratory



Overview of *Hypothetical* Mars Expedition

Based on: [Human Exploration of Mars, DRA 5.0, NASA-SP-2009-566](#), July 2009



Earth-to-Mars transit: ~6 months

Mars surface stay: ~18 months

Mars-to-Earth transit: ~6 months

Recent changes to NASA vehicle plan

	Pre-2010
Program	Constellation
Rockets	Ares-1 Ares-V
Vehicles	Orion, Altair (Shuttle)
Destination	Moon, eventually Mars



Recent changes to NASA vehicle plan

	Current
Program	
Rockets	NASA - Heavy Lift Commercial: Falcon 9, Taurus 2
Vehicles	NASA: Orion Commercial: Dragon, Cygnus
Destination	TBD, Asteroids?

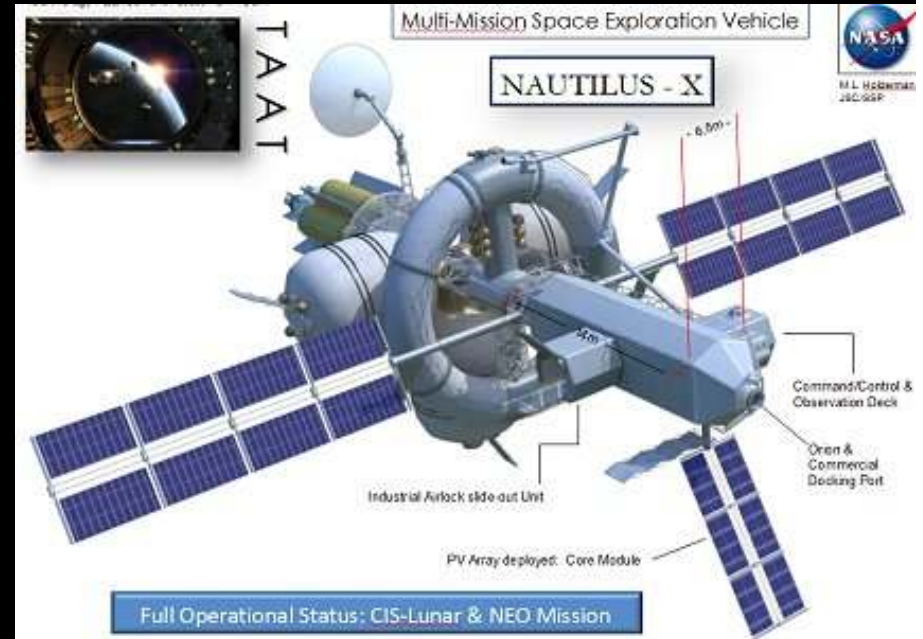


Feasible Exploration Vehicles




Multi-Mission Space Exploration Vehicle

- Effort by Lunar Electric Rover to remain relevant if there is no lunar landing
- One of the first responses to the "new vision"
- Uses modified LER cabin with additional propulsion packages

Impacts of Physiological Adaptation

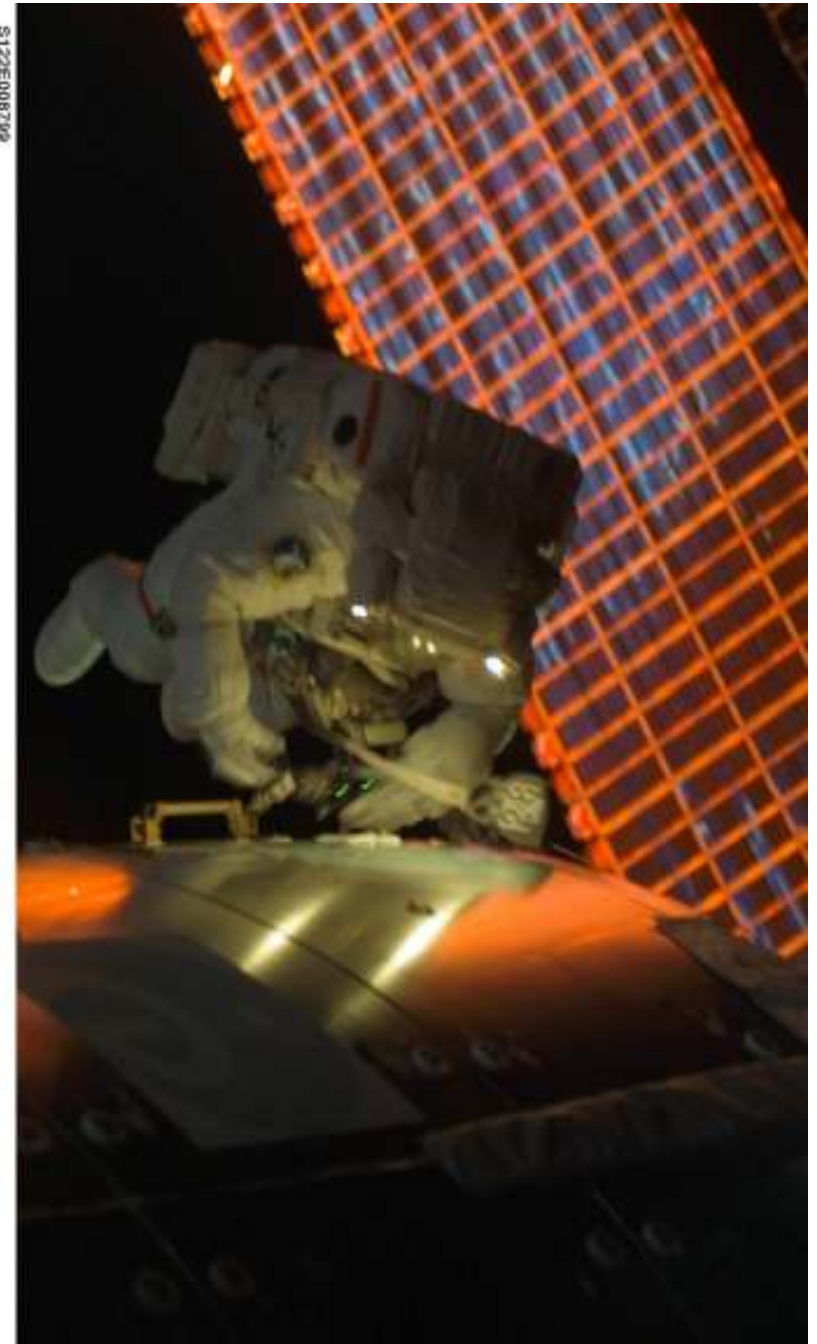
- Space flight-induced changes can affect operations during flight or crew function upon return to Earth
- They may also be deleterious to long term crew health
- These factors must be thoroughly understood and mitigated where possible in order to manage mission and crew health risks



S122E008248

Critical Mission Tasks

- EVA capability
- Nominal and contingency return
- Nominal and contingency egress
- Rapid post-flight return to nom ops
- Long term health issues





Human Research on ISS by HRP

- **Human Research Program (HRP) established Oct. 2005**
 - Succeeded Bioastronautics Research Division, OBPR
 - Dramatic shift from basic research to applied research
- **Program goals**
 - Perform research necessary to understand and reduce spaceflight human health and performance risks in support of exploration
 - Enable development of human spaceflight medical and human performance standards
 - Develop and validate technologies that serve to reduce medical risks associated with human spaceflight
- **Objectives**
 - Establish evidence base on astronaut health and performance for long duration missions in weightlessness
 - Identify greatest risks and develop optimal approach to mitigations and countermeasures
 - Test space biomedical technology and medical care procedures
 - Actively collaborate and share resources with the International Partners on space biomedical research

NASA Human Research Roadmap

- Guides all NASA ground/analog/flight human research
- Orients funded science towards prioritization for enabling exploration-class space missions
- Framework of defined/approved 'Clinical Risks', 'Knowledge Gaps', 'Tasks'
- All new proposals are directed to map against HRP knowledge gaps
- Ongoing internal and external reviews ensure NASA research maintains focus towards closing knowledge gaps, mitigating risks, enabling exploration.

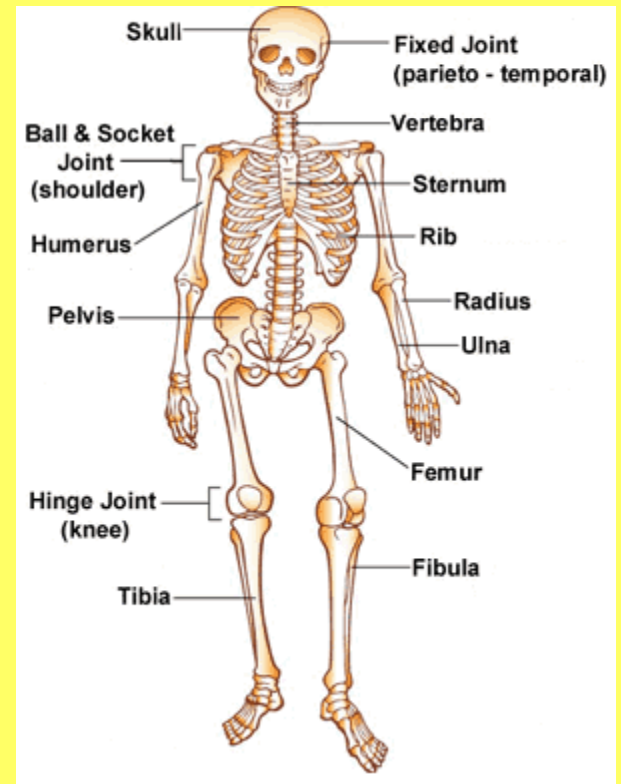
Human Research on ISS



- Establish an evidence base on crew health and performance for long duration missions in reduced gravity
- Identify greatest risks and develop optimal approach to mitigations and countermeasures
- Test space biomedical technology and medical care procedures
- Actively collaborate and share resources with the International Partners on space biomedical research

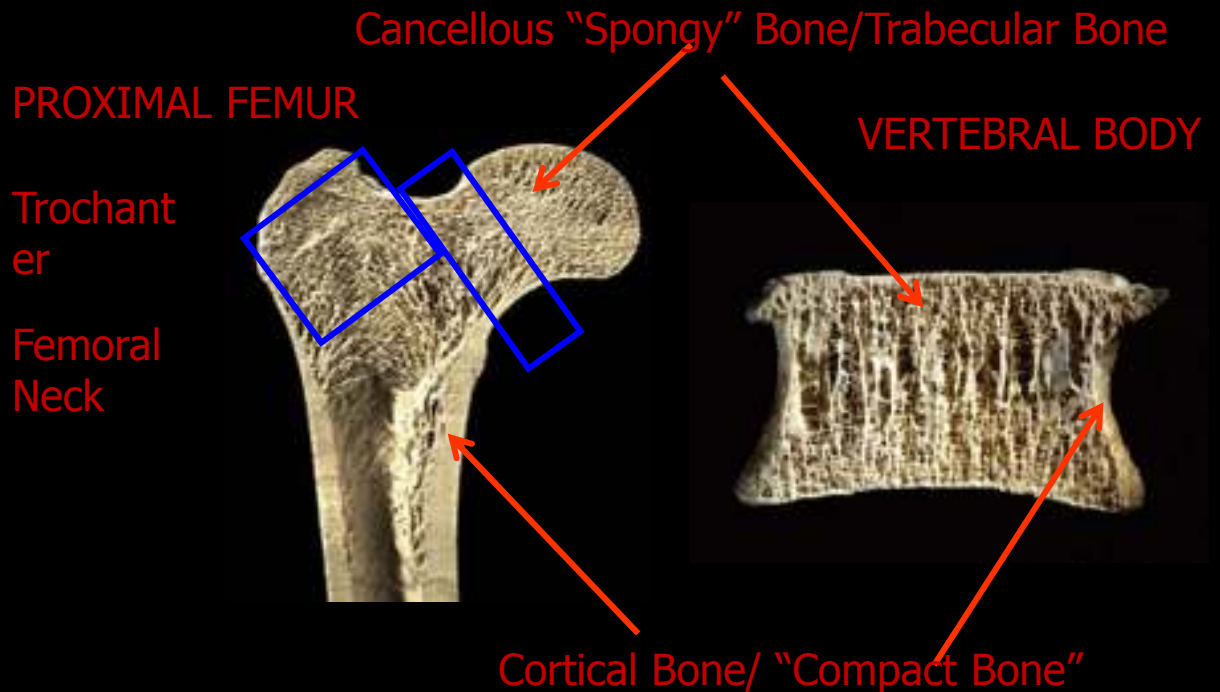


Bone



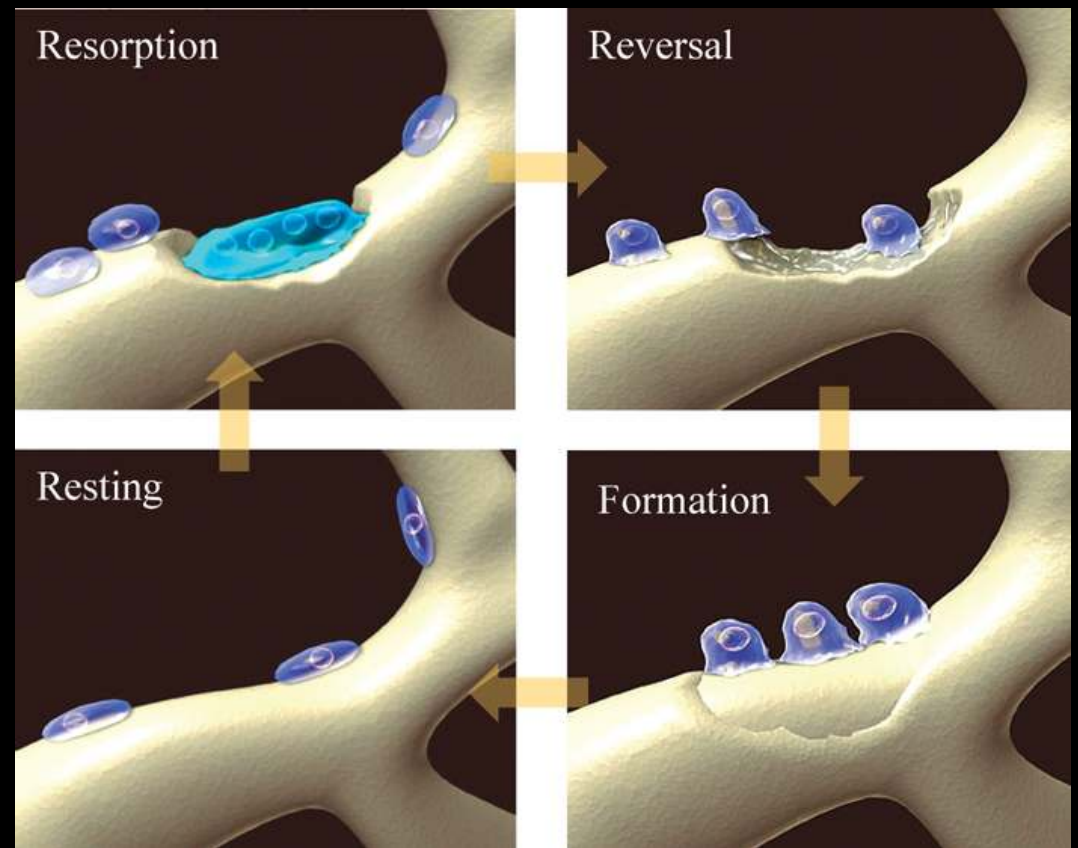
BONE ISSUE FOR SPACEFLIGHT

- Weakening of the bones due to the progressive loss of bone mass is a potentially serious side-effect of extended spaceflight
- Studies of cosmonauts and astronauts who spent many months on space station Mir revealed that space travelers can lose (on average) 1 to 2 percent of bone mass each month
- Spacefarers typically experience bone loss in the lower halves of their bodies, particularly in the lumbar vertebrae and the leg bones.
- Diminishing bone mass also triggers a rise in calcium levels in the blood, which increases the risk of kidney stones.

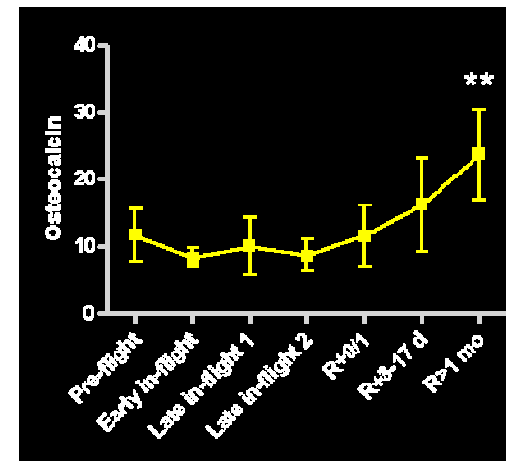
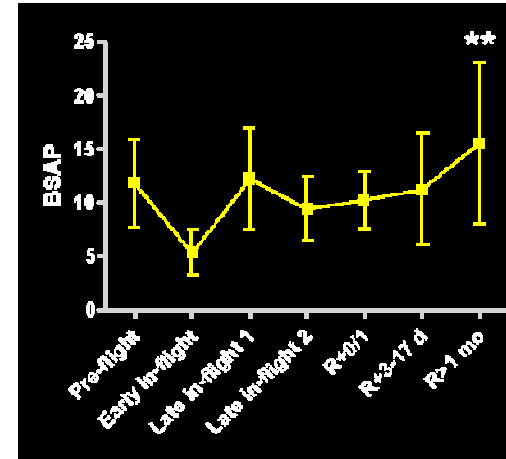
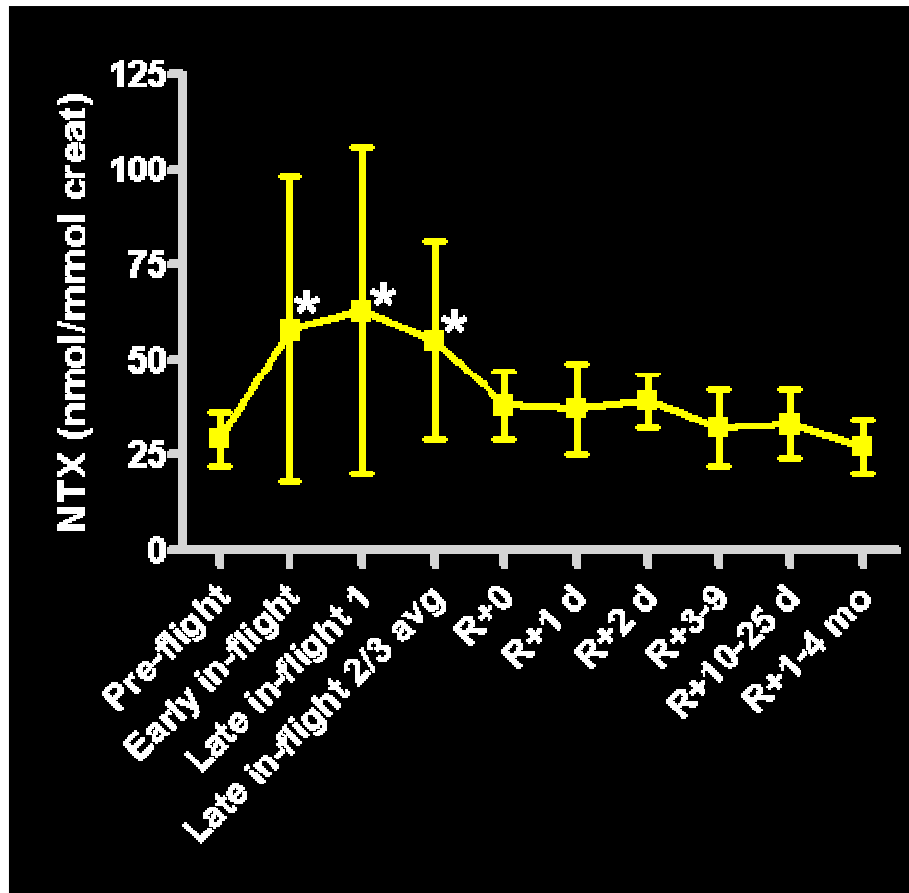


What is wrong?

- But bones are actually dynamic living tissues that constantly reshape themselves in response to the stresses placed on them
- Two cell types, "osteoblasts" and "osteoclasts" are constantly building or destroying bone. Usually these actions balance each other out. But when stresses on bones are reduced, removal outpaces replacement, leading to too little bone which can more easily break.
- In prolonged weightlessness, bone mass decreases because the lack of stress on the bones slows the formation of osteoblast cells.
- Fewer bone-building cells, along with a constant level of bone-destroying activity, translates into a net loss of bone mass.



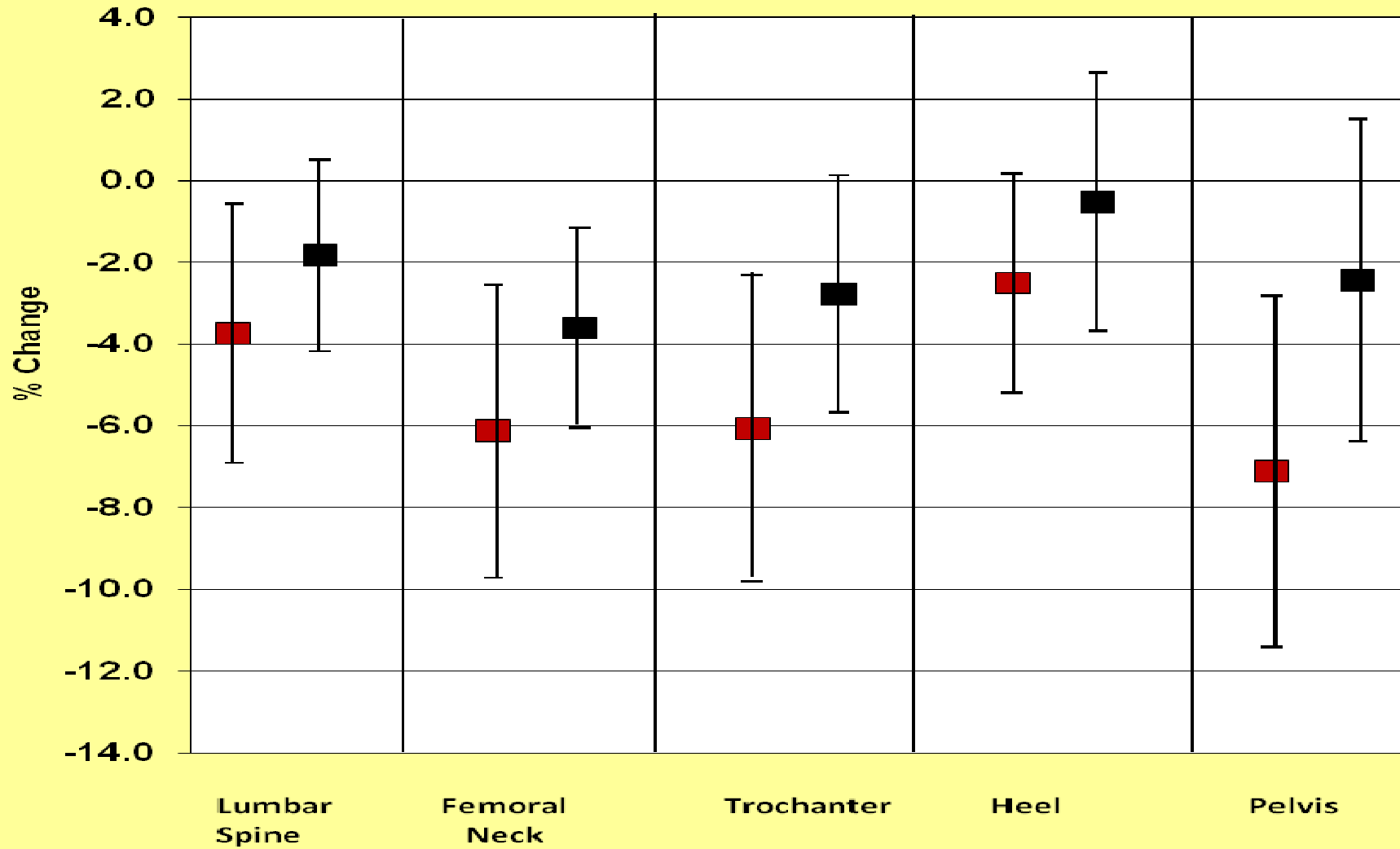
Bone turnover markers suggest that bone degradation is increased, formation is uncoupled from resorption, and bone gain and loss are unbalanced averaged over entire skeleton



More bone mass is subtracted FROM than added TO the ske
(Smith et al, JBMR 2005)

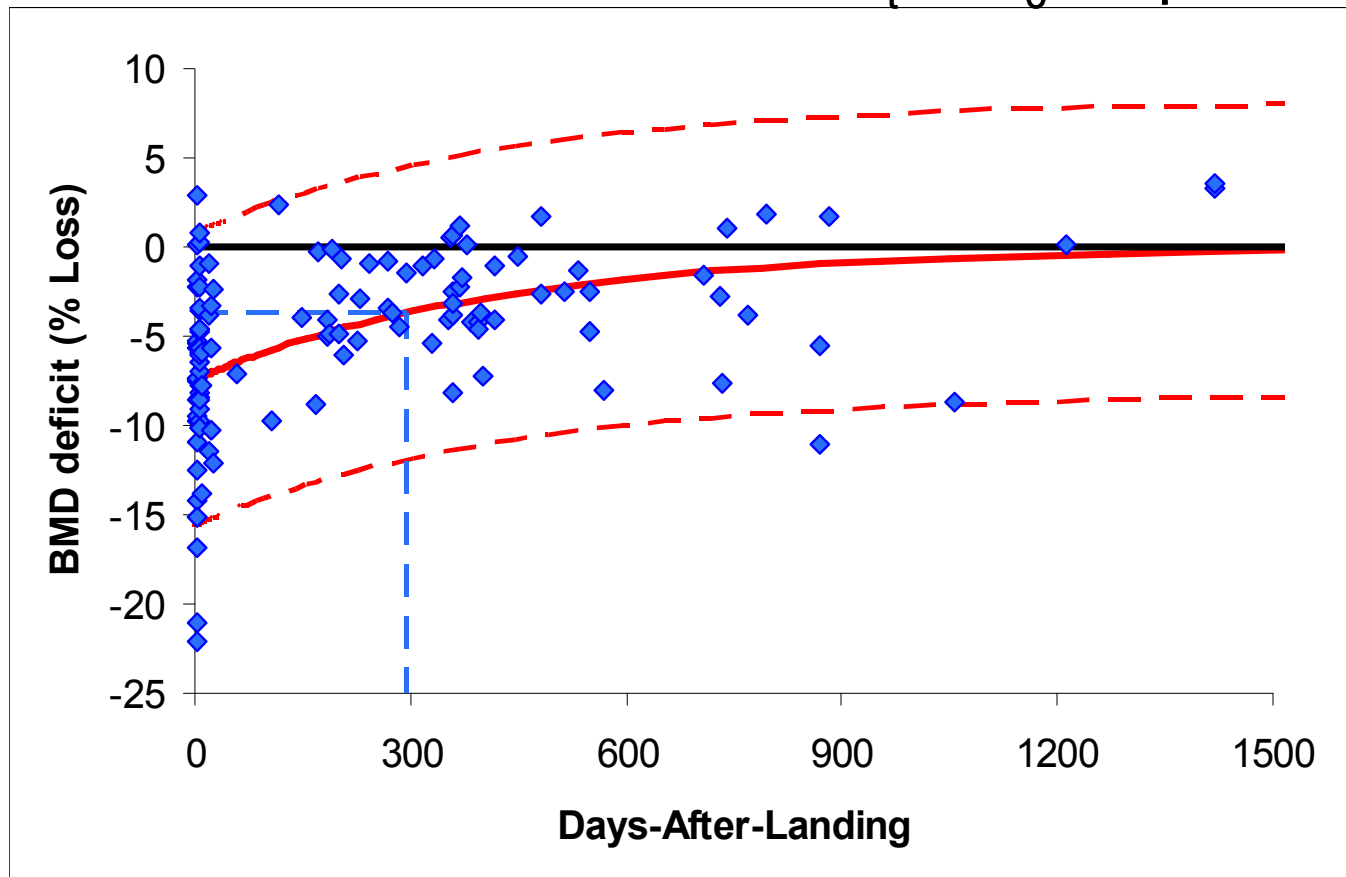
**BMD % Change from Preflight
Expeditions 1-25 (n=33)
(no bisphos, no combination ARED/Non-ARED users)**

non-ARED = Maroon; ARED = Black
Mean and Standard Deviations



Recovery of BMD with return to gravity

$$L_t = L_0 * \exp \ln(0.5)^{t/HL}$$

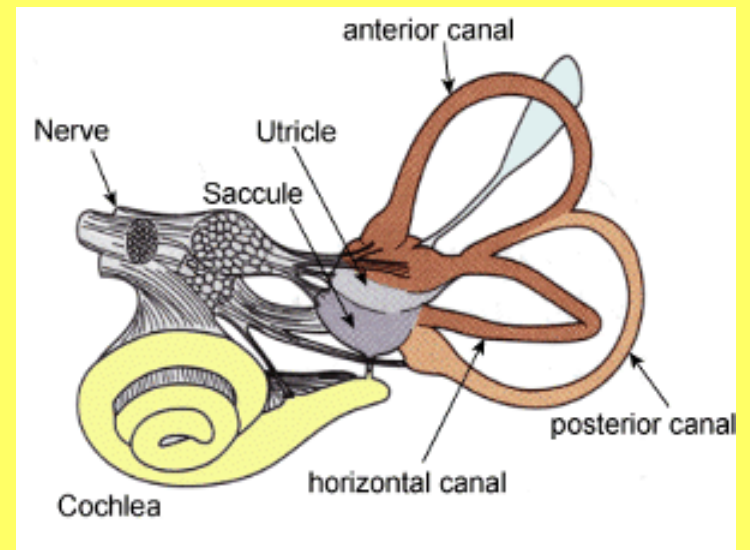


Trochanter BMD of ISS & Mir Crewmembers
Loss₀=7.4% Recovery Half-life=276 d

What did we learn?

- Confirmed overall bone loss rates of 1-1.5% per month in wt bearing bones
- Trabecular bone loses mineral significantly faster than the cortical bone (approx 2X)
- Overall bone density slow to recover
- Recovered structure not the same as original and may have less total strength
- Med ops taking several actions based on these findings
 - Following crew for longer post-flight with DXA and QCT
 - Developing a strategy for FEA modeling to determine strength levels
 - Further collaboration with research side for the Mayo cohort study to determine long term fracture risks

Neurovestibular



Role of Gravity (II)

Gravity provides the CNS a fundamental reference for estimating spatial orientation and coordinating movements.





Space Motion Sickness

- 0% on Mercury/Gemini
- 30% on Apollo/Vostok/Soyuz/Salyut
- 56% on Skylab
- 75% on Shuttle
- Incidence is
 - highest in larger spacecraft.
 - highest on days 1-2, declining on days 3-5
 - lower on second and subsequent space flights.
 - unrelated to gender, or prior flying experience.
 - so far, not reliably predicted by 1-g motion sickness susceptibility tests.
- “Earth Sickness” (part of “Landing Syndrome”) about 30% after 1-2 week missions, 90% after long duration flights.

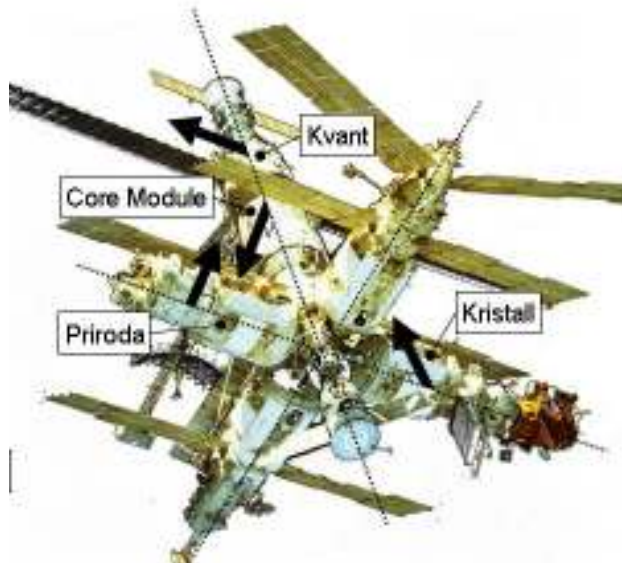
Spatial Disorientation



0-g Entry Illusions



Inversion Illusion



0-g Navigation Problems

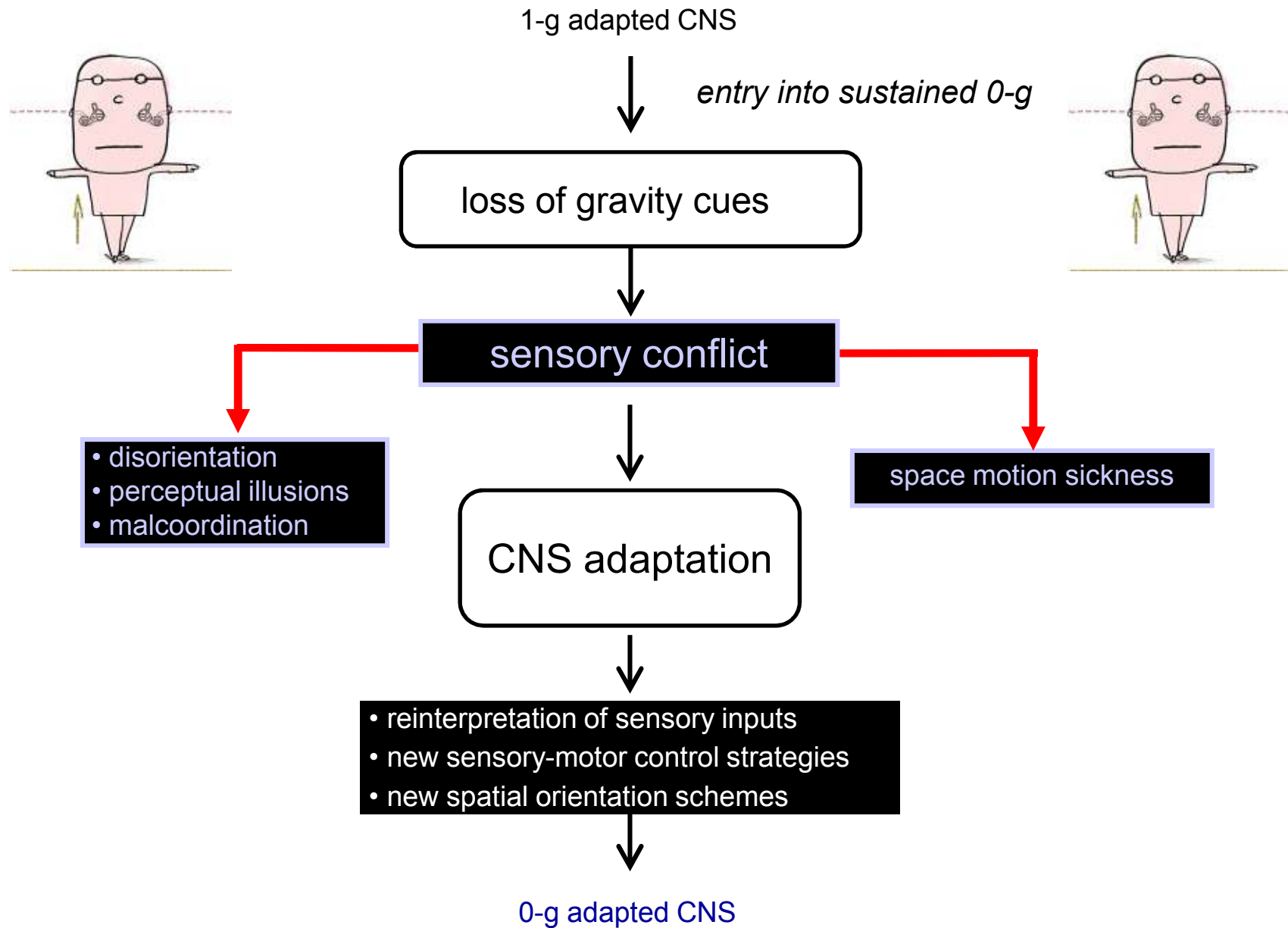


EVA Height Vertigo

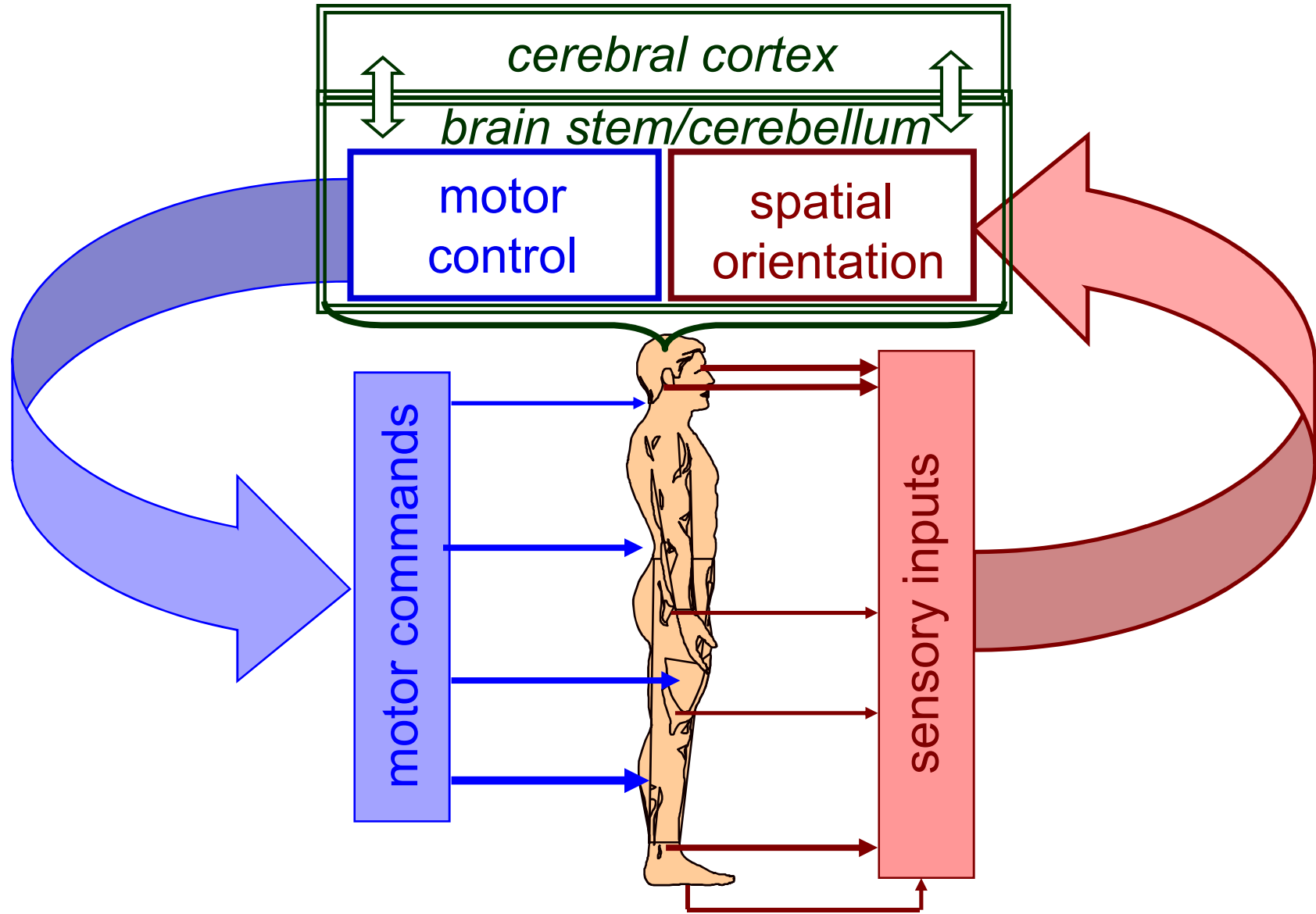


Visual Reorientation Illusion

CNS Response to Spaceflight






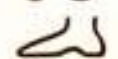














Human Sensory-Motor Balance Control



EquiTest™ Conditions

Sensory Analysis

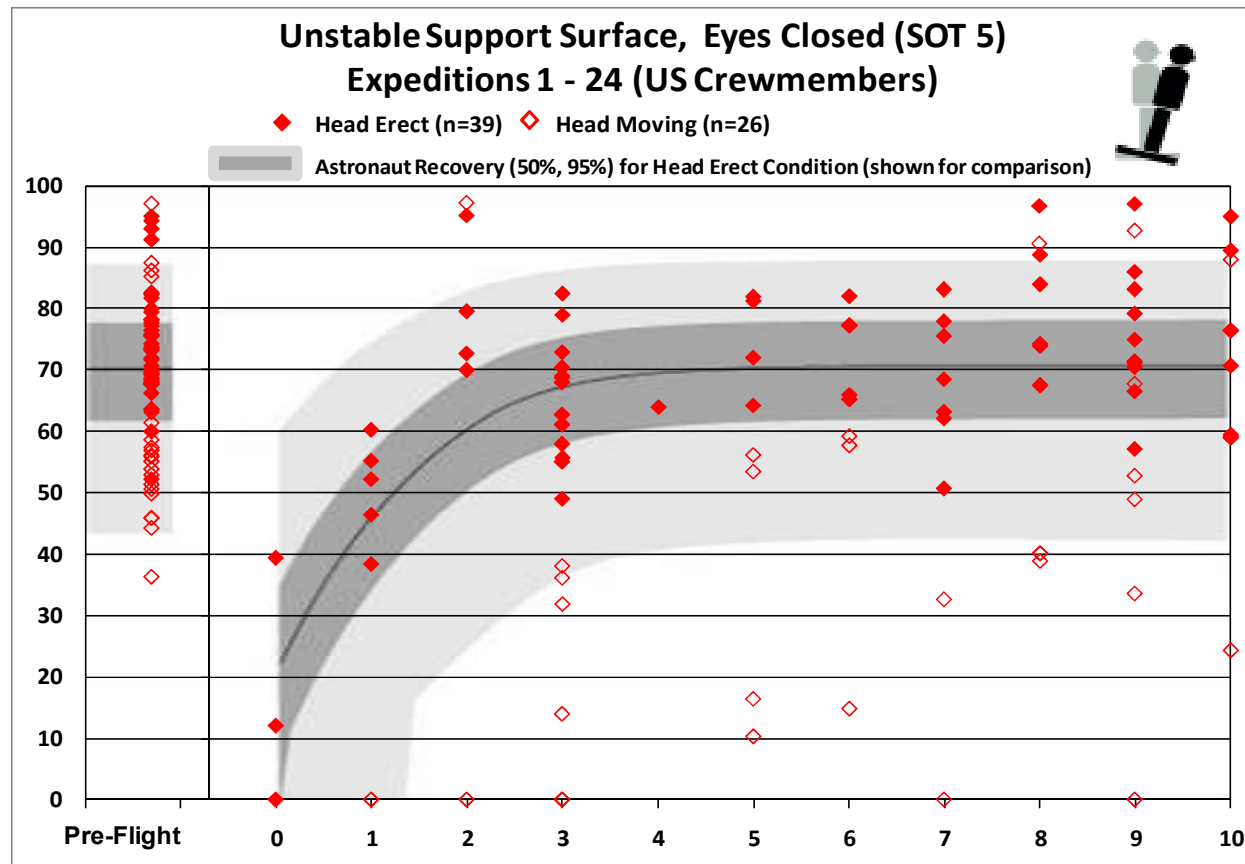
1.		Normal Vision	
		Fixed Support	
2.		Absent Vision	
		Fixed Support	
3.		Sway-Referenced Vision	
		Fixed Support	
4.		Normal Vision	
		Sway-Referenced Support	
5.		Absent Vision	
		Sway-Referenced Support	
6.		Sway-Referenced Vision	
		Sway-Referenced Support	



Long Duration Flight Balance Control Recovery

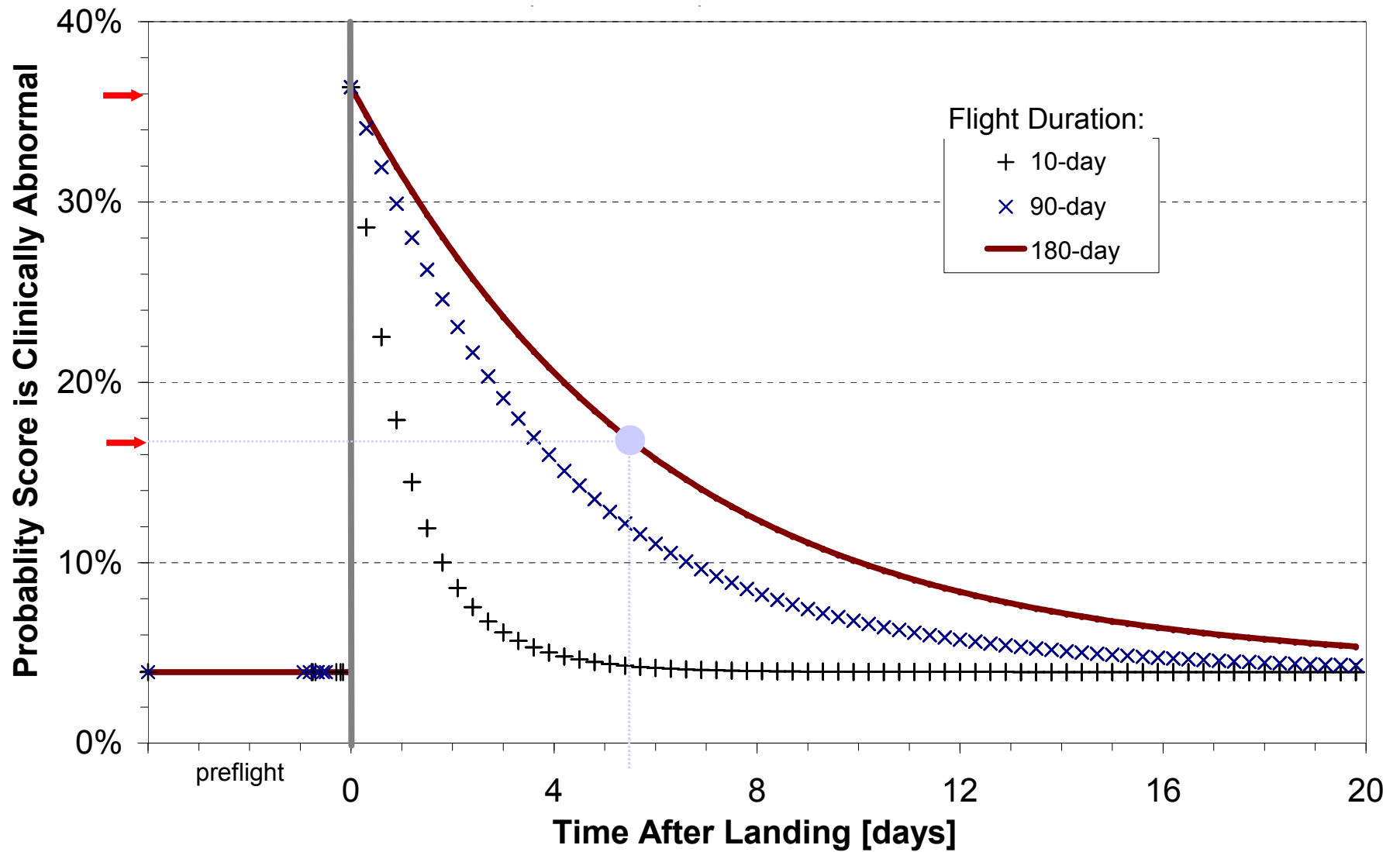
Functional Neurological Assessment

Sensory Organization Test 5 – Head Erect/Head Moving



Eyes closed on unstable surface shows moderate-to-severe deficits post-flight. Addition of head movements (open symbols) reveals greater inter-subject variability with longer return to baseline conditions.

Effect of Mission Duration on Balance Recovery



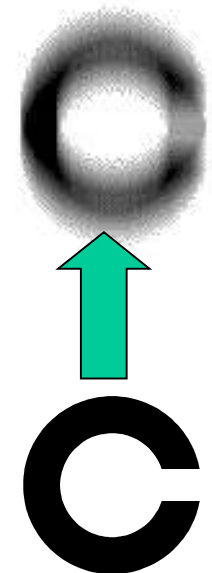
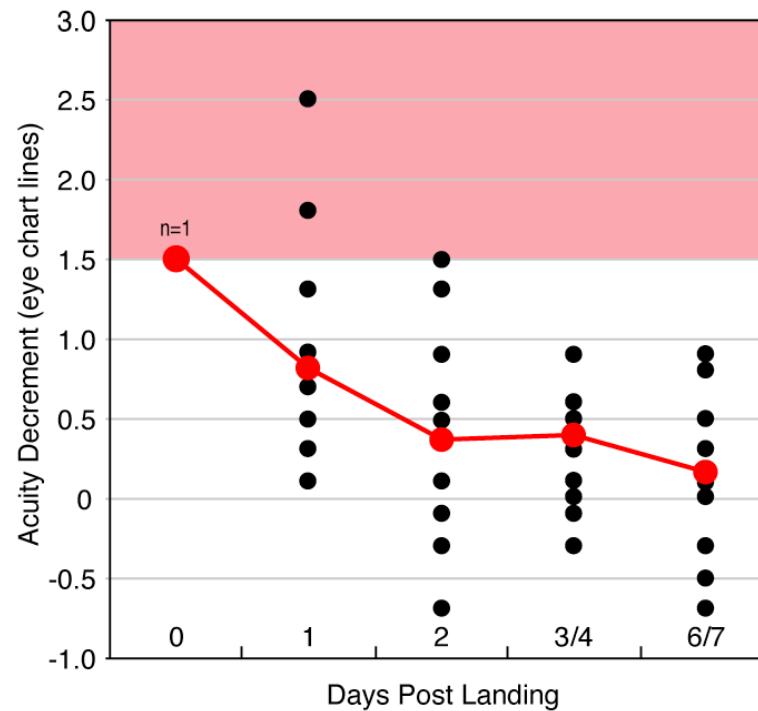
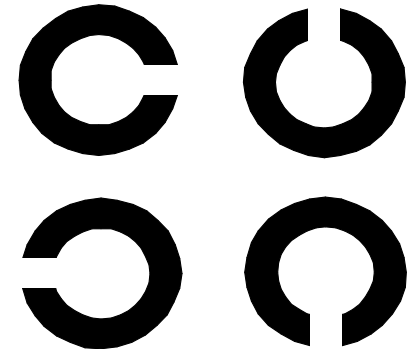
Dynamic Visual Acuity



Courtesy of J. Bloomberg, NASA JSC



Landolt-C



Manual Control

Flight: Shuttle, SLS-2, n=4, 2 on R+0

Task: Subjects asked to null out roll tilt in a Link flight simulator, in darkness, with Earth-fixed visual field, and with independent visual field motion

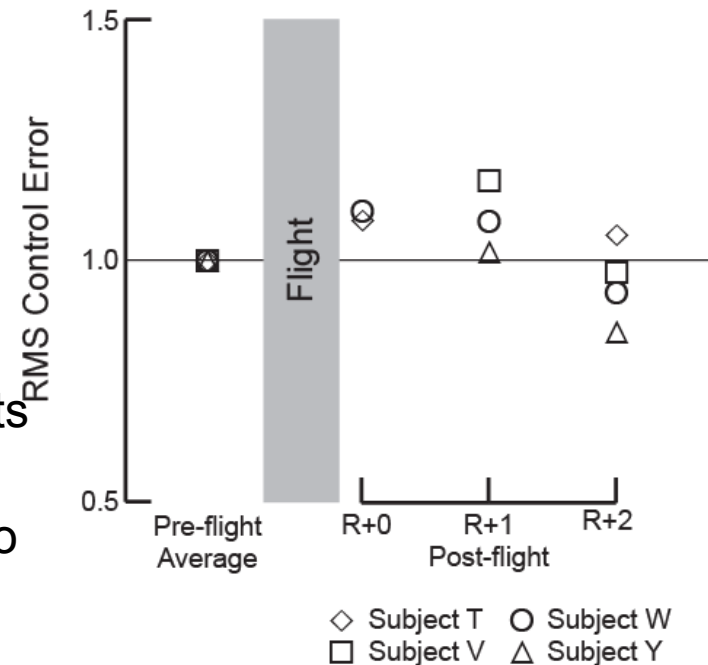
Subjects used control wheel to “keep themselves upright with respect to gravity”. Sum-of-sines motion profile (0.014 – 0.668 Hz)

Measurement: Manual control error.

Summary:

2 of 2 subjects exhibited significant decrements on R+0 in performance in the dark (all 4 subjects returned to pre-flight levels by R+2)

Implications: Sensorimotor changes may lead to disruption in piloting and driving performance.



What have we learned?

- Space flight induces an adaptation in the sensory motor system appropriate for operation in microgravity
- CNS must re-learn cues and controls for terrestrial activity
- These changes vary in intensity and outcome for different individuals
- Training can expedite the transitions and pharmacological agents can modulate adverse symptoms
- Objective predictors for performance in complex environments must continue to be developed

Cardiology



CARDIAC ISSUE FOR SPACEFLIGHT

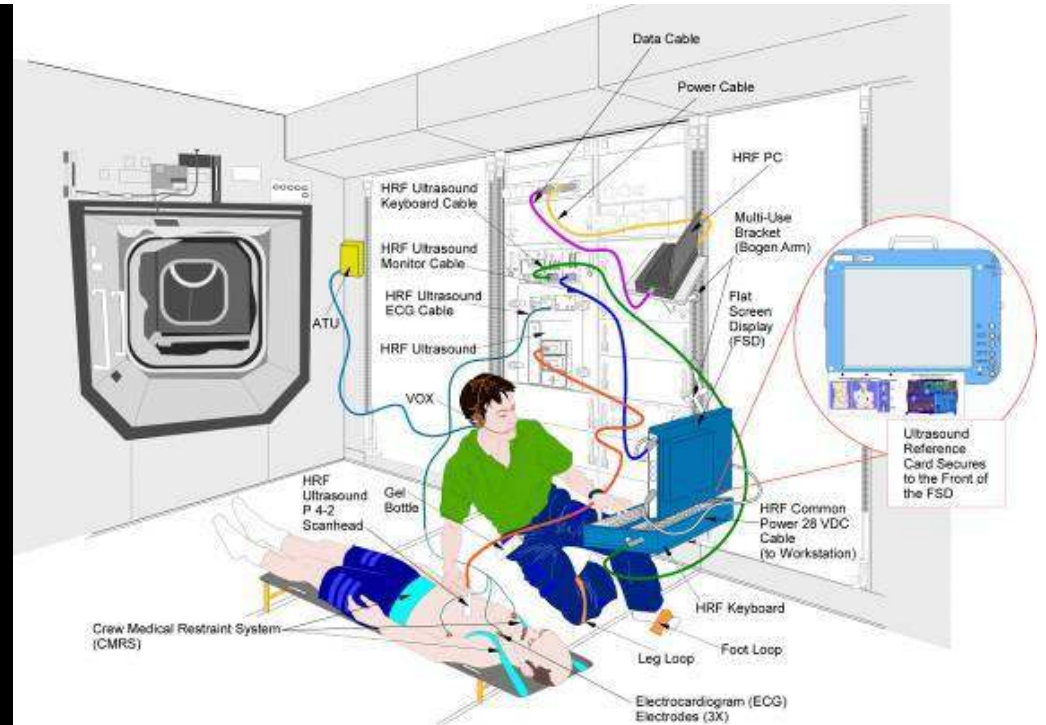
- Cardiac atrophy (a decrease in the size of the heart muscle) appears to develop during space flight or its ground-based analogues leading to diastolic dysfunction (abnormal left ventricular function in the heart) and orthostatic hypotension (drop in blood pressure upon standing).
- Such atrophy may have been a potential mechanism for the cardiac arrhythmias (irregular heart rhythms) identified in some crewmembers after long-duration exposure to microgravity aboard the Mir Space Station.
- Recent studies suggest that cardiac atrophy may be progressive, without a clear plateau over at least 12 weeks of bedrest, and thus may be a significant limiting factor for extended duration space exploration missions.
- Atrophy may result in impaired cardiac function and/or fainting (orthostatic intolerance) post-landing on the Earth, moon or Mars.



'Integrated Cardiovascular'

Current NASA research aims to determine the significance of cardiac atrophy and identify its mechanisms.

The functional consequences of this atrophy are being determined for *cardiac filling dynamics, orthostatic tolerance, exercise tolerance, and arrhythmia susceptibility*.



The Integrated Cardiovascular experiment investigates the magnitude of ventricular atrophy using MRI, relates this type of atrophy to measures of physical activity and cardiac work in flight, and determines the time course and pattern of the progression of cardiac atrophy cardiac ultrasound.

This investigation also determines the functional importance of cardiac atrophy for cardiac diastolic function and the regulation of stroke volume (volume of blood pumped by the heart in one contraction) during gravitational transitions, as well as identifies changes in ventricular conduction, depolarization and repolarization during and after long-duration space flight, and relates these factors to changes in heart mass and morphology (shape and form).

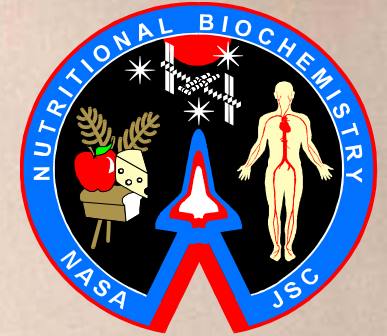
Nicole Stott performs routine tasks aboard the ISS while ECG (using the HRF Holter Monitor 2) and continuous blood pressure data (using the ESA Cardiopres) are recorded for the Integrated Cardiovascular experiment.



Nutrition



Space Nutrition



Nutrient Requirements

Energy
CHO (fiber), Fat, Protein
Fat-soluble vitamins
Water-soluble vitamins
Minerals
Fluid

Systems

Bone
Muscle
Cardio
Fluid/Electrolyte
Immunology
Hematology
Neurovestibular
Endocrine
GI
BHP
Vision

Countermeasures

Energy	Bisphosphonates
Amino acids	KCitrate
Protein	Other Meds
Sodium	Exercise
Fatty acids	Other
Antioxidants	
Other	

Vehicle/Mission

Duration
Food System
Radiation
EVA
Schedule

Nutrition is critical for any type of exploration mission, and is

Dietary Intake



Nutrition Food Frequency Questionnaire

User: SMS Expedition: 15 Number of Packets

Fruit

Dried fruit, fruit roll-ups, prunes
Kuraga, mashed dried apricots, prunes.....

Cobbler, cranapple dessert.....

Other fruit, like apples with spice, applesauce, berry medley, fruit cocktail, mandarin oranges, mixed fruit, peach ambrosia, peaches, pears, pineapple, strawberries
Apple cranberry sauce, apple dessert, cherries with cream sauce, foxberries, peach dessert.....

Raw fresh fruits or vegetables, like apples, onions, oranges, tomatoes.....

Beans, Soups

Black beans.....

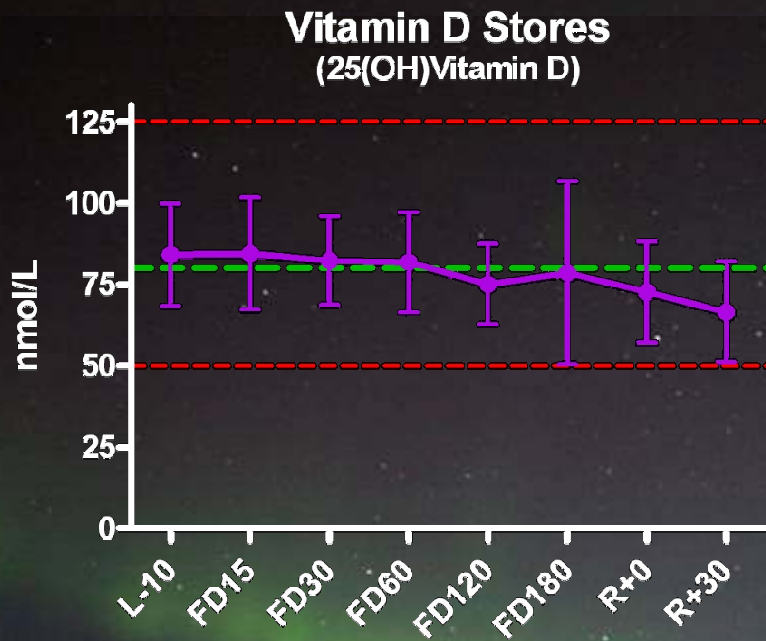
Chicken consommé, cream of mushroom, hot and sour, minestrone, potato, tomato basil, vegetarian vegetable soup
Pureed pea soup, pureed vegetable soup.....

Chicken noodle soup
Borsch with meat, cucumber soup, Kharcho mutton soup, meat and vegetable soup, noodle soup with meat.....

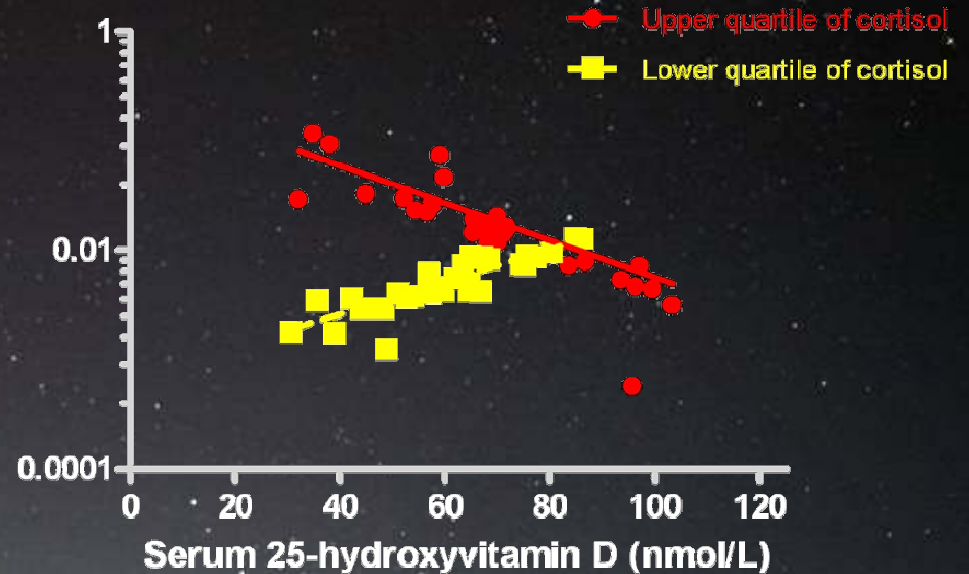
Red beans and rice, split pea soup

Maintaining dietary intake during flight is very important. Inadequate intakes are associated with greater bone and muscle loss, altered cardiovascular performance, and other health risks. Intake for ISS crewmembers is tracked with a computer-based Food Frequency Questionnaire (above).

Vitamin D



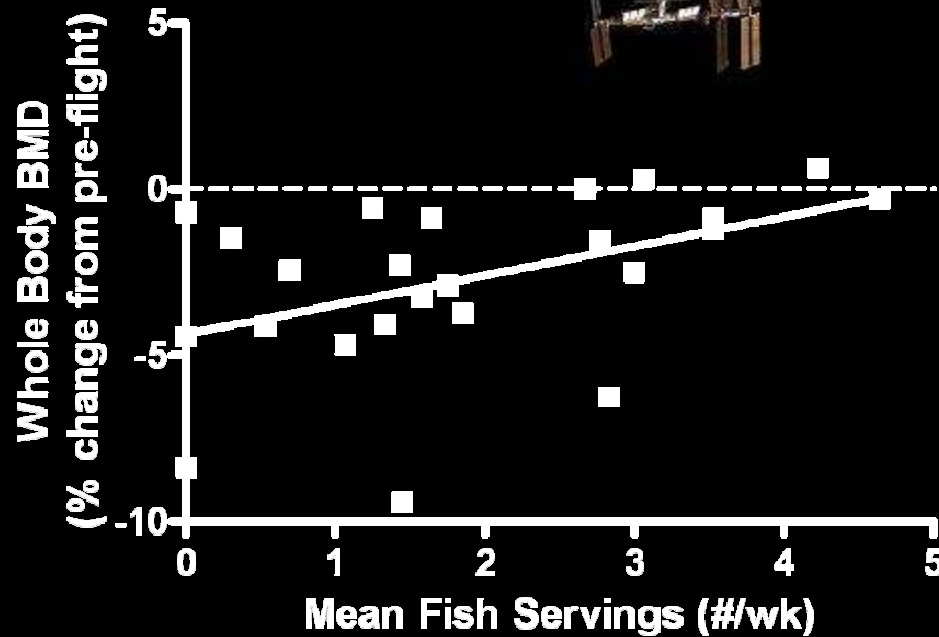
Probability of EBV shedding



Vitamin D intake is critical for astronauts, where the food system does not provide adequate amounts, and the crews are shielded from ultraviolet light.

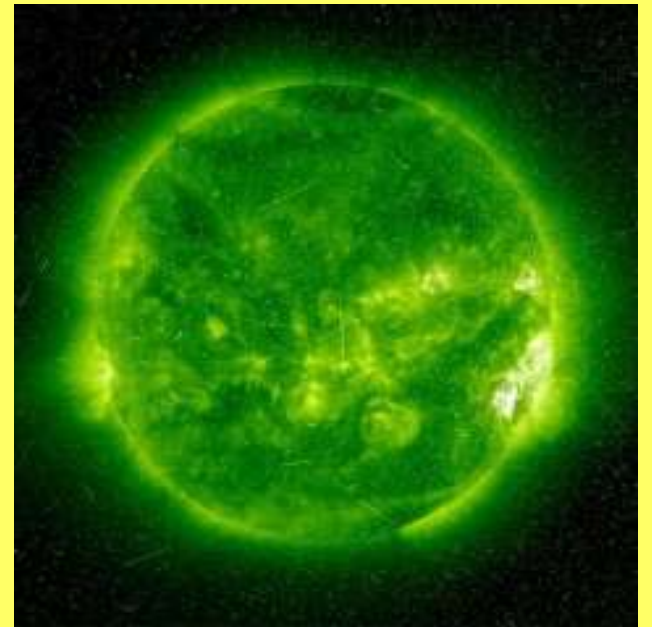
Supplementation with 800 IU vit D/day maintains status during flight (left panel). Antarctic studies show vitamin D, stress, and viral reactivation are interrelated.

Omega-3 Fatty Acids



Fish intake is associated with lower bone loss. Fish, and omega-3 fatty acids in particular, may mitigate bone and muscle loss, cardiovascular, and cancer risks.

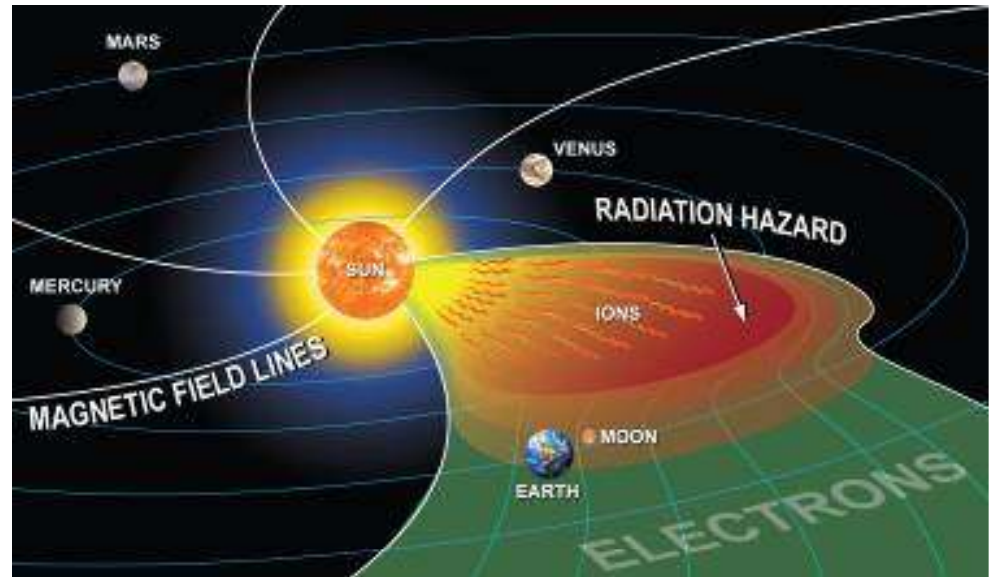
Radiation



The Space Radiation Problem

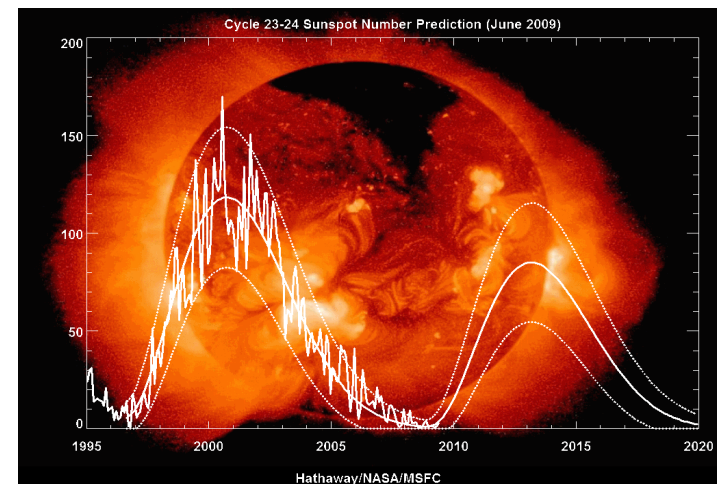
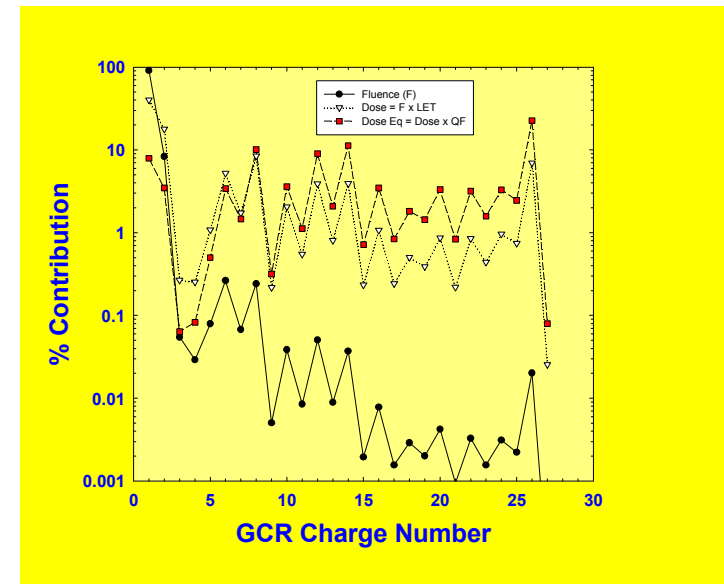
Space radiation is comprised of high-energy protons and heavy ions (HZE's) and secondary protons, neutrons, and heavy ions produced in shielding

- Unique damage to biomolecules, cells, and tissues occurs from HZE ions
- No human data to estimate risk
- Expt. models must be applied or developed to estimate cancer, and other risks
- Shielding has excessive costs and will not eliminate galactic cosmic rays (GCR)



Space Radiation Environments

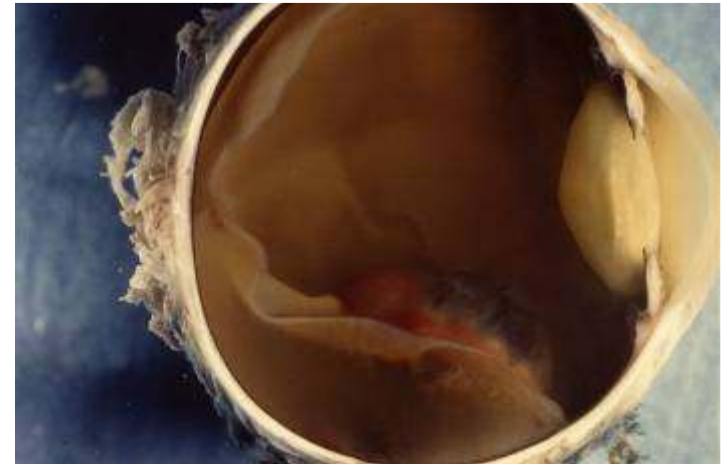
- Galactic cosmic rays (GCR) penetrating protons and heavy nuclei - a biological science challenge
 - shielding is not effective
 - large biological uncertainties limits ability to evaluate risks and effectiveness of mitigations
- Solar Particle Events (SPE) largely medium energy protons – a shielding, operational, and risk assessment challenge
 - shielding is effective; optimization needed to reduce weight
 - improved understanding of radiobiology needed to perform optimization
 - accurate event alert and responses is essential for crew safety



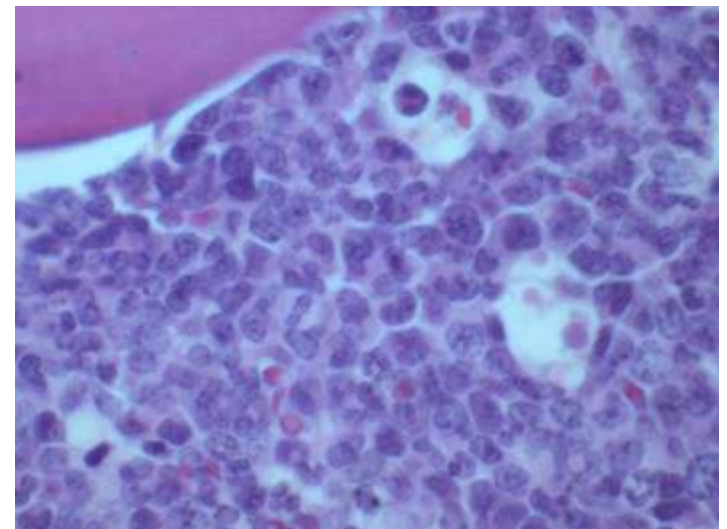
Categories of Radiation Risk

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

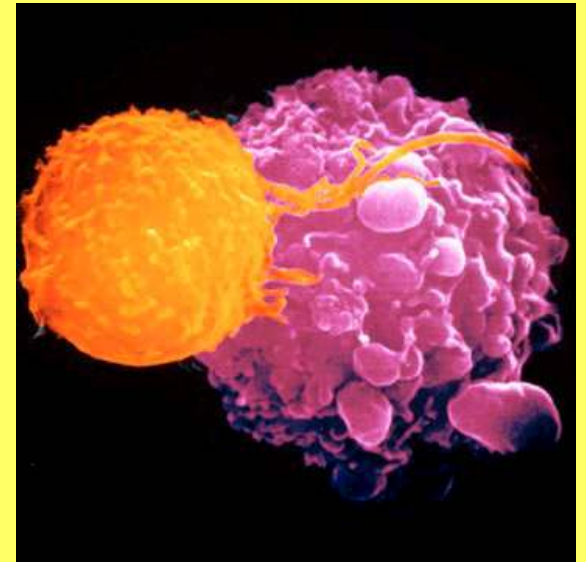


cataracts



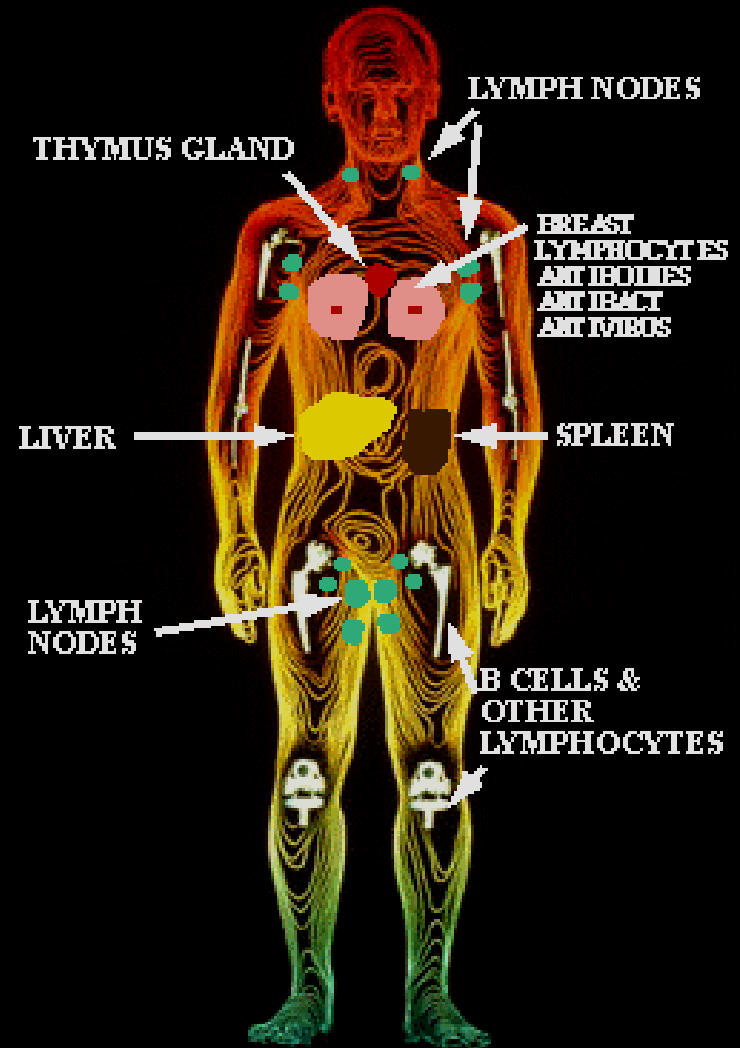
First experiments for leukemia

IMMUNOLOGY

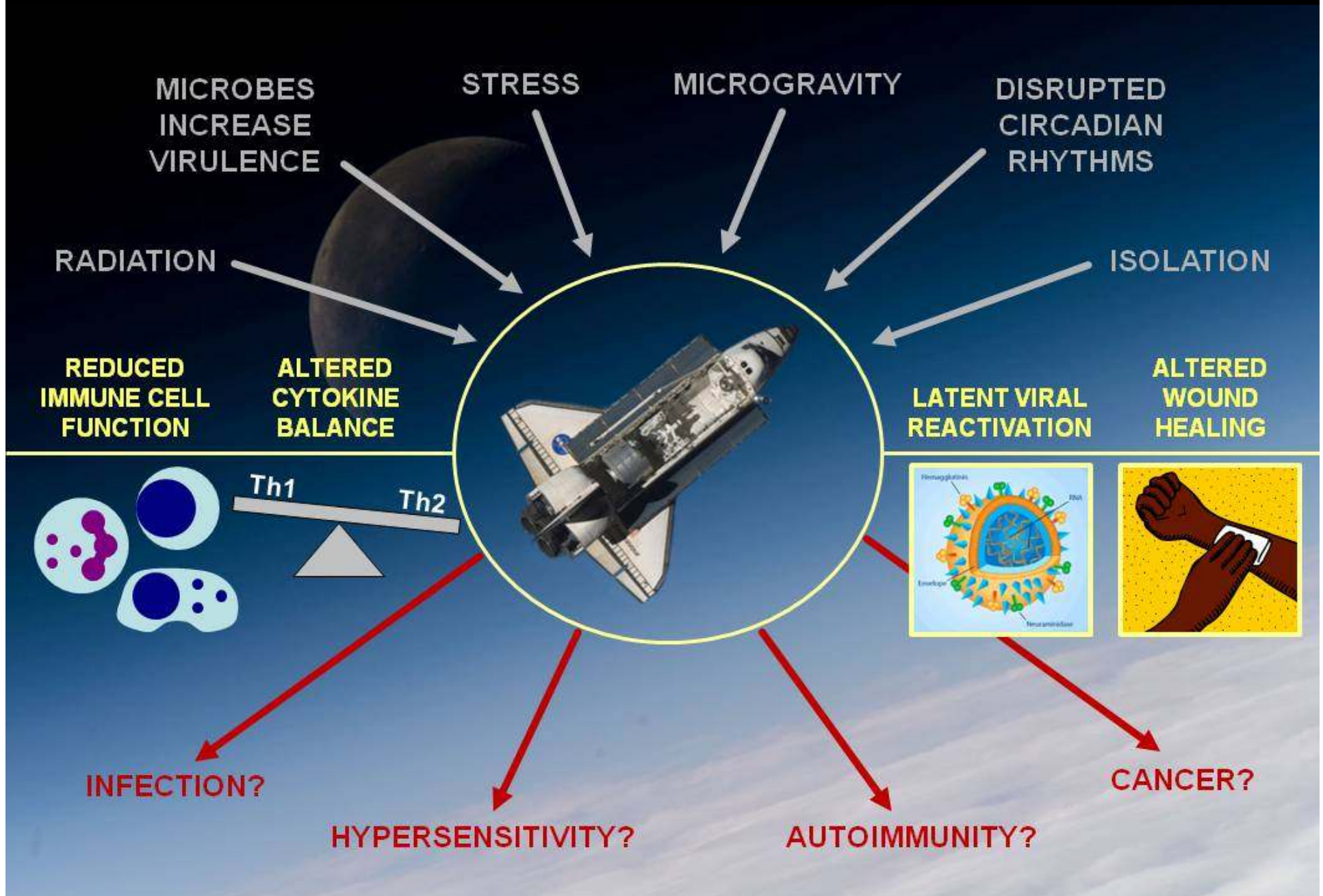


THE IMMUNE SYSTEM

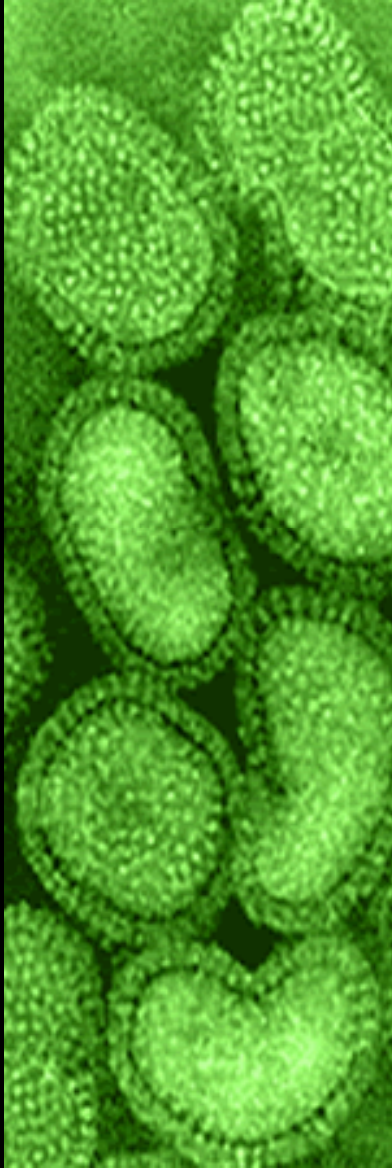
- One of largest tissues in the human body, although largely in fluid state.
- Consists primarily of white blood cells (WBCs) located in lymph nodes and the peripheral blood.
- Responsible for protection against viral and bacterial infection, latent viral reactivation, tumor surveillance, wound healing, etc.
- Dysregulation can result in increased infection rate, malignancy, autoimmunity, allergy, etc.



Overview: Spaceflight-Associated Immune Dysregulation



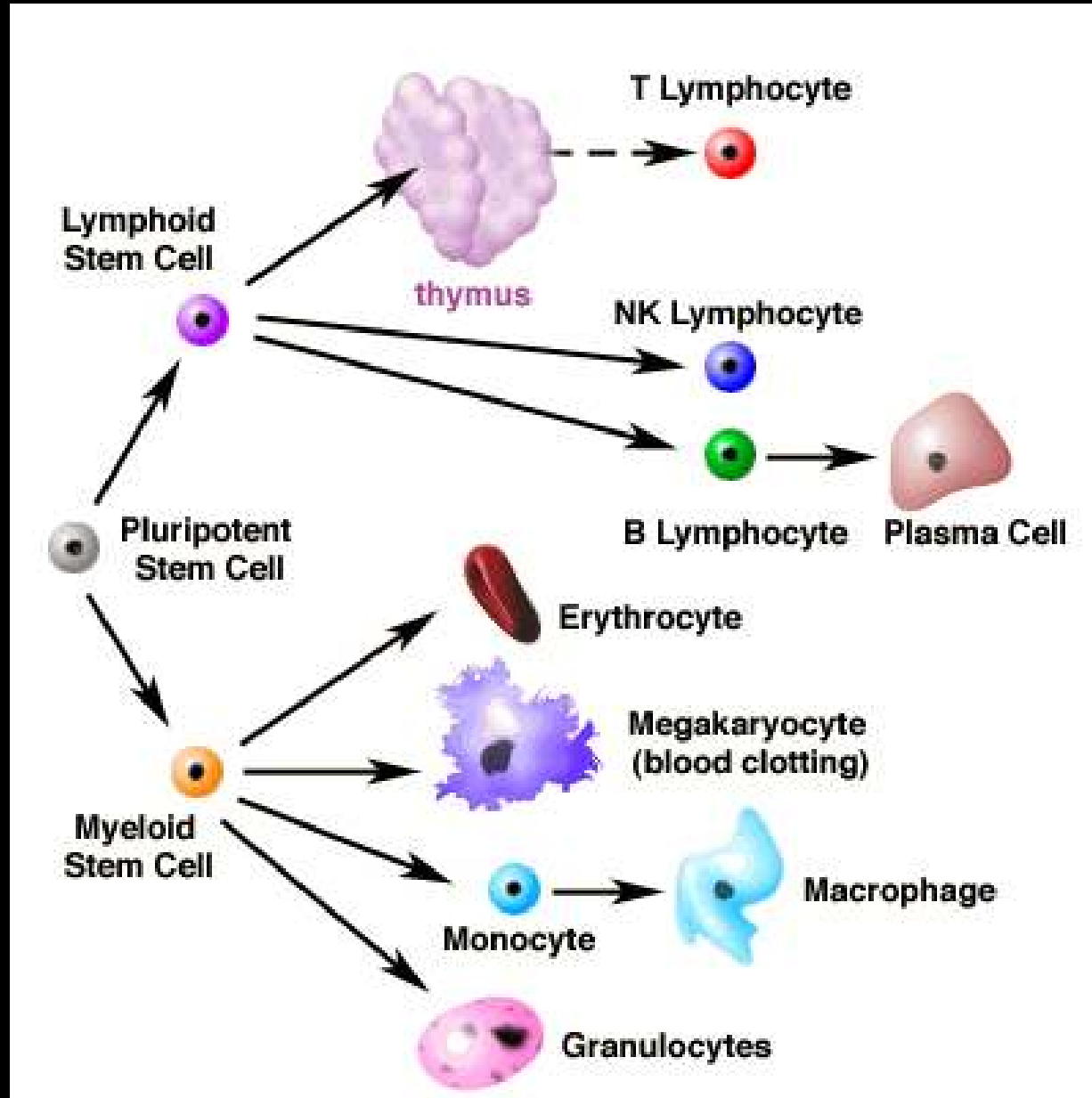
Shuttle: Incidence of In-flight Infectious Disease (STS-1 through STS-108)



Number	Infectious Disease
8	Fever, chills
5	Fungal infection
3	Flu-like syndrome
4	Urinary tract infections
3	Aphthous stomatitis
2	Viral gastrointestinal disease
2	Subcutaneous skin infection
2	Other viral disease
<hr/>	
29	Total incidents in 106 Shuttle flights

Based upon post-flight medical debriefs [Longitudinal study of Astronaut Health]
by Dr. Kathy Johnson, NASA-JSC

CELLS OF THE IMMUNE SYSTEM



In-flight cell culture

-Intracellular signaling, cytoskeleton rearrangement, microtubule organizing center orientation, generalized proliferative responses all altered during flight.

Reactivation of latent herpesviruses

-EBV, CMV, VZV reactivation during flight
-Infectious VZV particles secreted in saliva



Short duration

Long duration

Post-flight observations

-Altered circulating leukocyte distribution
Altered cytokine production patterns (secreted, intracellular, Th1/Th2)
-Decreased NK cell function
-Decreased granulocyte function
-Decreased T cell function*
-Altered immunoglobulin levels
-Latent viral reactivation
-Altered virus-specific immunity
-Expression of EBV IE/late genes*
-Altered neuroendocrine responses

Humoral immunity

-Immunization with antigen generates normal antibody response during flight (MIR-18)

Reduced cell mediated immunity

-CMI Multitest, common recall antigens, long duration flight

*Post-flight observations differ between long vs. short duration space flight.

SKYLAB IMMUNE DATA - 1973

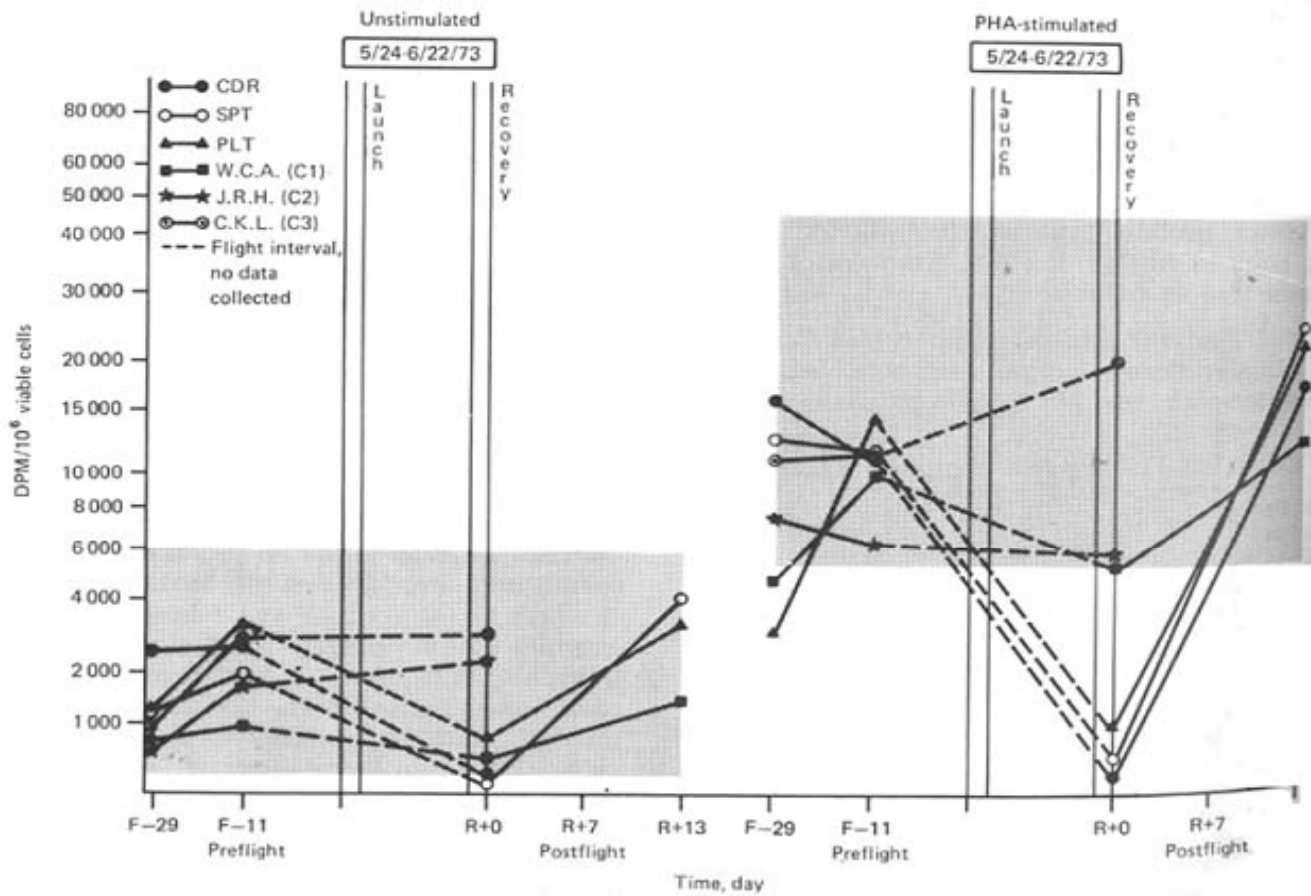
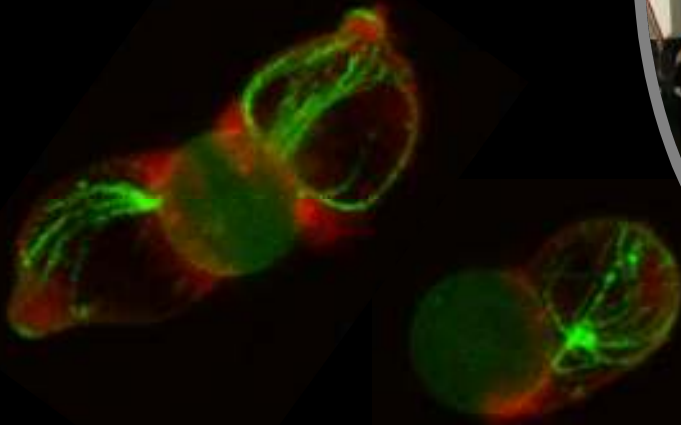
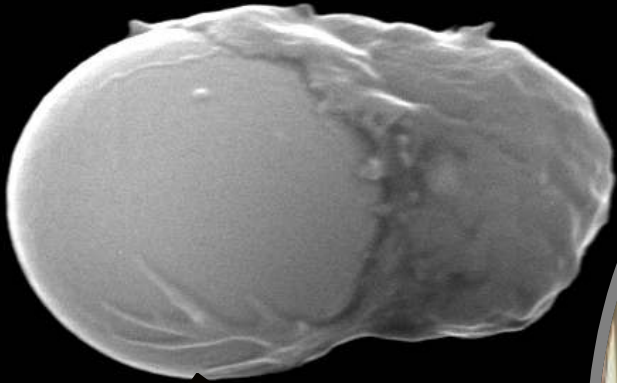


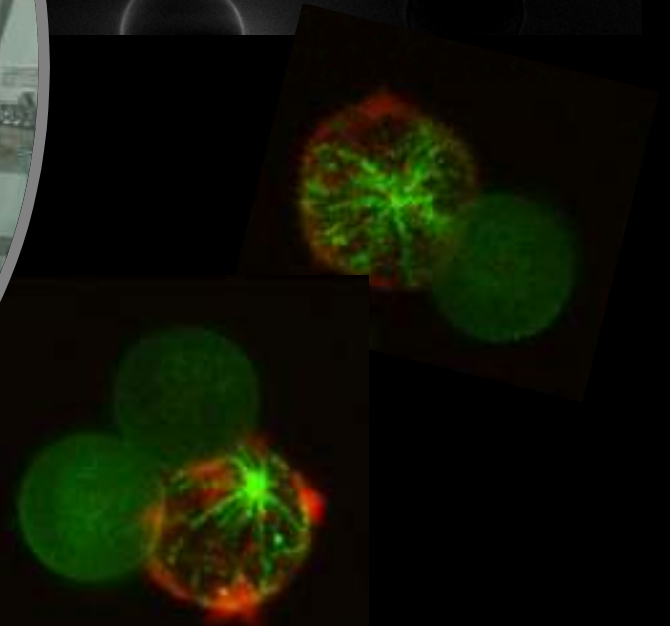
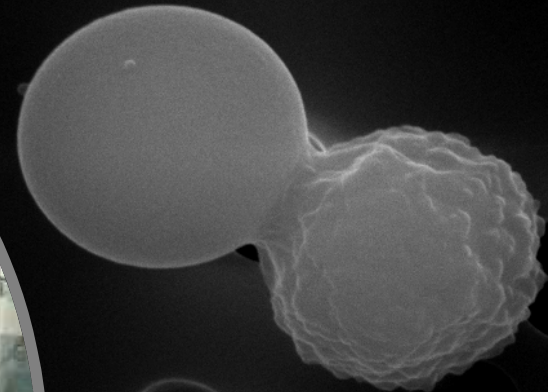
FIGURE 28-1a.—RNA synthesis rates in lymphocytes, cultured with and without PHA, obtained from the Skylab crews and control groups. The cells were pulsed with ³H-uridine at 23 h and harvested at 24 h after initiation of the cultures.



1xG CONTROL



MODELED MICROGRAVITY



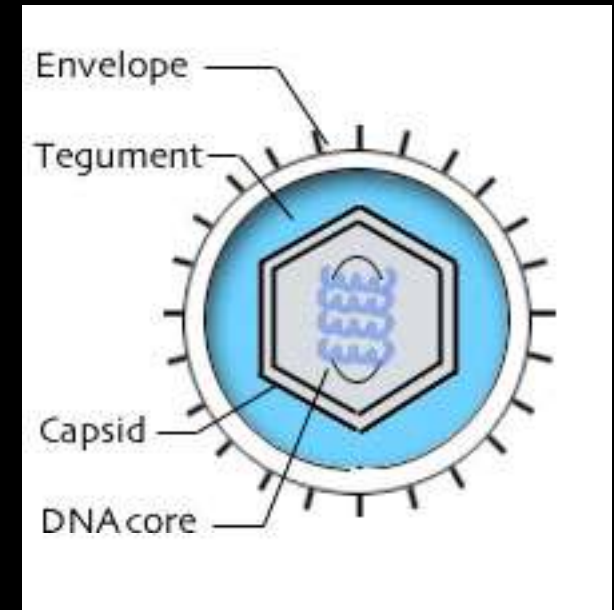
Red: Actin localization

Green: Microtubules/MTOC

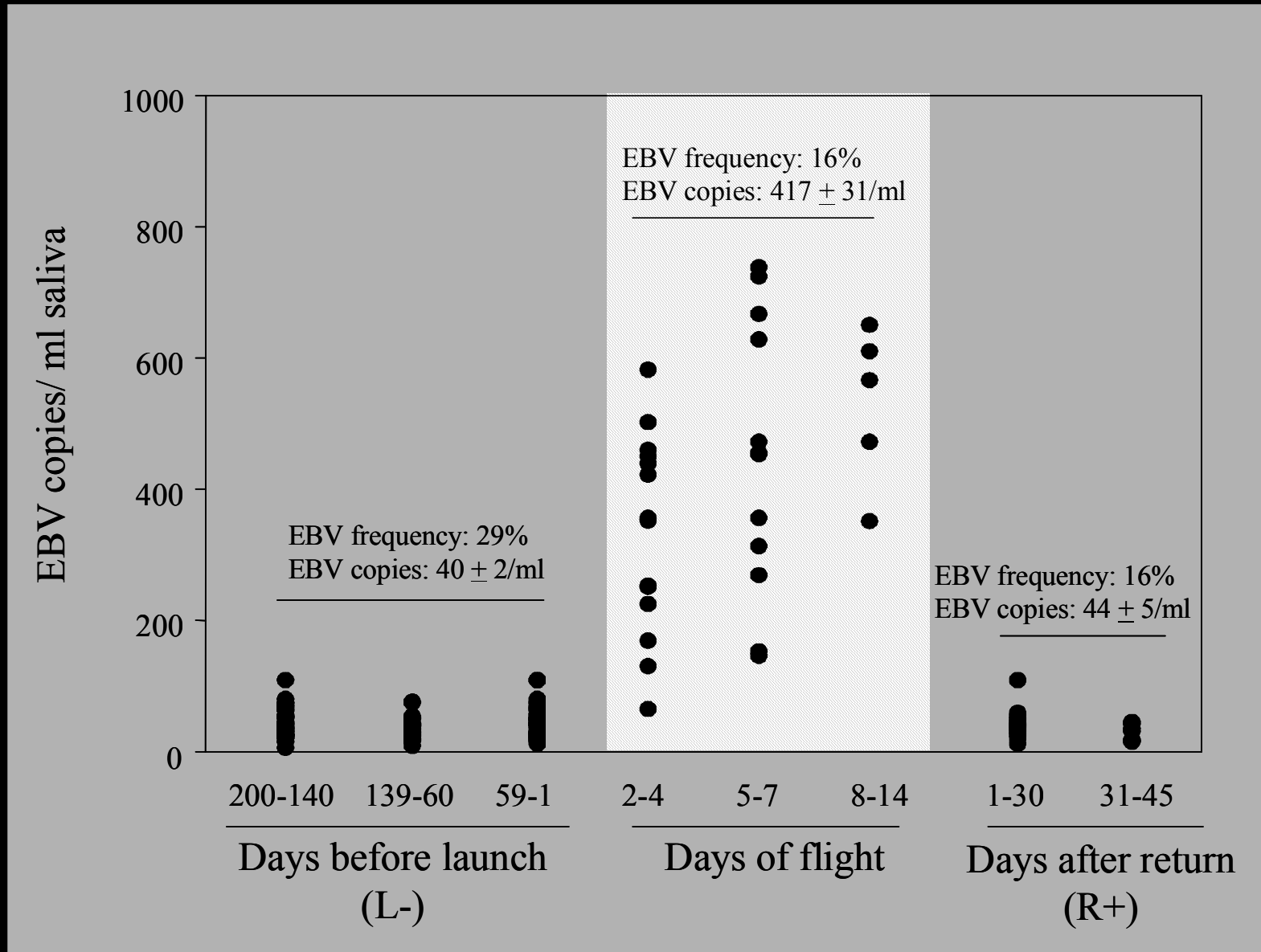
-Mayra Nelman-Gonzalez/JSC

Latent Virus Reactivation

- Herpesviruses and polyomaviruses are common latent viruses
 - Ubiquitous
 - important infectious disease risks
 - oncogenic potential
- Risk not mitigated by preflight quarantine
- Space flight stress alters immune response
- Diminished immunity results in reactivation and dissemination (“shedding”) of latent viruses
- May serve as an early predictor of medically significant changes in immune response



Viral Reactivation During Spaceflight



Current Flight Study



RECENT SPACE IMMUNE STUDIES

Russian Med-Ops/ CYTOKINE DSO-501 (ISS)			L-60		L-10											R+0		R+7	R+14				
Latent Virus/ DSO-493 (SHUTTLE)	L-180				L-10		saliva	saliva								R+0	saliva	saliva	saliva	R+14			
Immune Function/ DSO-498 (SHUTTLE)					L-10											R+0					R+21		
Japan Immunology/ DSO-206 (SHUTTLE)			L-60	L-30												R+0	R+3	R+7			R+30		R+90
Epstein Barr/ DSO-500 (SHUTTLE)		L-120	L-65		L-10	L-3/2										R+0	R+3			R+14		AME/ R+120	
Epstein Barr/ E129 (ISS)	AME/ L-180		L-60		L-10	L-3/2										R+0	R+3			R+14			AME/ R+180
Immuno- ESA/ (ISS/SOYUZ)				L-30				L+90 to L+120						R-15 to R-7		R+1			R+7			R+28	

Integrated Immune/ SDBI-1900 (SHUTTLE)	AME**/ L-180				L-10**										R-1	R+0**				R+14			
Integrated Immune/ SMO-015 (ISS)	AME**/ L-180			L-30**			MD 8-10				MID*				R-1	R+0**						R+30**	
	PRE-FLIGHT						IN-FLIGHT						POST-FLIGHT										

*If possible via visiting Shuttle mission. Samples would be collected from the ISS crew and returned on the Shuttle.

** In conjunction with Med-Ops draw.

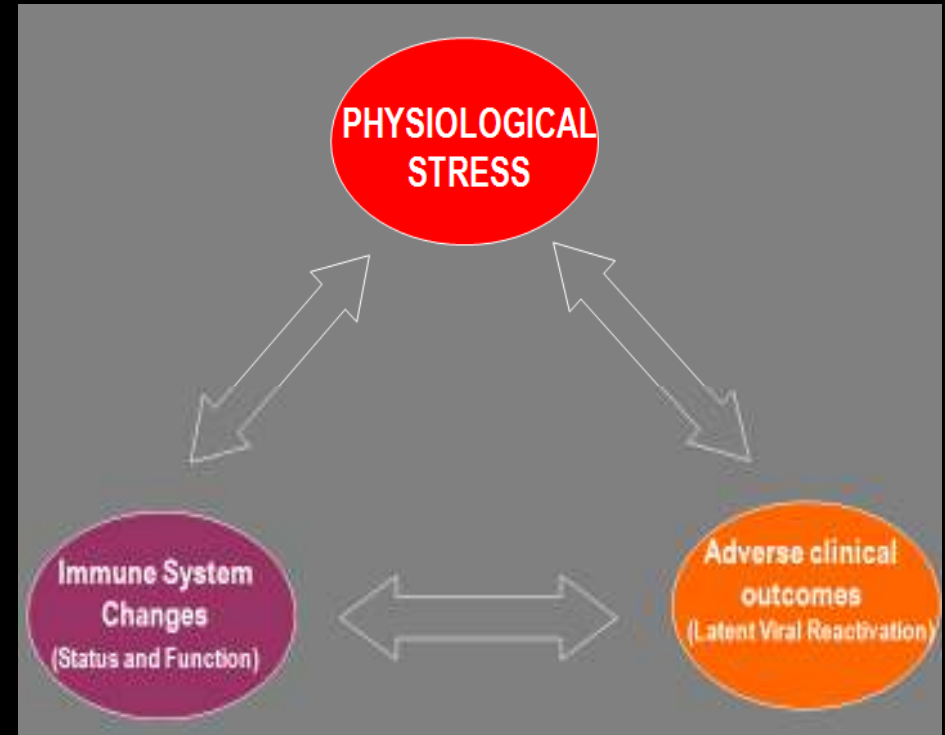
Assays

- JSC Immunology Laboratory**
- Leukocyte subsets
 - T cell function
 - Intracellular/secreted cytokine profiles
-

- Mercer University**
- Plasma cytokine balance
 - Leukocyte cytokine RNA
-

- Microgen Laboratories**
- Virus specific T cell number
 - Virus specific T cell function
 - Plasma stress hormones
-

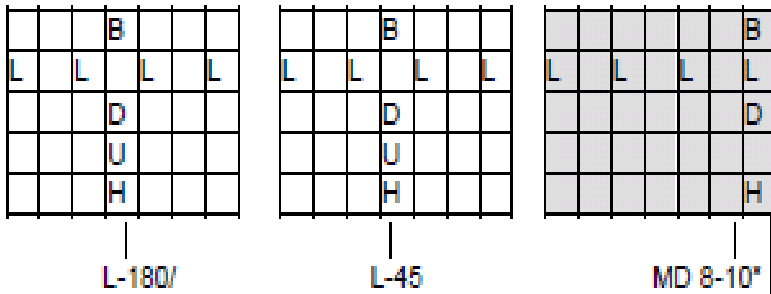
- JSC Microbiology Laboratory**
- Latent herpesvirus reactivation (saliva/urine)
 - Saliva/urine stress hormones
 - Circadian rhythm analysis



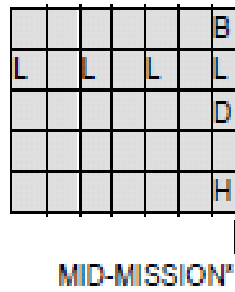
Samples - Timepoints

- BLOOD
- SALIVA (liquid)
- SALIVA (dry book)
- URINE
- Health Survey

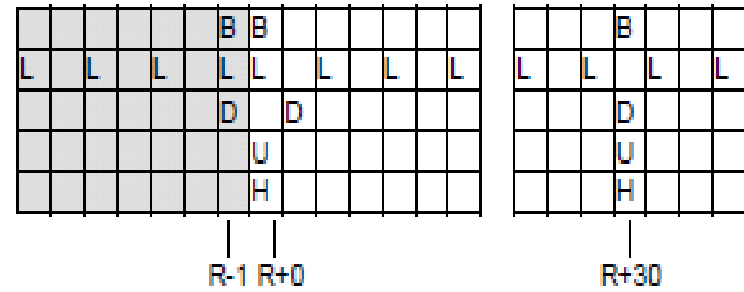
PRE-FLIGHT



IN-FLIGHT



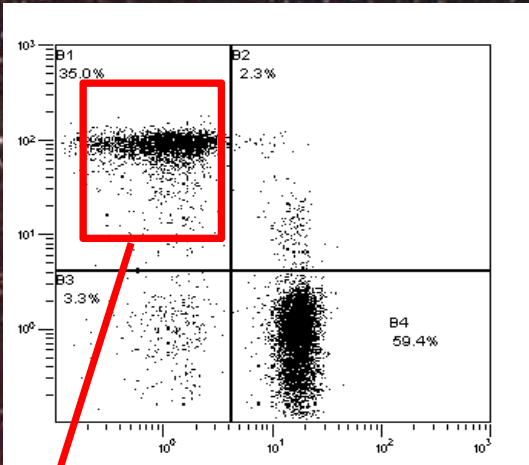
POST-FLIGHT



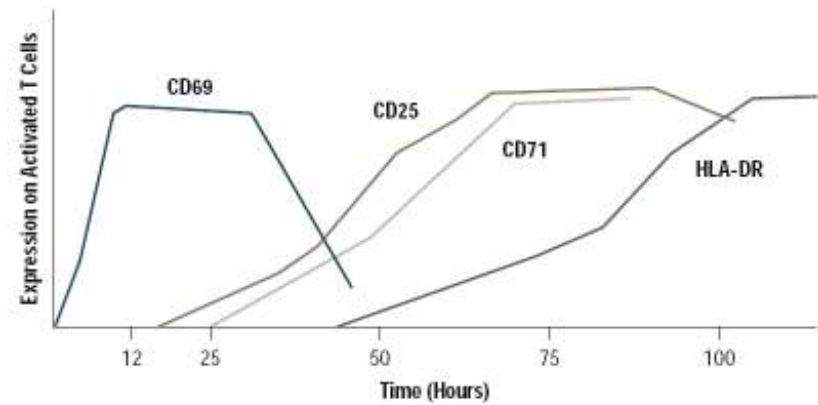
Flight Hardware



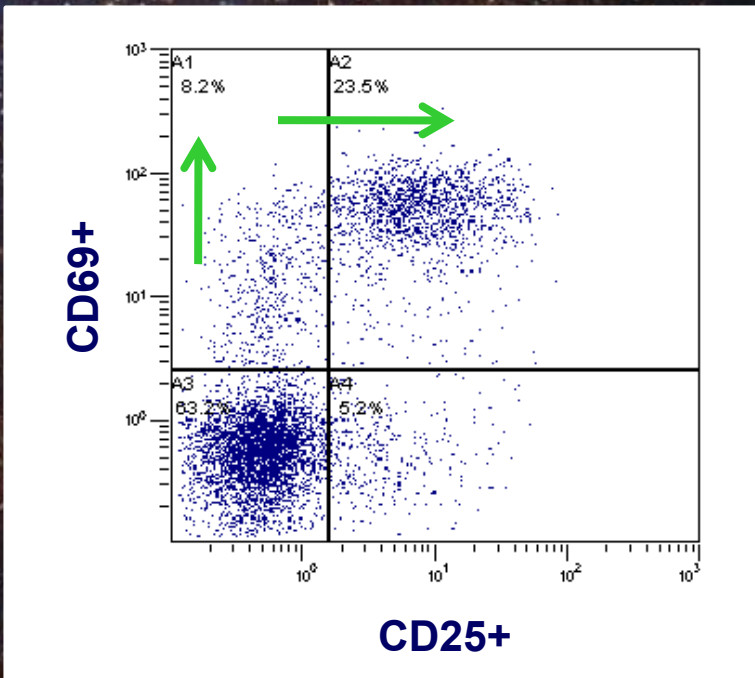
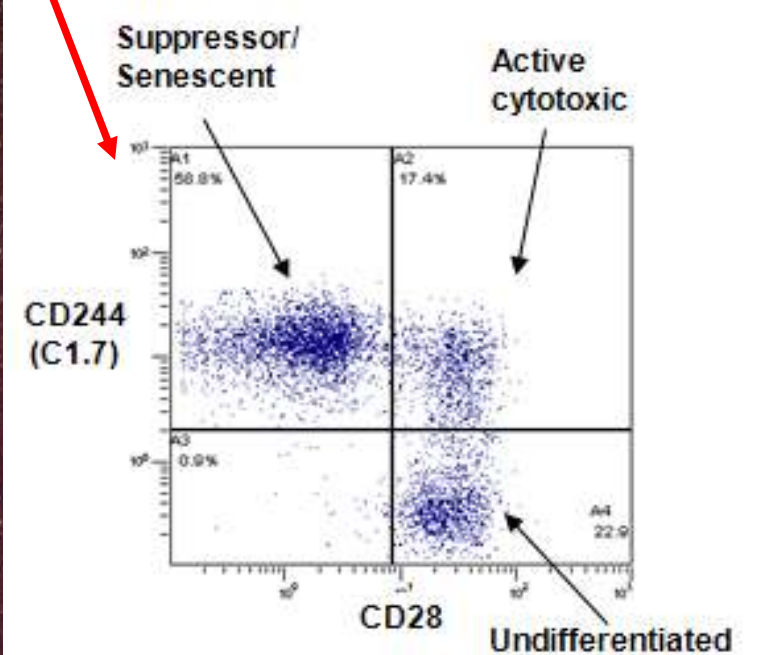
Cell Distribution



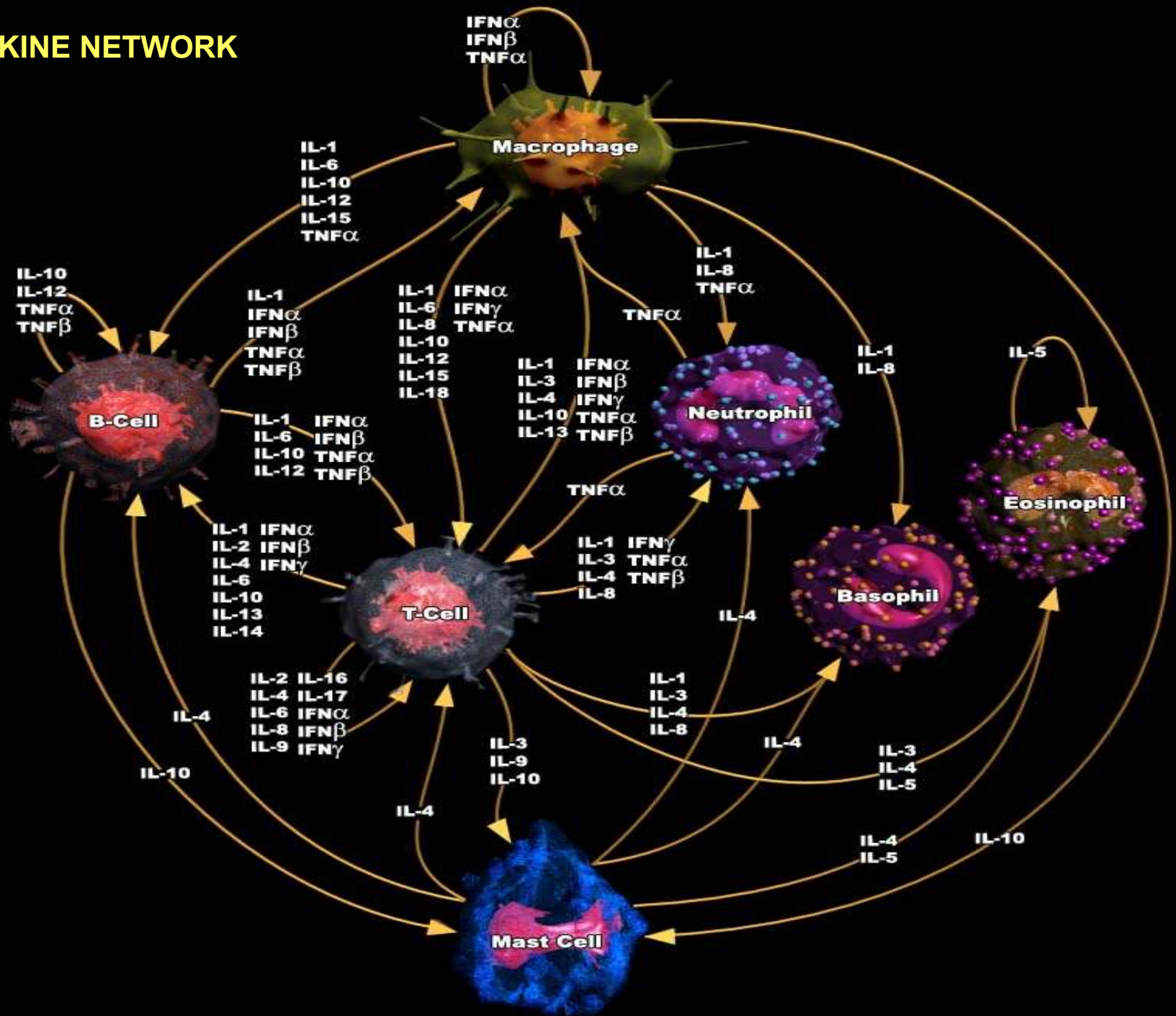
Cell Function



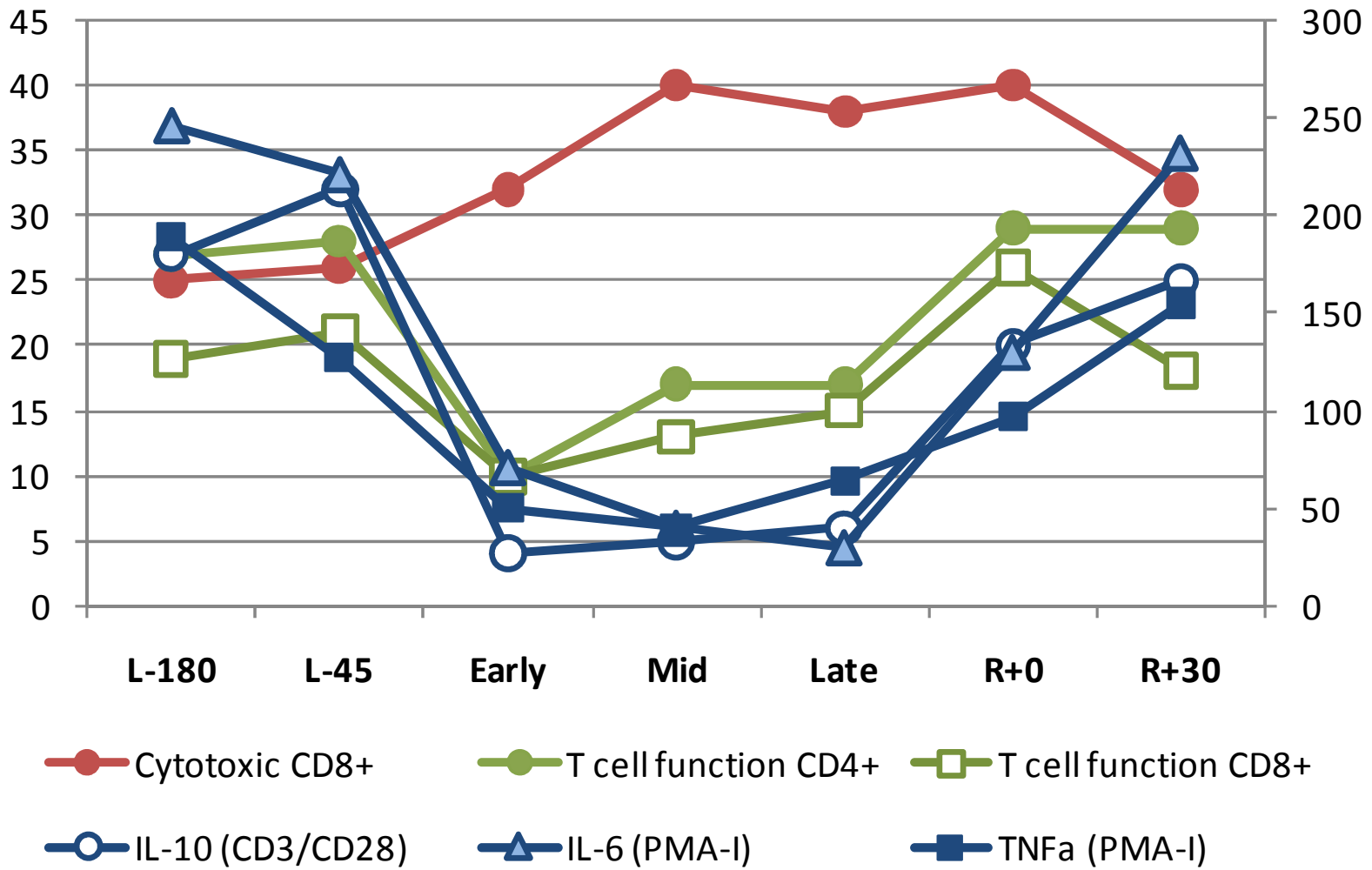
Kinetics of Expression of Activation Antigens on T Cells

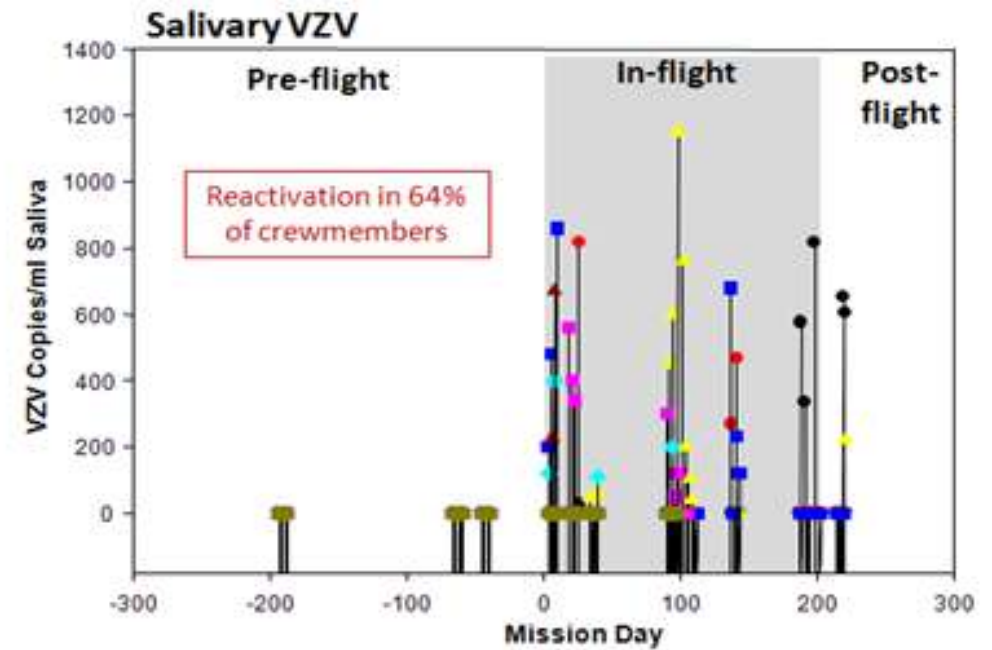
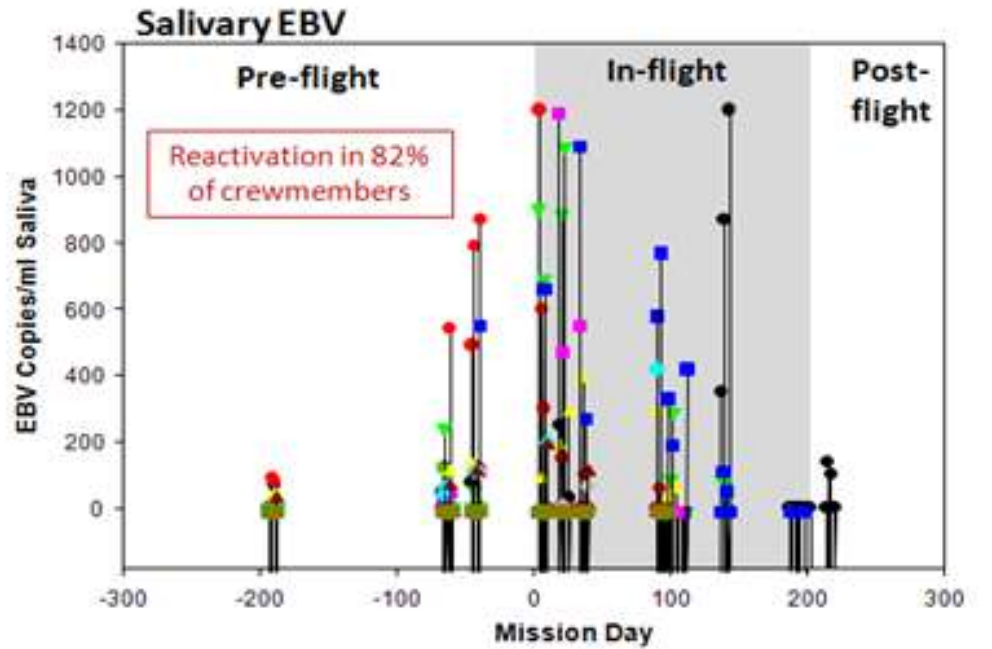


CYTOKINE NETWORK



Immune dysregulation during long-duration spaceflight (SMO-015 mid-study data; n=10)





Go Forward Plan...

- Define 'space normal' for immunity
- Validate a monitoring strategy
- Perform clinical relevance studies using terrestrial patient populations
- Determine clinical risk for immune dysregulation during spaceflight (context of exploration class missions)



- Determine the best available ground analog for immune dysregulation (feeds both data regarding mechanism and a platform to validate countermeasures)
- If necessary proceed to countermeasures validation (both ground and flight)

SPACEFLIGHT GROUND ANALOGS



What are **GROUND BASED SPACEFLIGHT ANALOGS**?

-Simulate some aspects of spaceflight on Earth for research purposes.

-Routinely used for:

human physiology research

development of a monitoring strategy

investigation of mechanism

countermeasures development/validation.

-Useful considering the microgravity restrictions on flight hardware.

Ground-based Space Flight Analogs

Extended head-down bed rest



MARS-500 (IBMP – Moscow)



Closed Chamber Confinement



NEEMO Aquarius Station



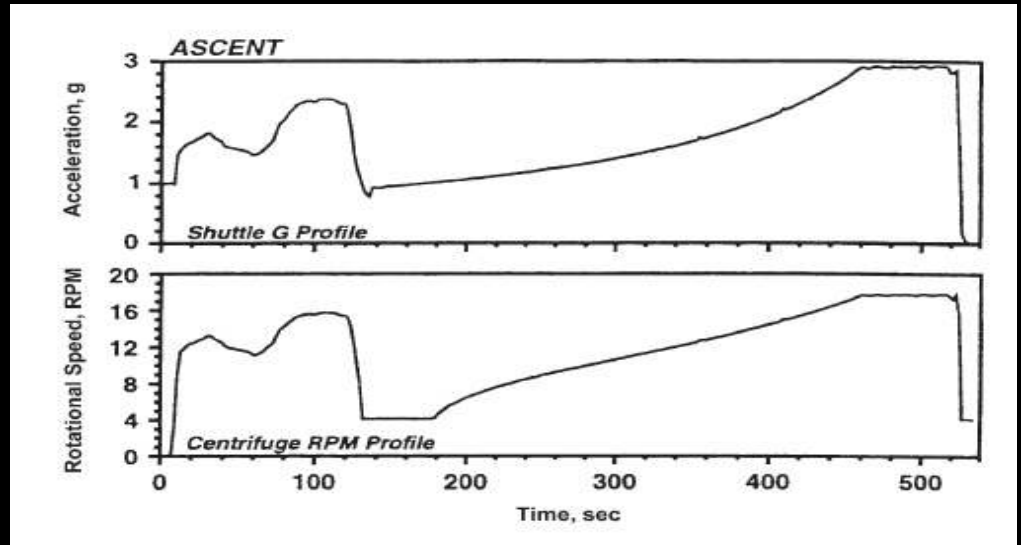
Houghton-Mars Project



Antarctica winter over



Bed Rest + Artificial Launch/Landing Stress



Bed Rest + Artificial Gravity as a Countermeasure



WHAT CAUSES IMMUNE CHANGES DURING SPACEFLIGHT?



FLIGHT-RELATED

- Radiation
- Microgravity



MISSION-ASSOCIATED

- Physiological stress
- Confinement
- Prolonged isolation
- Altered microbial environment
- Altered nutrition
- Disrupted circadian rhythms

Analog Usage: Best Analog for Immune Dysregulation?

- Simulated (or actual) mission-deployment
- Mission/exploration activities
- Intra-vehicle/extra-vehicle activities
- Associated health risk
- Adverse environment
- Isolation
- Psychological stress
- Physiological stress,
- Disrupted circadian rhythms, etc.

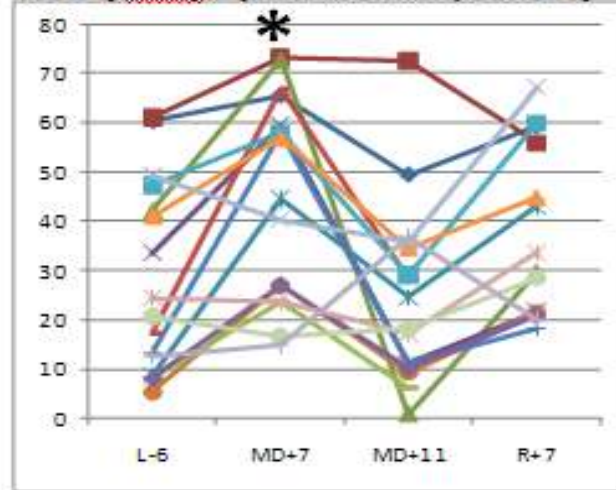
NEEMO Aquarius Station (Key Largo - Florida)



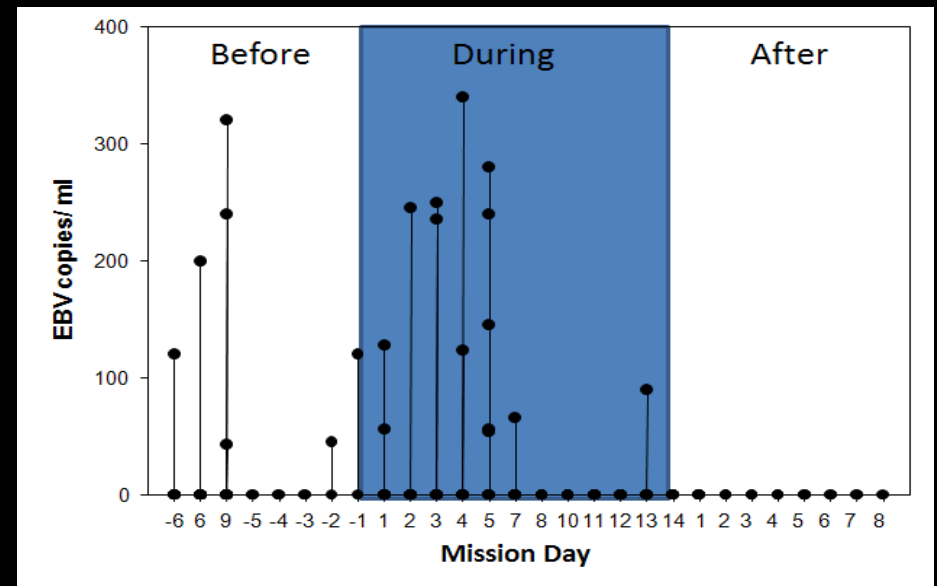
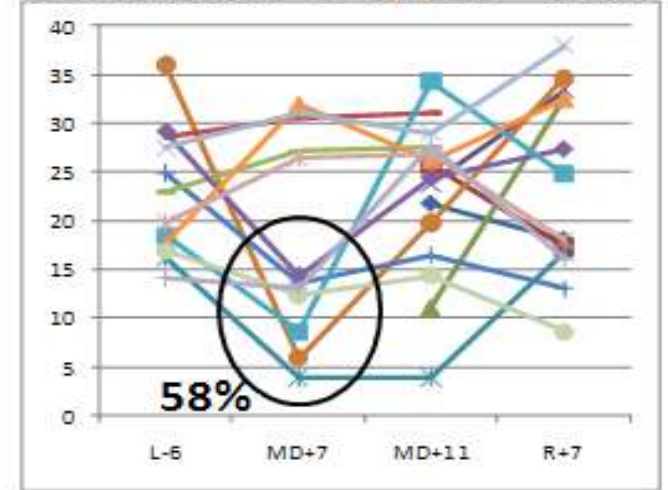


NEEMO Immune Data: N12, 13, 14 Pilot Study

CD8+/IFN γ + (Intracellular, PMA-I)



T Cell Function - CD4+/CD69+ (SEA/B)

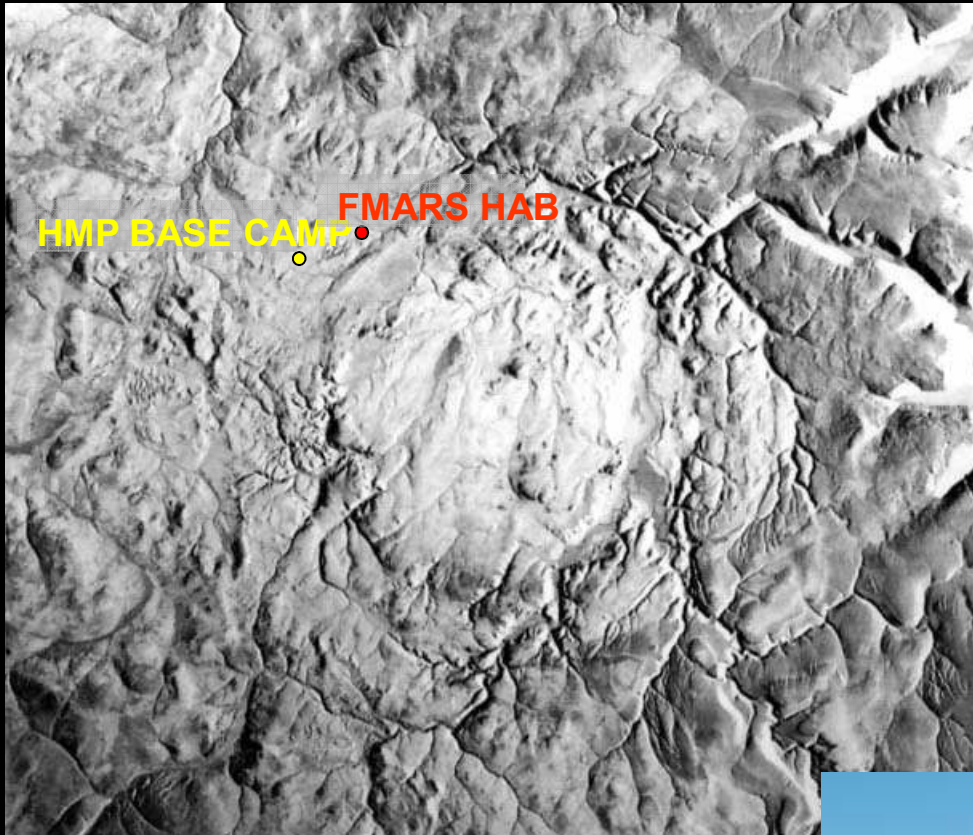




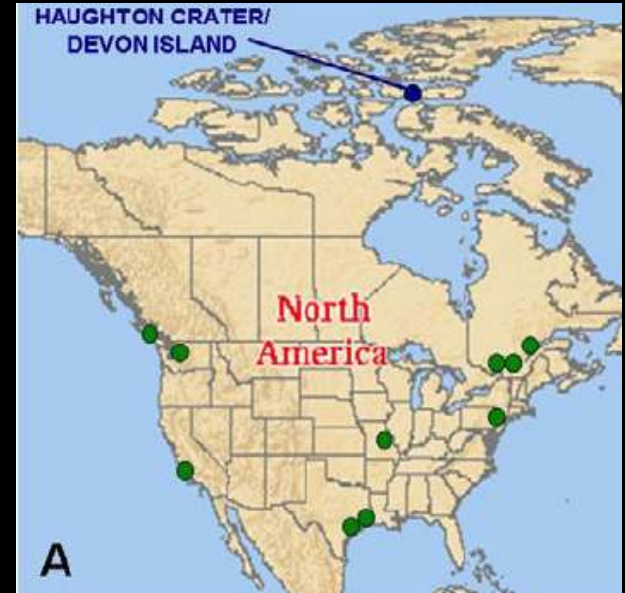
Haughton-Mars Project (High Canadian Arctic – Devon Island)



Houghton Crater



HMP 2002 Pilot Study



HMIA 2002
SAMPLE COLLECTION vs. FIELD SEASON DATES

SUBJECT	PRE-MISSION	HMIA ON-SITE ACTIVITY																												POST-MISSION									
		30-Jun-02	1-Jul-02	2-Jul-02	3-Jul-02	4-Jul-02	5-Jul-02	6-Jul-02	7-Jul-02	8-Jul-02	9-Jul-02	10-Jul-02	11-Jul-02	12-Jul-02	13-Jul-02	14-Jul-02	15-Jul-02	16-Jul-02	17-Jul-02	18-Jul-02	19-Jul-02	20-Jul-02	21-Jul-02	22-Jul-02	23-Jul-02	24-Jul-02	25-Jul-02	26-Jul-02	27-Jul-02		28-Jul-02	29-Jul-02	30-Jul-02	31-Jul-02	1-Aug-02	2-Aug-02	3-Aug-02		
1	6-Jun-02																			X																		18-Oct-02	
2	10-Jun-02																			X																		23-Sep-02	
3	12-Jun-02																						X																19-Sep-02
4	12-Jun-02																				X																		17-Sep-02
5	18-Jun-02																					X																	18-Oct-02
6	18-Jun-02																					X																	
7	25-Jun-02																					X																	7-Nov-02
8	25-Jun-02																						X																30-Sep-02
9	1-Jul-02																		X																			4-Nov-02	
10	2-Jul-02																						X																18-Sep-02

= subject on Devon Island
X = date of blood collection



Research article

Open Access

Immune system changes during simulated planetary exploration on Devon Island, high arctic

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Rainer Effenhauser⁴, Raymond Widen⁵ and Clarence Sams⁴

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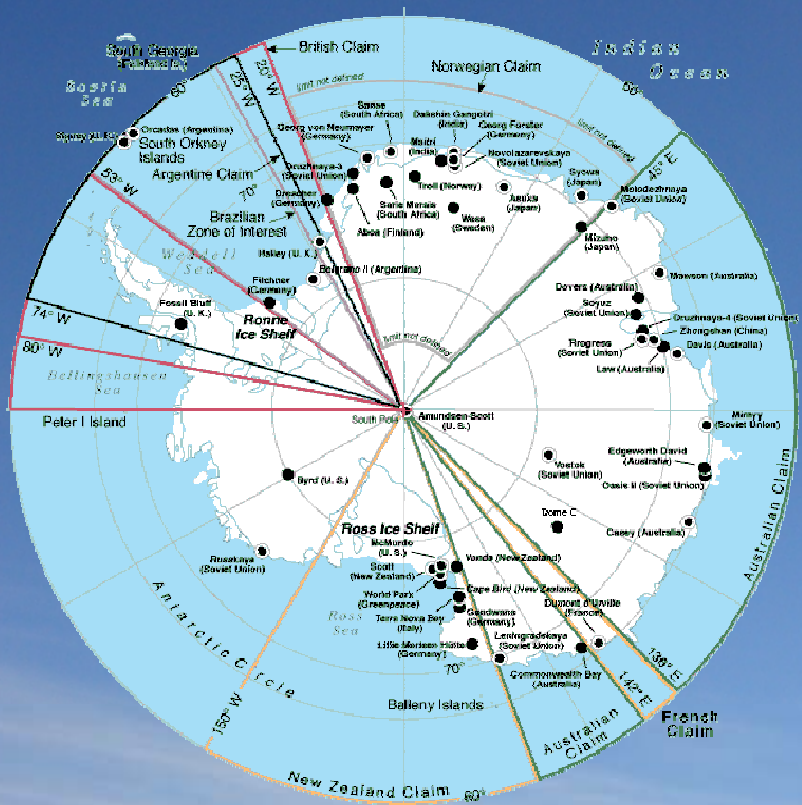
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Abstract

Background: Dysregulation of the immune system has been shown to occur during spaceflight, although the detailed nature of the phenomenon and the clinical risks for exploration class missions have yet to be established. Also, the growing clinical significance of immune system evaluation combined with epidemic infectious disease rates in third world countries provides a strong rationale for the development of field-compatible clinical immunology techniques and equipment. In July 2002 NASA performed a comprehensive immune assessment on field team members participating in the Haughton-Mars Project (HMP) on Devon Island in the high Canadian Arctic. The purpose of the study was to evaluate the effect of mission-associated stressors on the human immune system. To perform the study, the development of techniques for processing immune samples in remote field locations was required. Ten HMP-2002 participants volunteered for the study. A field protocol was developed at NASA-JSC for performing sample collection, blood staining/processing for immunophenotype analysis, whole-blood mitogenic culture for functional assessments and cell-sample preservation on-location at Devon Island. Specific assays included peripheral leukocyte distribution; constitutively activated T cells, intracellular cytokine profiles, plasma cortisol and EBV viral antibody levels. Study timepoints were 30 days prior to mission start, mid-mission and 60 days after mission completion.

Results: The protocol developed for immune sample processing in remote field locations functioned properly. Samples were processed on Devon Island, and stabilized for subsequent analysis at the Johnson Space Center in Houston. The data indicated that some phenotype, immune function and stress hormone changes occurred in the HMP field participants that were largely distinct from pre-mission baseline and post-mission recovery data. These immune changes appear similar to those observed in astronauts following spaceflight.

Conclusion: The immune system changes described during the HMP field deployment validate the use of the HMP as a ground-based spaceflight/planetary exploration analog for some aspects of human physiology. The sample processing protocol developed for this study may have applications for immune studies in remote terrestrial field locations. Elements of this protocol could possibly be adapted for future in-flight immunology studies conducted during space missions.



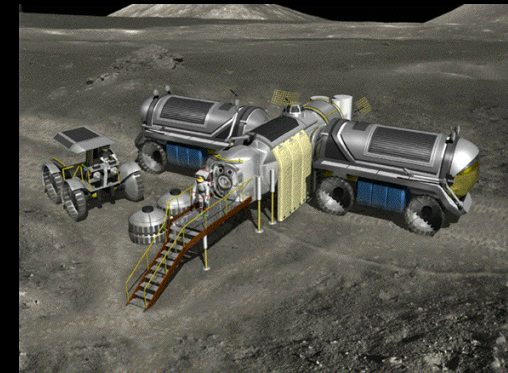
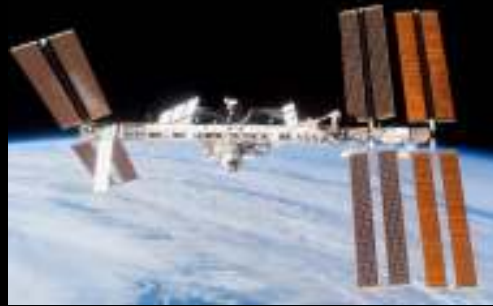
CHOICE₂

CONSEQUENCES OF LONGTERM-CONFINEMENT AND HYPOBARIC HYPOXIA ON IMMUNITY IN THE ANTARCTIC CONCORDIA ENVIRONMENT



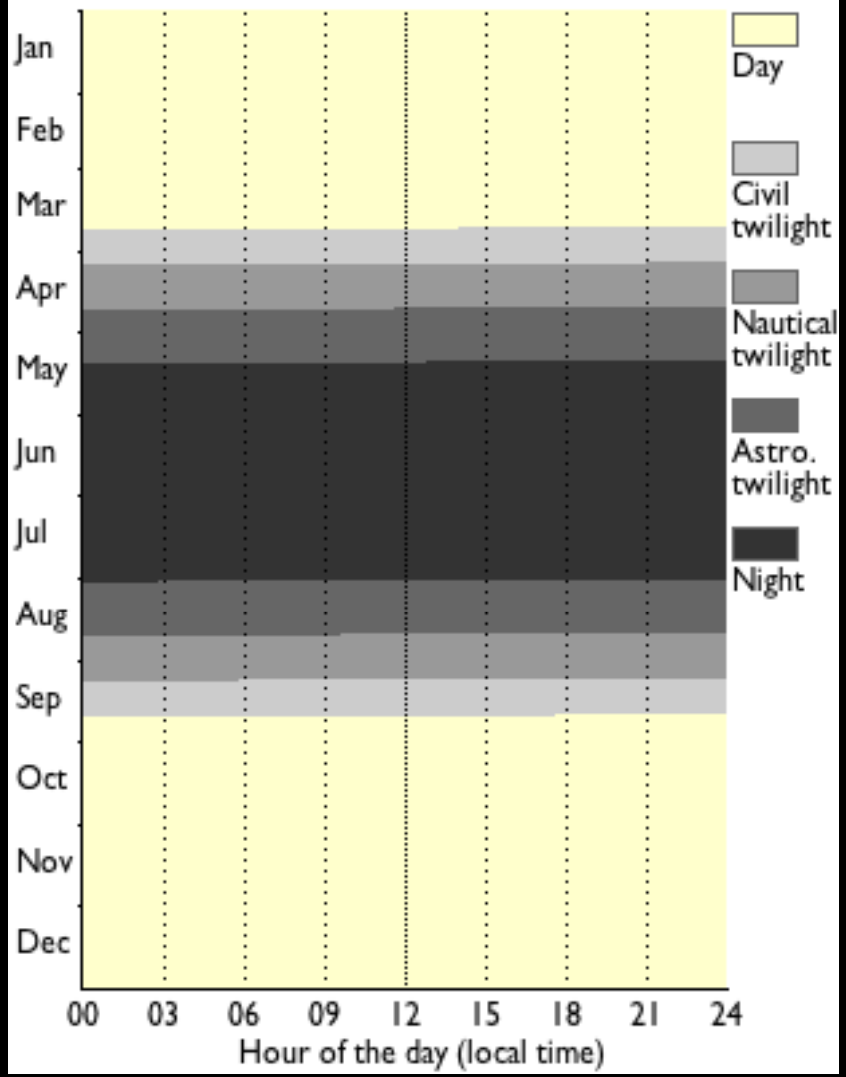
Concordia Station as Spaceflight-Planetary Exploration Analog

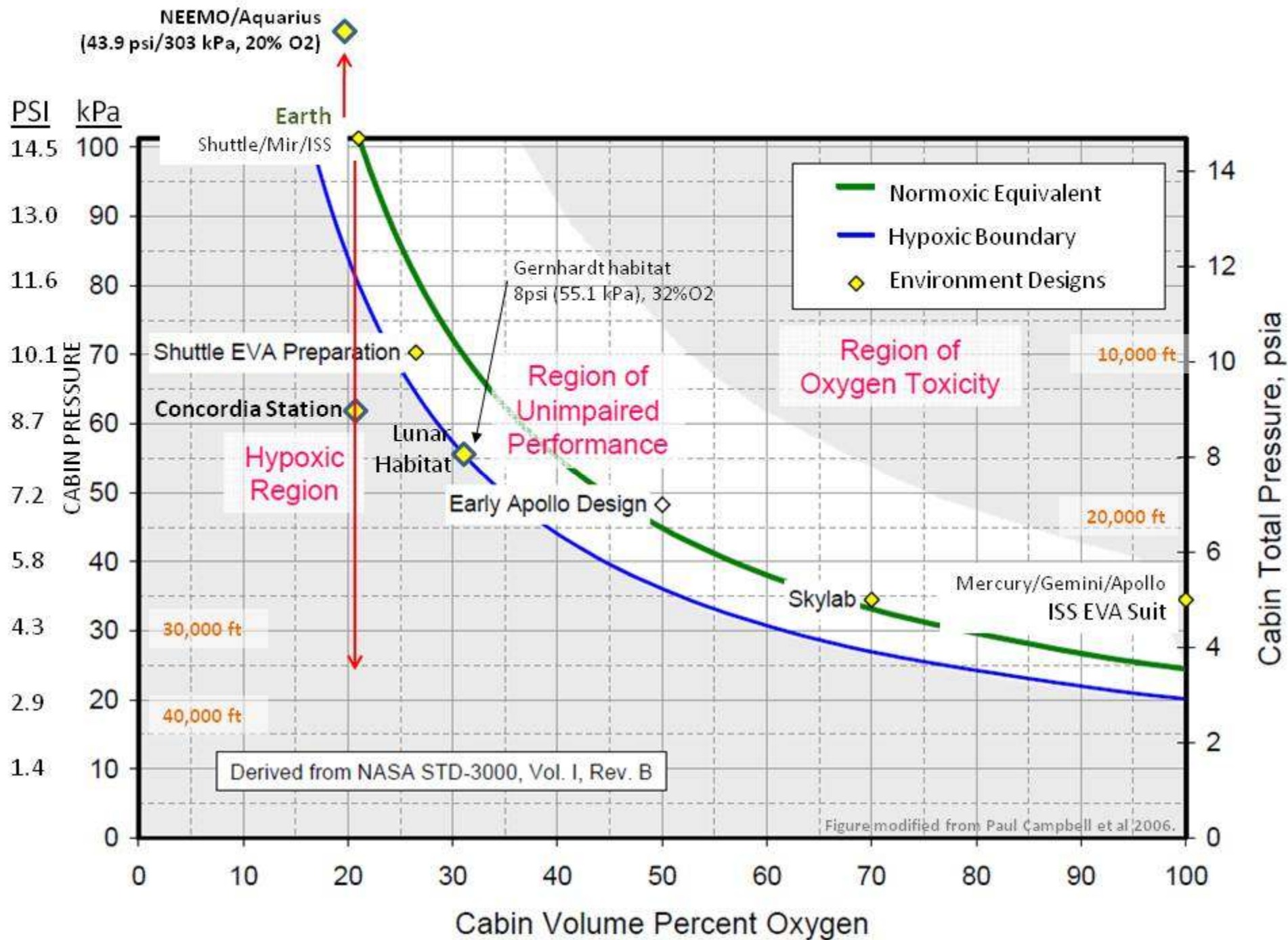
- Difficult travel in/out
- Extreme isolation, even greater than ISS
- Altitude 3200m (10,500 ft)
- Air pressure 645hPa (mbar) = chronic hypobaric hypoxia
- Oxygen content ~half sea level
- Lack of CO₂ in air
- Higher ionization in air (increases oxidative metabolism)



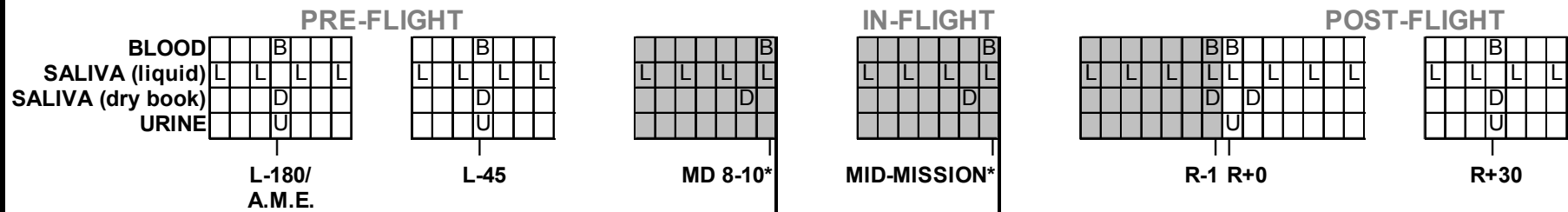
- Relative humidity 3-5%
- Snowfall ~1cm/yr
- High winds
- Elevated UV exposure (summer)
- Mean winter temperature -60 C (-72 F)
- Mean summer temperature -30 C (-22 F)
- Disrupted circadian rhythms
- Altered nutritional aspects

South Pole (90°S) Sunlight – 2011





INTEGRATED IMMUNE



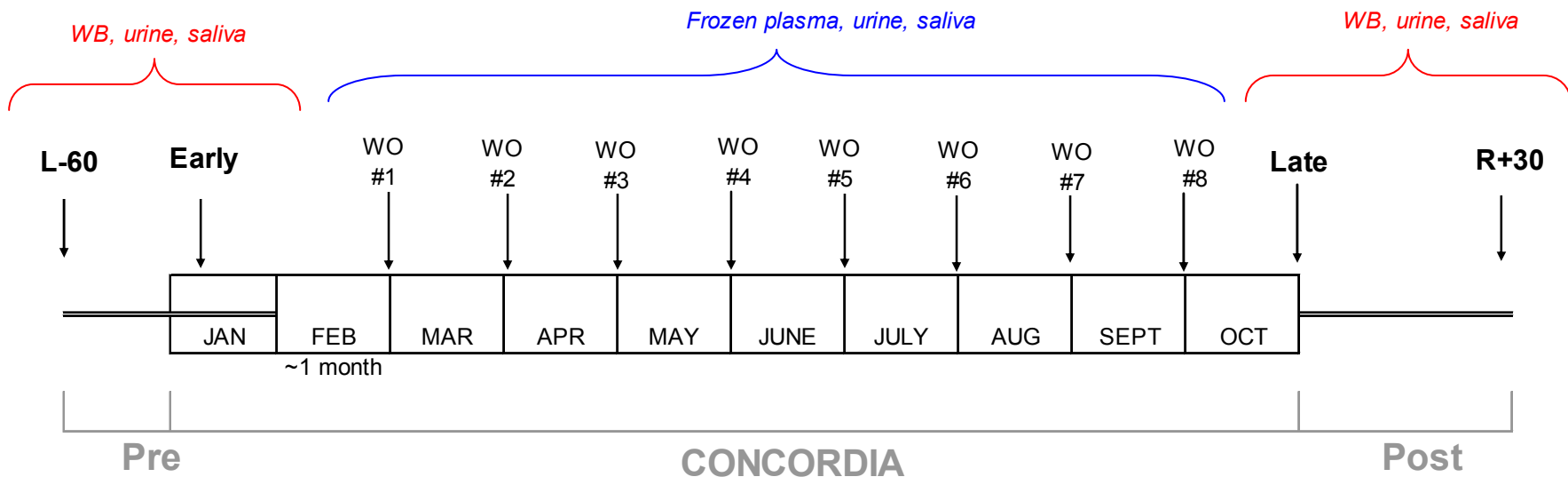
KEY:

- B Single blood collection
- L Single liquid saliva collection in A.M.
- D Single day of dry saliva collections (5 throughout day)
- U Single 24 hour urine collection (void by void).

Shuttle or Soyuz undocking occurs. ISS crew (staying on station) to be sampled during last full day of docked operations. Samples to be returned on Shuttle/Soyuz.

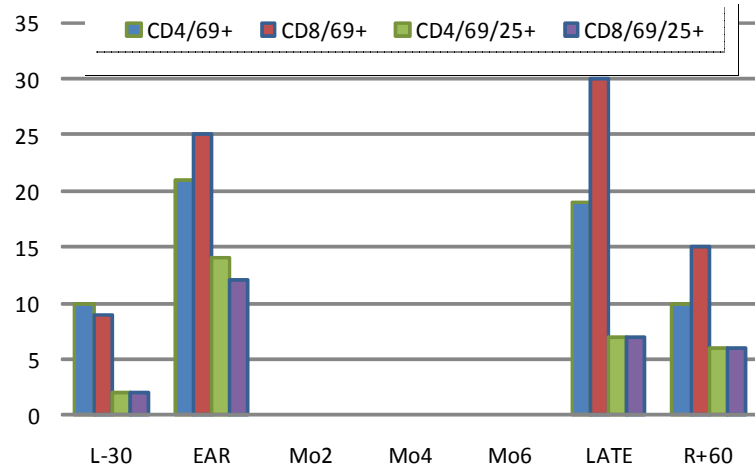
*Early/mid ISS samples to be collected only if sample return possible by other returning/visiting Shuttle/Soyuz vehicle. All ground blood collections coincide with AME or Med-Ops draws when possible.

CHOICE

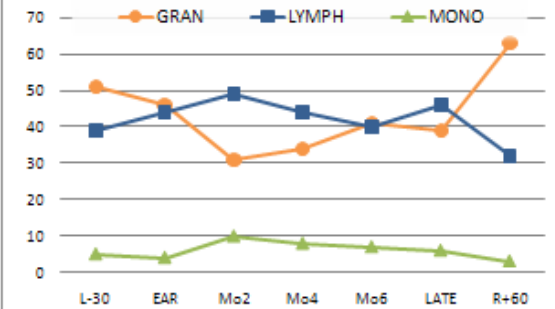


NASA/ESA Concordia/Antarctic Immune Study

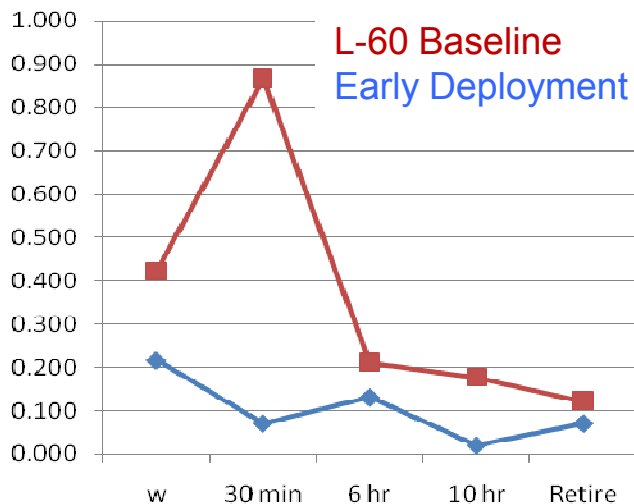
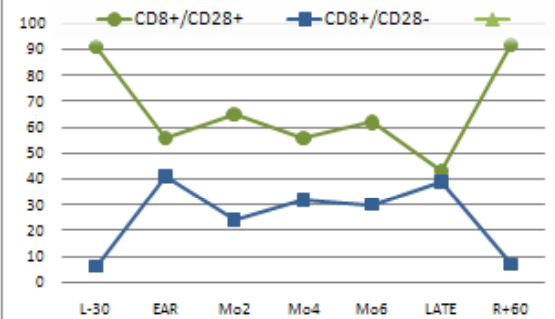
T Cell Function: A+B



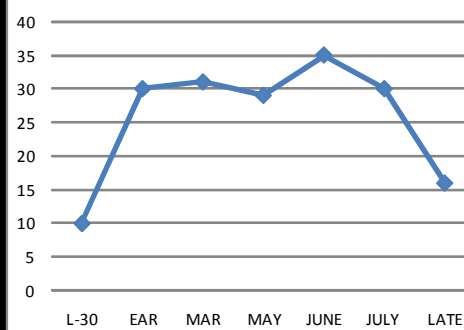
Leukocyte Subsets



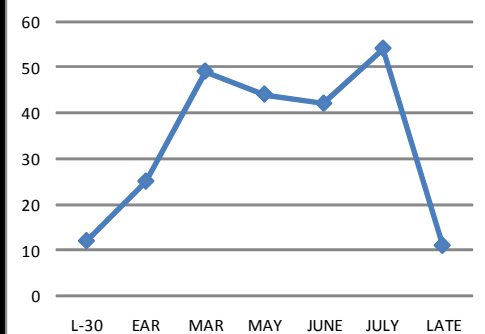
CD8+ Differentiation State



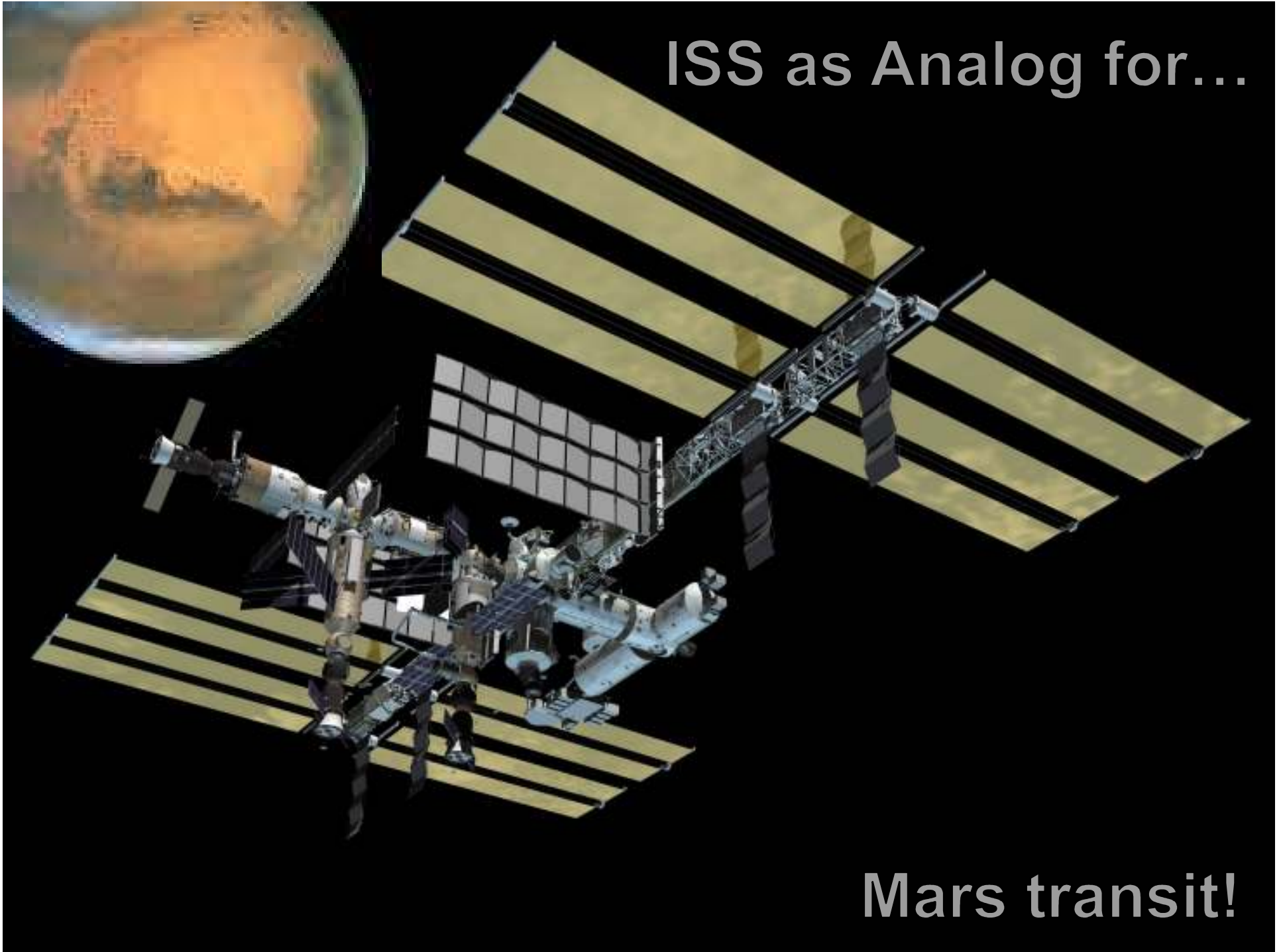
LPS: TNFa



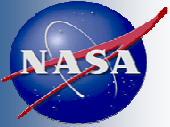
LPS: IL-10



ISS as Analog for...



Mars transit!



Mars-ISS Analog Mission Concept

Use ISS as test platform to reduce risk to humans of Mars transit mission (outbound or return) and Mars surface transition

- ISS as high-fidelity, cost-effective simulation of eventual Mars mission: personnel (flight, ground); vehicle; environment; perceived risk; meaningful work.
- Limitations: Earth outside window; infrastructure (resupply timing; real-time MCC monitoring); capability to break simulation when necessary.
- Near-Term
 - Assess and reduce crew health and mission risks such as weightless deconditioning, crew autonomy, communication delays, planning and execution, and new technologies
 - Exploit ISS as unique testbed providing weightlessness and psychological factors not available in other analogs
- Longer-Term
 - Full Mars (or NEO) mission duration (900 days)
 - Expanded landing site exploration activities

What can ISS offer to human research for a simulated Mars transit?

Strengths

Weightless duration comparable to opposition-class mission Earth-to-Mars and Mars-to-Earth transits

Physiology

Countermeasures development/validation

High-fidelity representation of astronauts in a spacecraft in the flight environment with operational tasks and facing meaningful risks

Behavioral health and performance

Human factors

Weaknesses

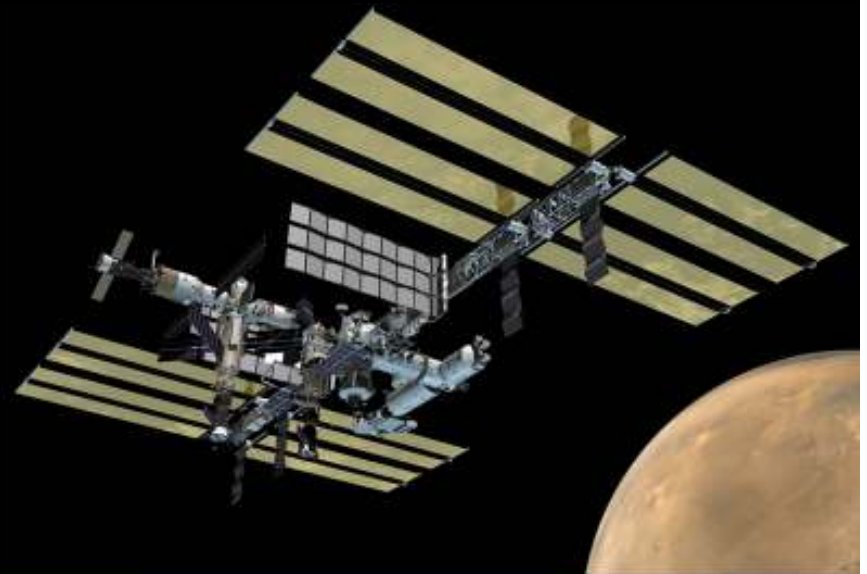
Shielded from deep-space radiation environment

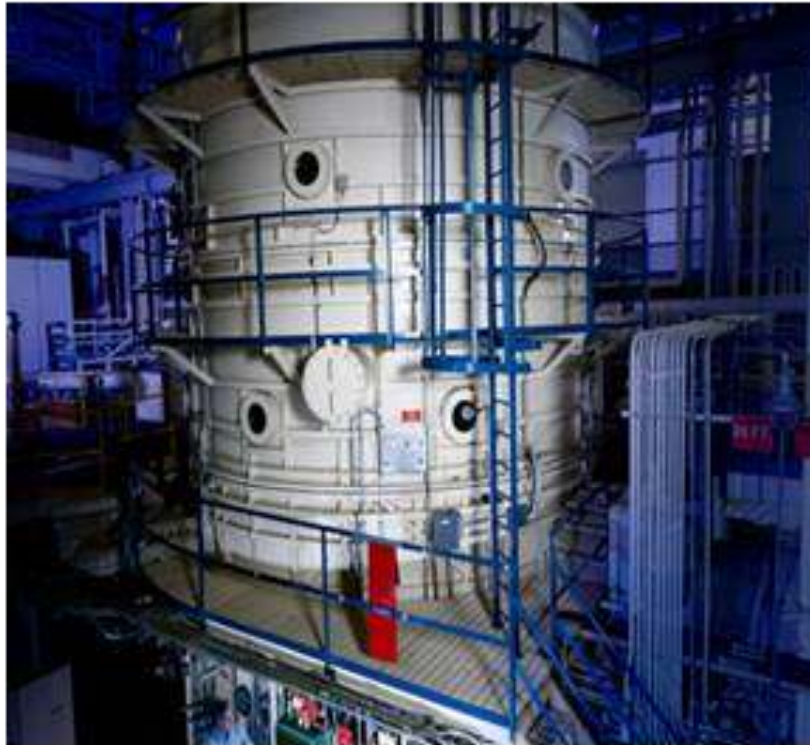
Proximity to Earth

Minimal time delay in communications

Frequent abort opportunities

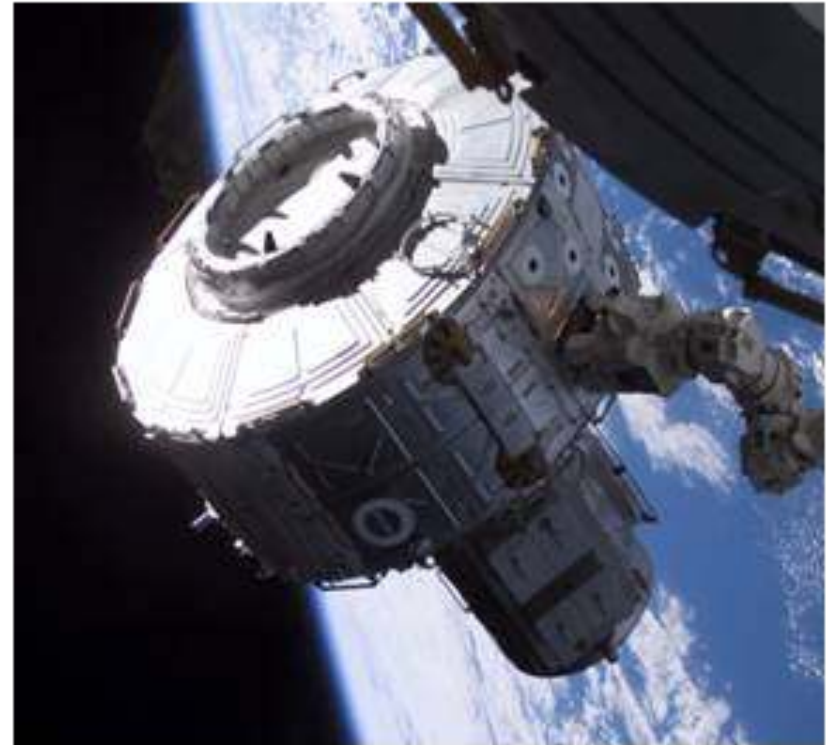
Earth is always just outside the window





Phase 1: JSC 20ft Chamber (2012)

- 30 subjects
- 10d isolation/EVA activities
- 8/32 atmosphere



Phase 2: ISS Airlock (2013-14)

- 2 crewmembers - Expedition 35/36
- 3 week isolation/EVA activities
- 8/32 atmosphere

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Materials to aid educators who want

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Human Health and Safety



About Human Health & Safety

In recent years, the objectives of our nation's space program have grown increasingly sophisticated and ambitious. Future missions will focus on exploration at greater distances from Earth and extended stays in space. To ensure that these goals are achieved, NASA's astronauts must be able to perform at peak productivity under even the most daunting conditions. The Human Research Program is dedicated to discovering the best methods and technologies to support safe, productive human space travel.



From the challenges of providing appetizing food and optimal nutrition to managing the environmental risks posed by radiation and lunar dust, HRP scientists and engineers work to predict, assess, and solve the problems that humans encounter in space. Planned future missions, including a return to the lunar surface and human exploration of Mars, will dramatically increase the scope of the challenges and demands that face NASA's astronauts. The HRP is working to improve astronaut's ability to collect data, solve problems, respond to emergencies, and remain healthy during and after extended space travel.

Part of HRP's mission is to educate the public about the challenges of human space travel. As you navigate this site, you can learn more about the research and technology that supports and facilitates the work of the men and women who navigate the outer reaches of space.

Areas of Study

Physiology



The human body is a remarkably complex assembly of systems. To carry out even the simplest task requires the input and cooperation of a highly orchestrated set of subsystems, such as nerves, bones, ...

[Learn more](#)

Human Research Program

Working with HRP

The Human Research Program conducts research and develops technologies that allow humans to travel safely and productively in the environment of space.

Human Research Roadmap

The Integrated Research Plan (IRP) describes the portfolio of HRP research and technology tasks. A web-based version of the IRP is accessible via the Human Research Roadmap.

2010 HRP Annual Report

The Human Research Program 2010 Year in Review.

Human Research Videos

How Space Exploration Affects Astronauts' Bones

[View This Video](#)

How Space Exploration Affects Muscles

Exercise Helps Keep Astronauts Healthy in Space

Radiation and Human Space Exploration

<http://www.nasa.gov/exploration/humanresearch/>



Human Research Roadmap



A Risk Reduction Strategy for Human Space Exploration

[Explore the Roadmap](#)

[Search the Roadmap](#)

[HRP Architecture](#)

Crew health and performance is critical to successful human exploration beyond low Earth orbit. The Human Research Program (HRP) investigates and mitigates the highest risks to human health and performance, providing essential countermeasures and technologies for human space exploration. Risks include physiological effects from radiation, hypogravity, and terrestrial environments, as well as unique challenges in medical support, human factors, and behavioral health support. The HRP utilizes an [Integrated Research Plan \(IRP\)](#) to identify the approach and research activities planned to address these risks, which are assigned to specific Elements within the program. The Human Research Roadmap is the web-based tool for communicating the IRP content.

<http://humanresearchroadmap.nasa.gov/>

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NASA Education

All Student Programs

Achieving Competence in Computing, Engineering and Space Science

[Students Higher Education]

[Available: Nationally]

ACCESS provides summer internships to highly qualified students with disabilities.

[Find out More](#)

[View site](#)

Airborne Research Experiences for Educators Project

[Educators Grades 6-12 & Students Higher Education]

[Available Nationally]

NASA offers the perfect package of adventure and career development. Teachers earn graduate level credits while spending six weeks in California as part of a residential science research program that includes flying on a NASA aircraft.

[Find out More](#)

[View site](#)

Alliance for Learning and Vision for Underrepresented Americans

[Students Grade 12]

[Available: Nationally]

ALVA is a bridge project through a partnership between the Jet Propulsion Laboratory and the University of Washington College of Engineering.

[Find out More](#)

[View site](#)

Applied Physics Laboratory Internship Project

[Students Higher Education]

[Available: Nationally]

The NASA APL Internship project is a 10-week summer internship at the Johns Hopkins Applied Physics Laboratory for students interested in civil and/or defense space projects.

[Find out More](#)

Astro Camp

[Students Grades K-8]

[Available: Nationally]

Astro Camp is an exciting, week-long mission for children located in Bay St. Louis, MS. Each year, it has activities centered around a new space exploration theme.

[Find out More](#)

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<http://www.nasa.gov/offices/education/programs/descriptions/Students-rd.html>

Questions?