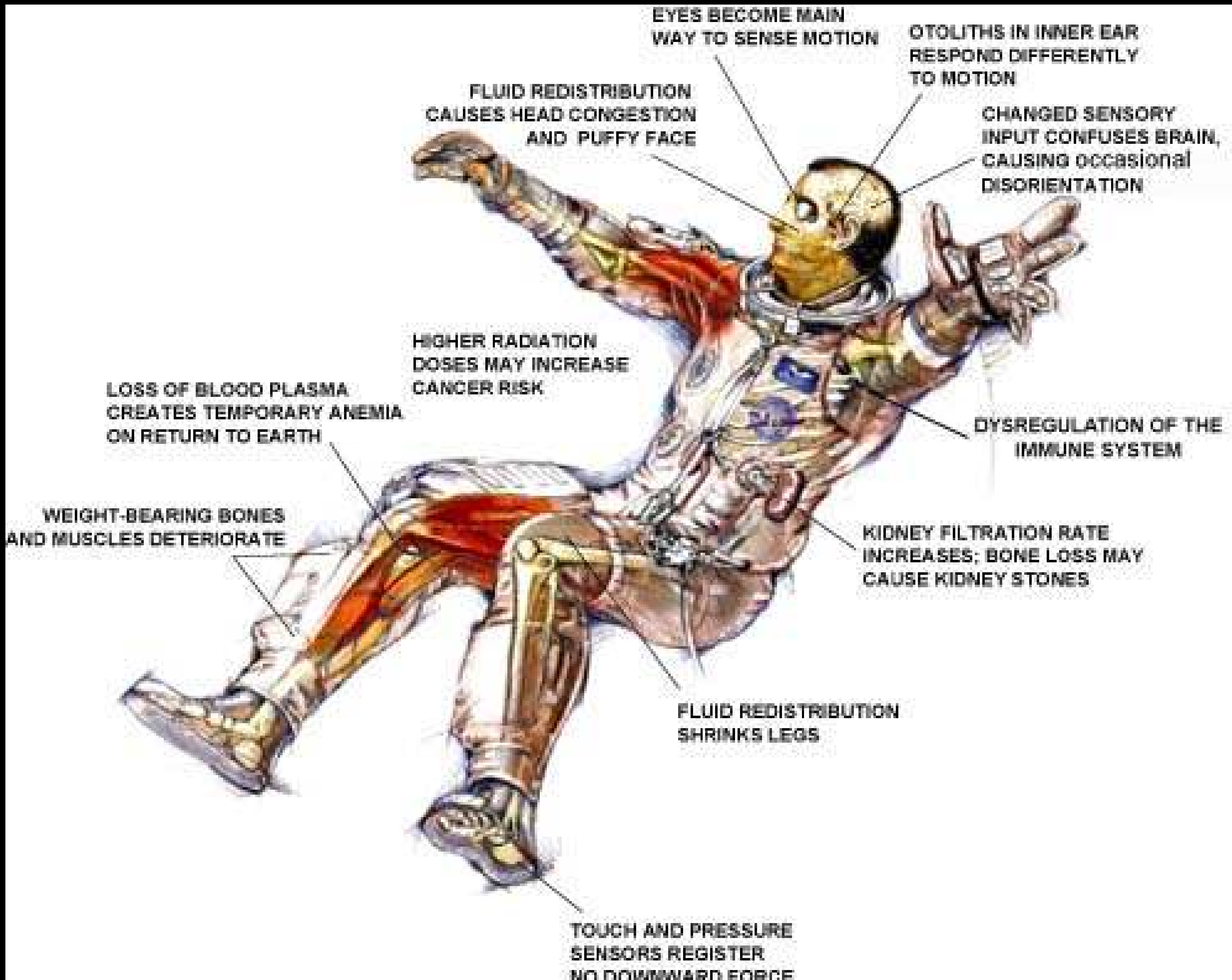
Medical Concerns for Exploration Class Space Missions

Brian Crucian, Ph.D.
September 20, 2011

Micrography Effects on the Human Body

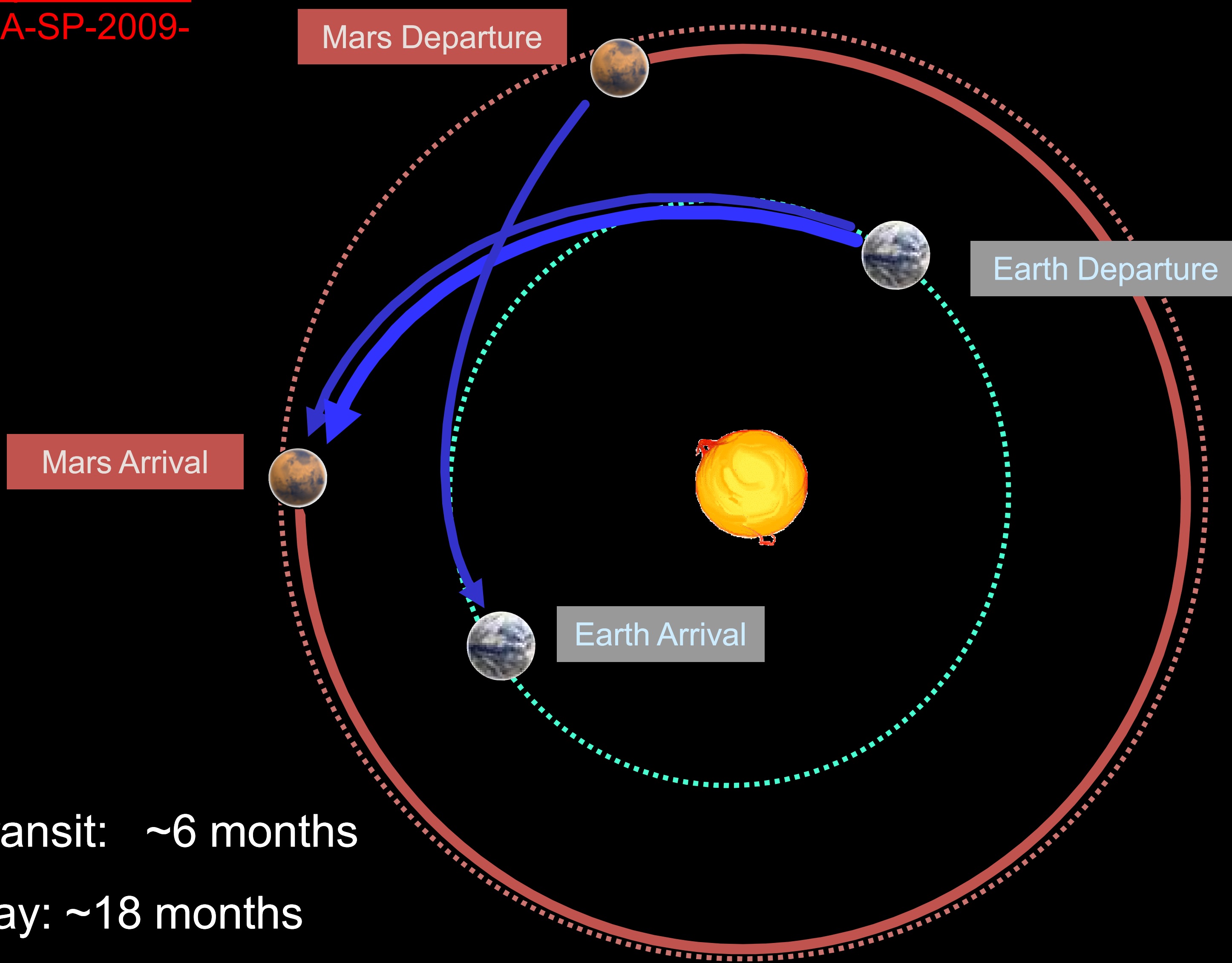


Life Sciences Research Laboratories (Bldg. 37)

- 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

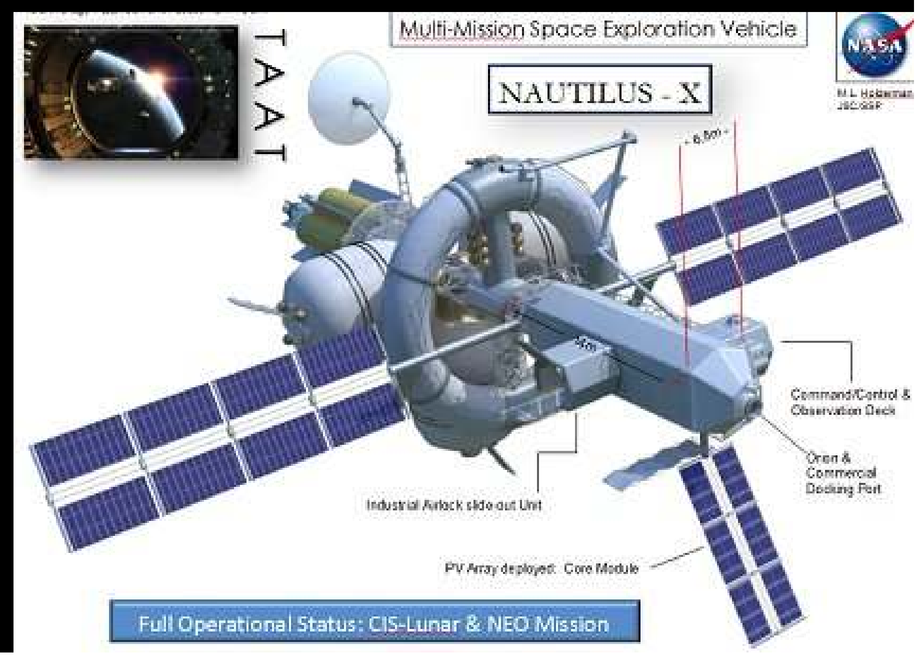
Recent changes to NASA vehicle plan

	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



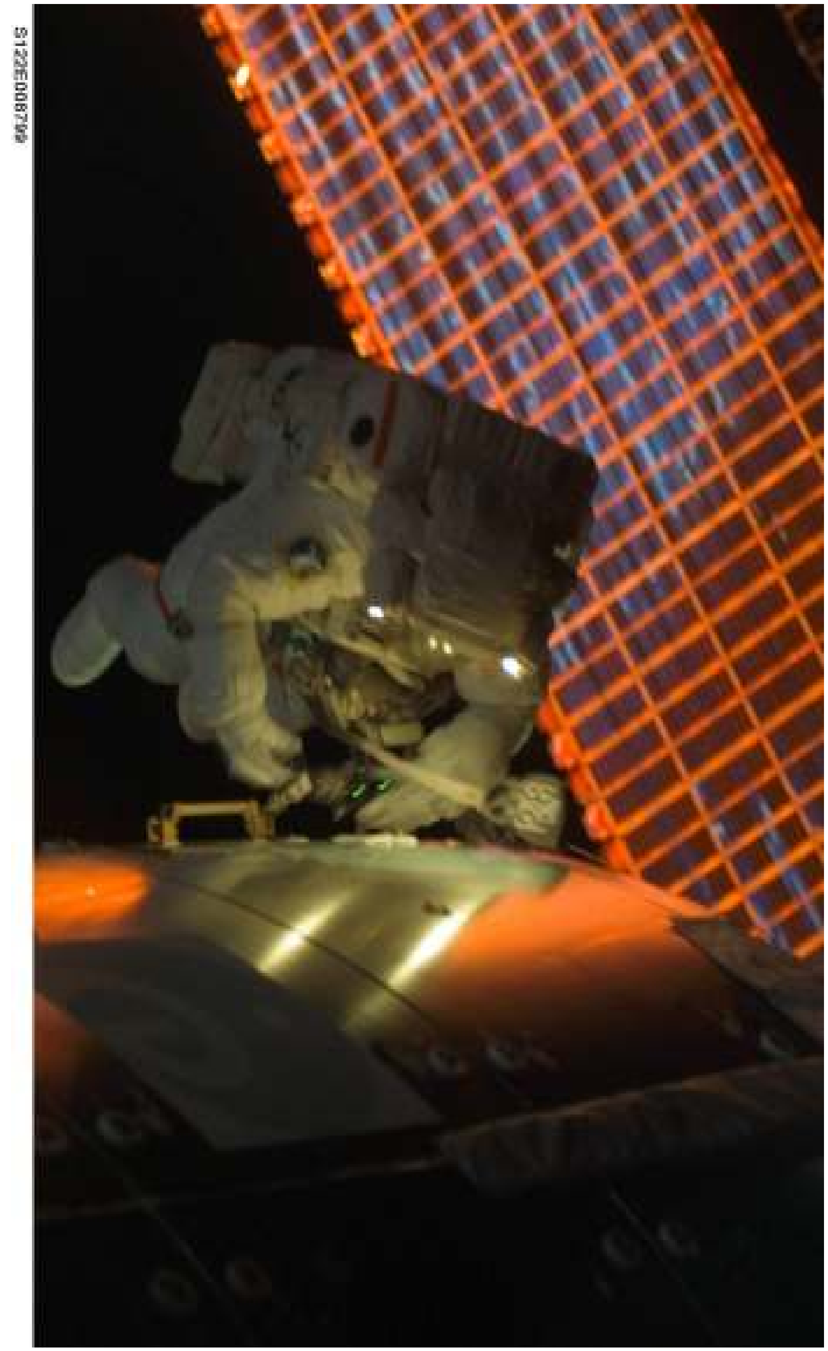
Impacts of Physiological Adaptation

- 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

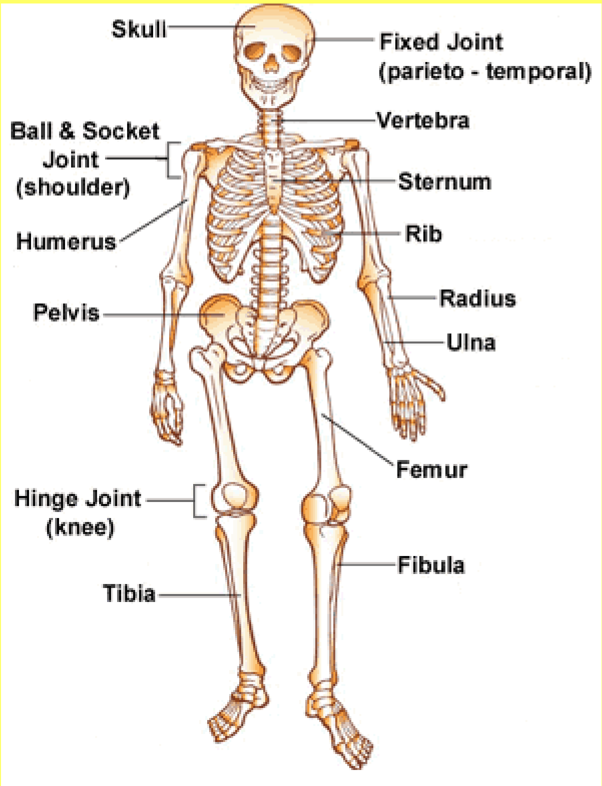
NASA Human Research Roadmap

- 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

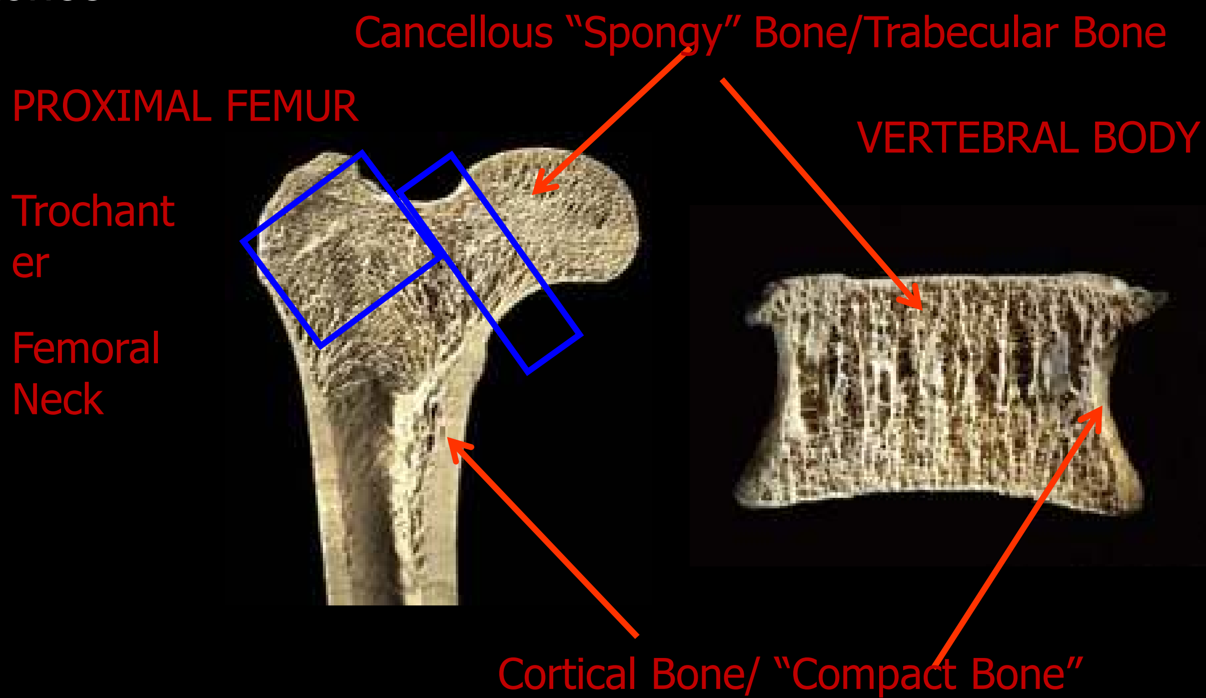
- Establish an evidence base on crew health and performance for long duration missions in reduced gravity
- Identify greatest risks and develop optimal approach to mitigations and countermeasures
- Test space biomedical technology and medical care procedures
- Actively collaborate and share resources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

Bone


Skull
Fixed Joint
(parieto - temporal)
Vertebra
Ball & Socket
Joint
(shoulder)
Sternum
Rib
Humerus
Radius
Pelvis
Ulna
Femur
Hinge Joint
(knee)
Fibula
Tibia

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.



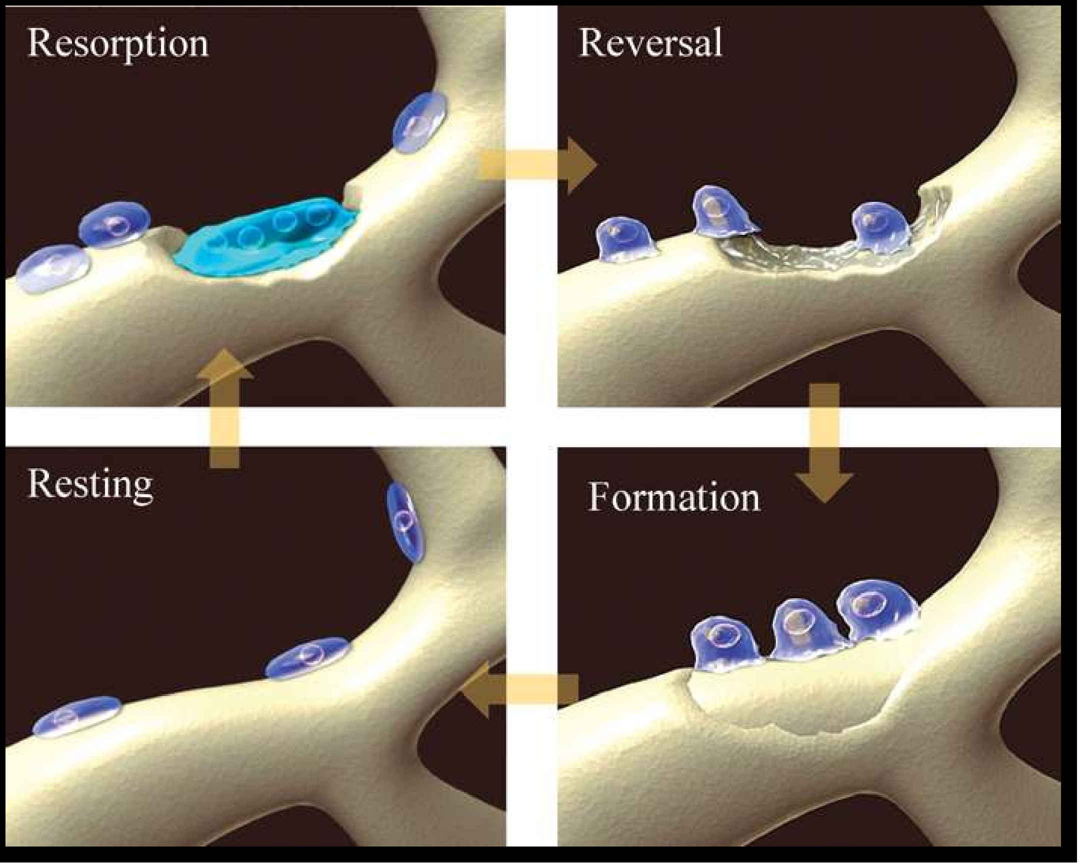
What is wrong?

•But bones are actually dynamic living tissues that constantly reshape themselves in response to the stresses placed on them

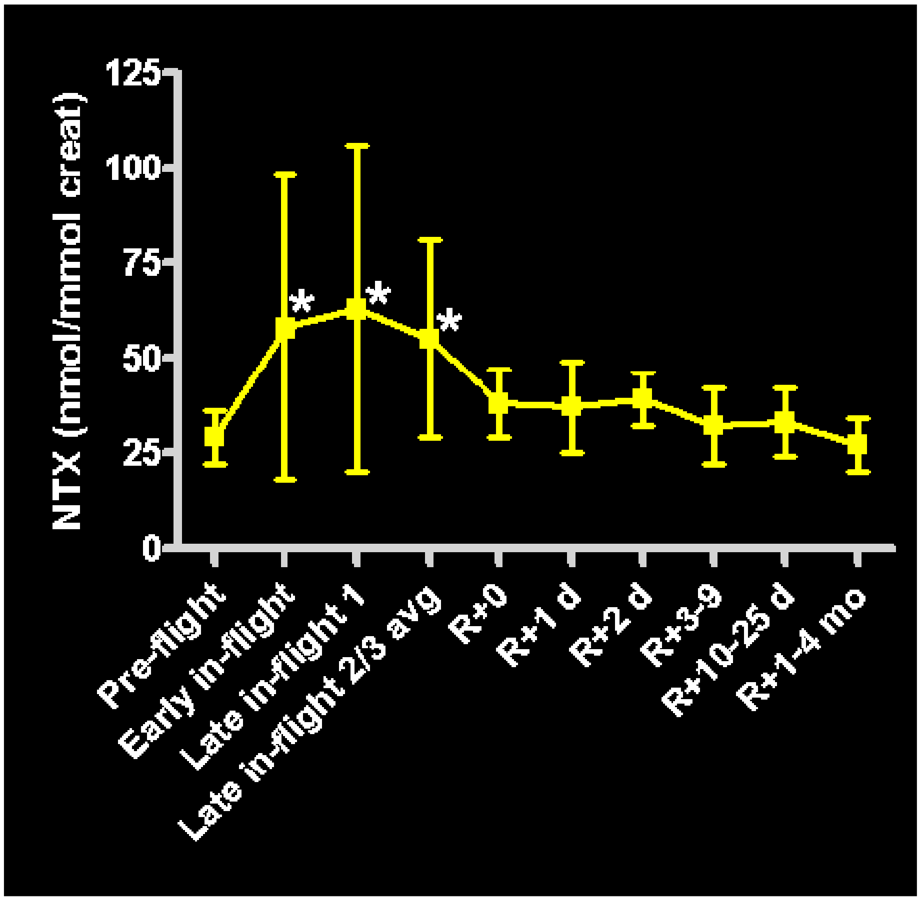
•Two cell types, "osteoblasts" and "osteoclasts" are constantly building or destroying bone. Usually these actions balance each other out. But when stresses on bones are reduced, removal outpaces replacement, leading to too little bone which can more easily break.

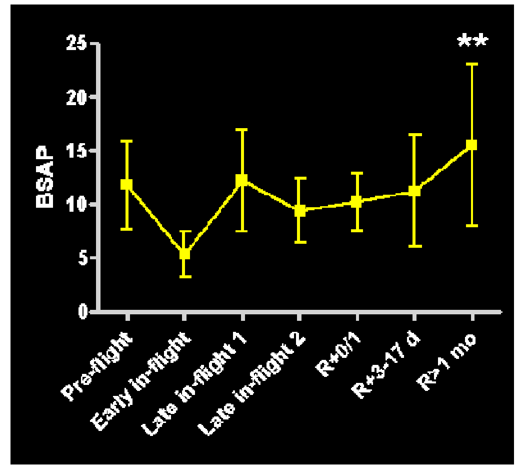
•In prolonged weightlessness, bone mass decreases because the lack of stress on the bones slows the formation of osteoblast cells.

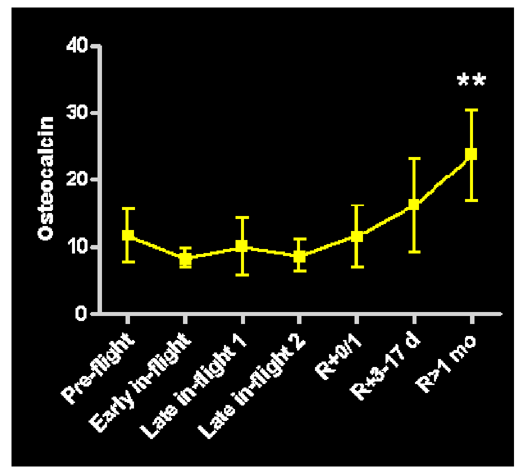
•Fewer bone-building cells, along with a constant level of bone-destroying activity, translates into a net loss of bone mass.



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

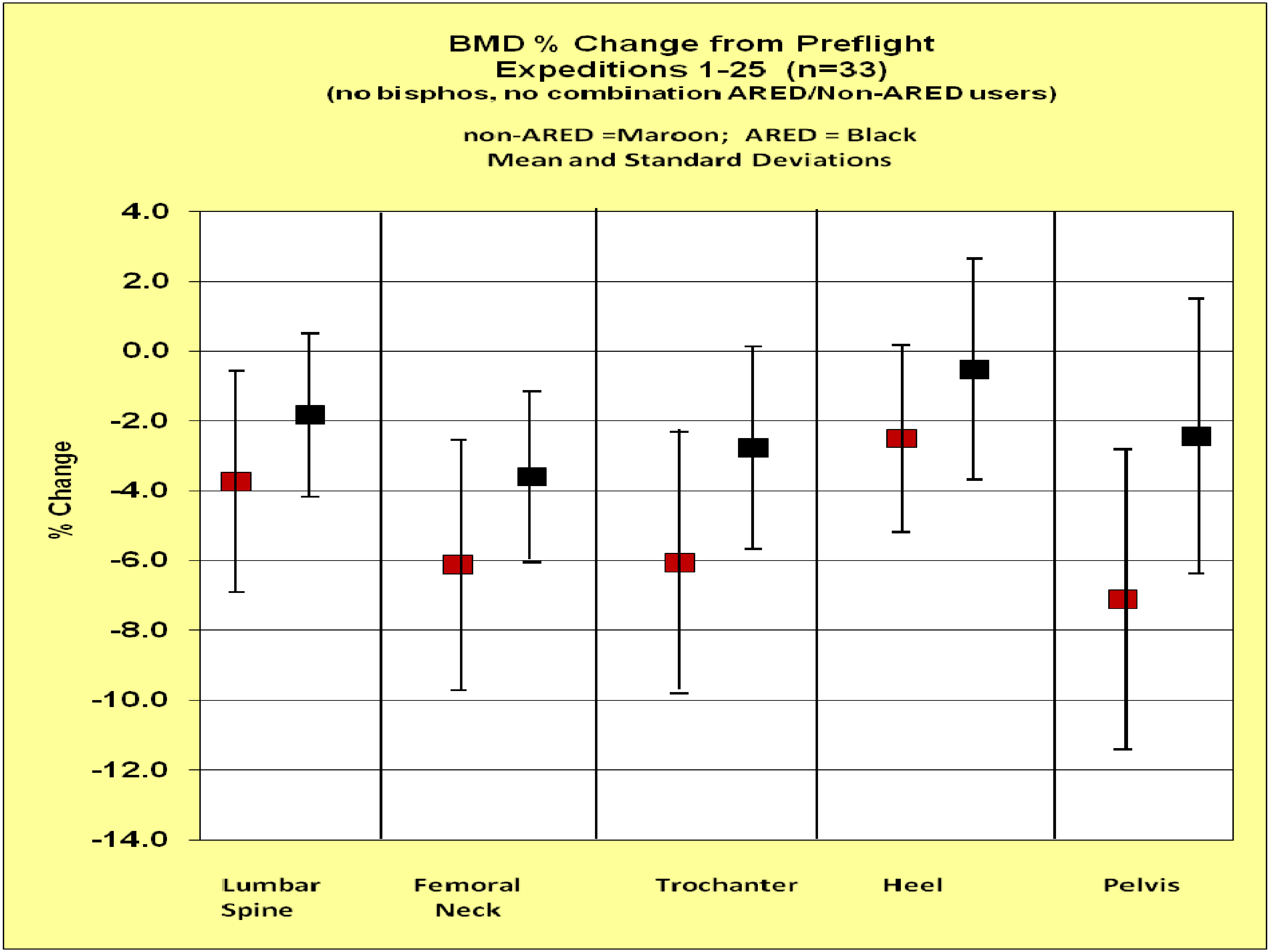






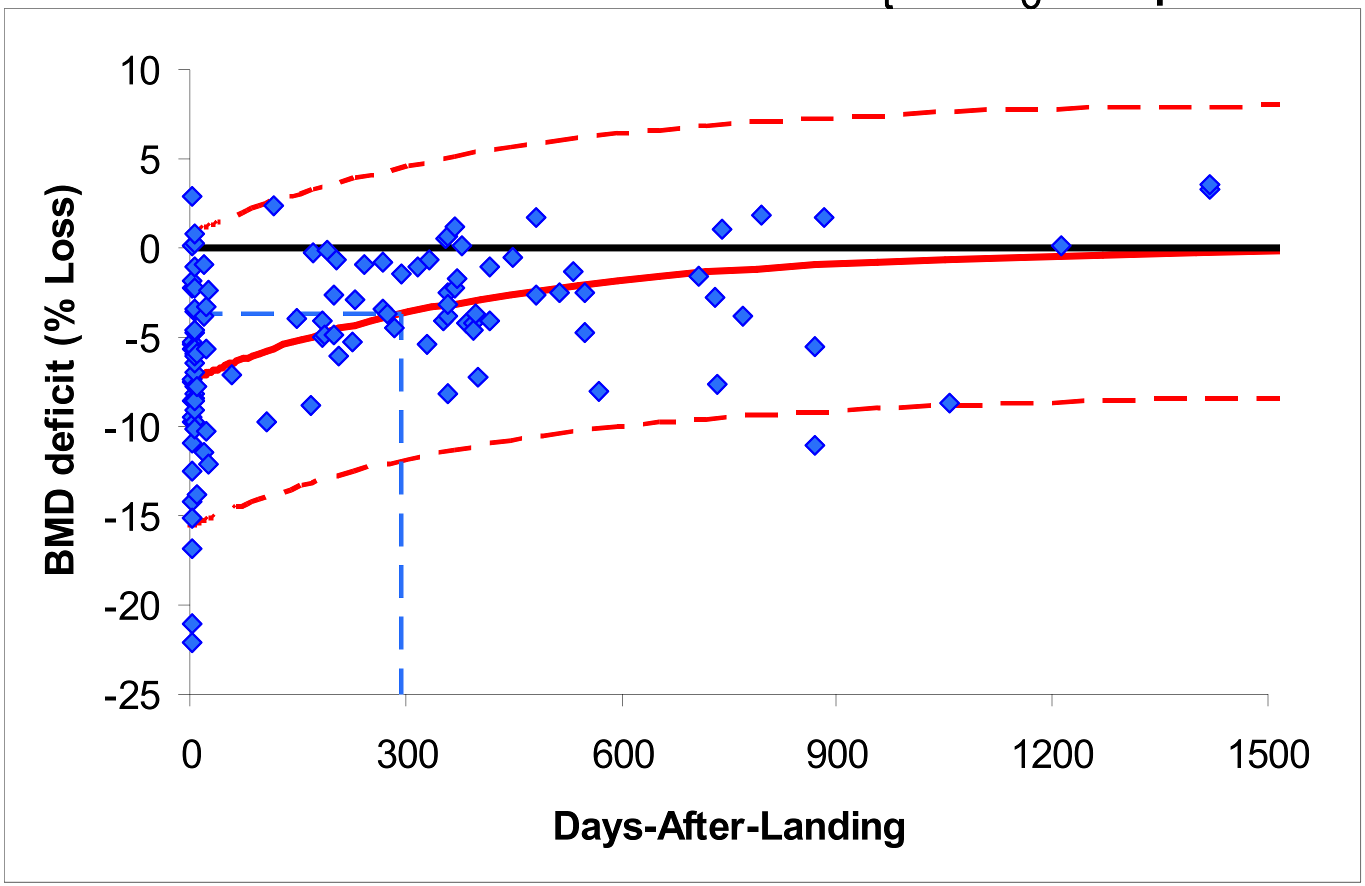
More bone mass is subtracted FROM than added TO the ske

(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
% Change
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
-12.0
-14.0
Lumbar Spine
Femoral Neck
Trochanter
Heel
Pelvis

Recovery of BMD with return to gravity

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

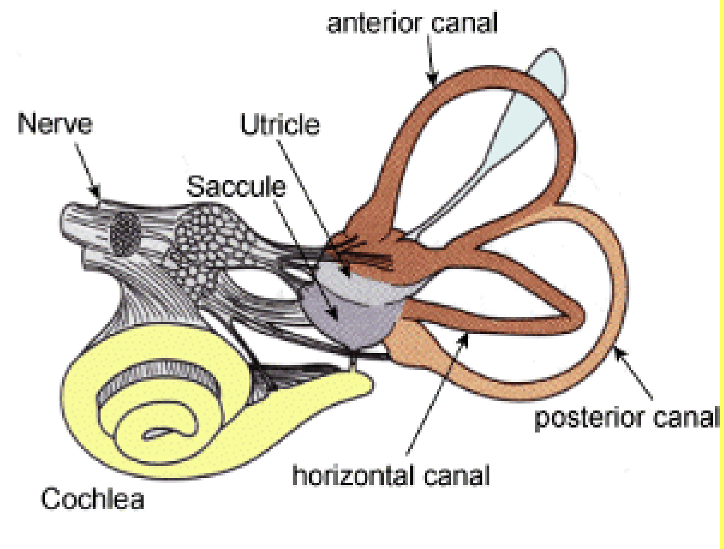


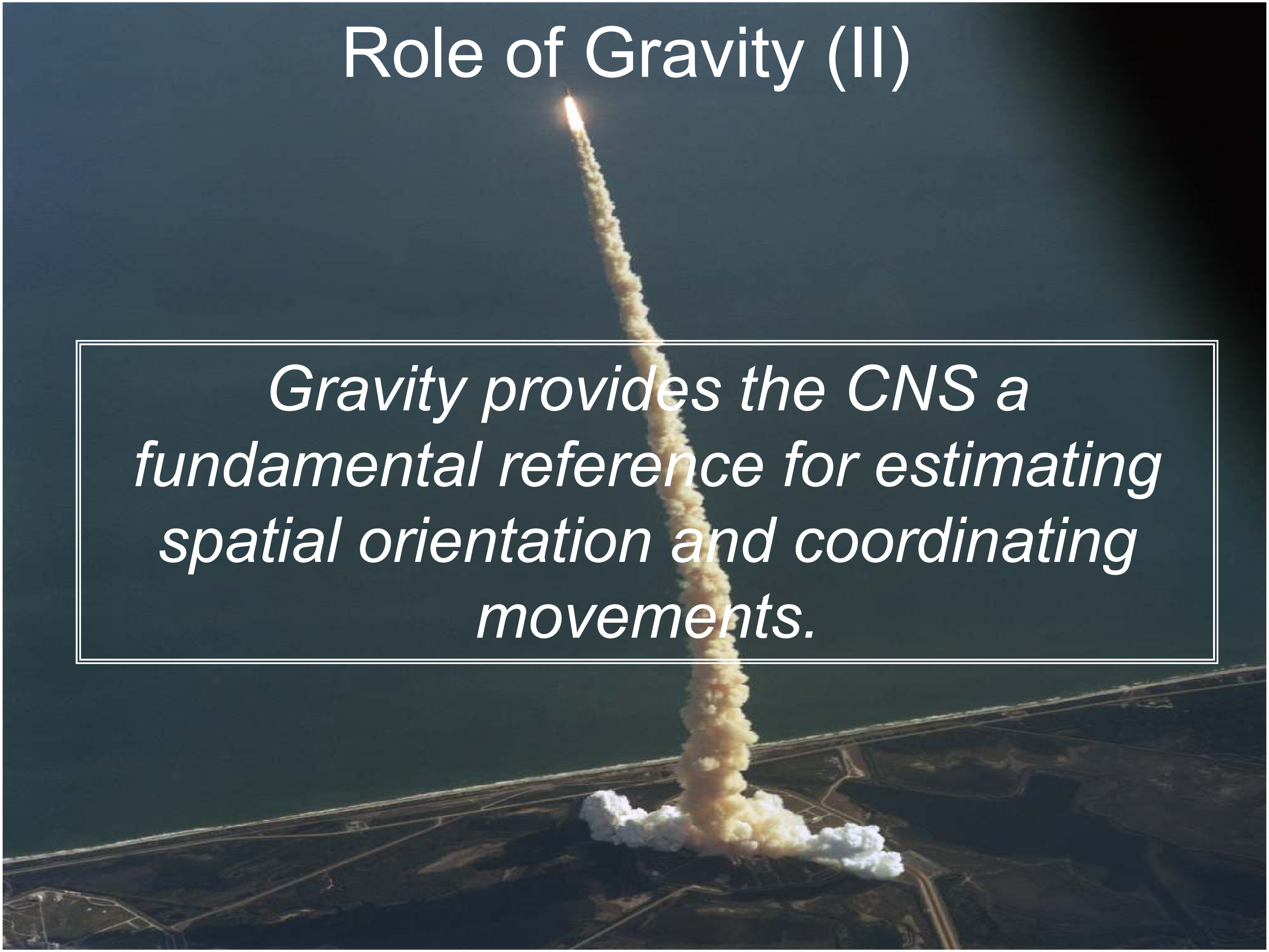
Trochanter BMD of ISS & Mir Crewmembers
Loss0=7.4% Recovery Half-life=276 d

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

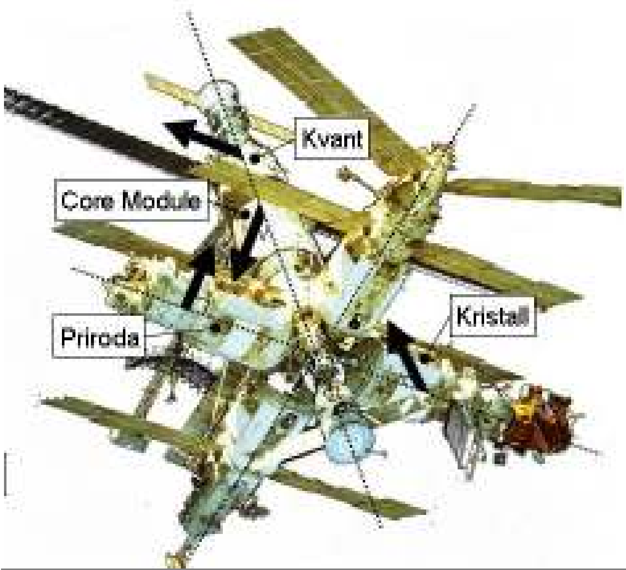
- 0% on Mercury/Gemini
- 30% on Apollo/Vostok/Soyuz/Salyut
- 56% on Skylab
- 75% on Shuttle
- Incidence is
  - highest in larger spacecraft.
  - highest on days 1-2, declining on days 3-5
  - lower on second and subsequent space flights.
  - unrelated to gender, or prior flying experience.
  - so far, 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

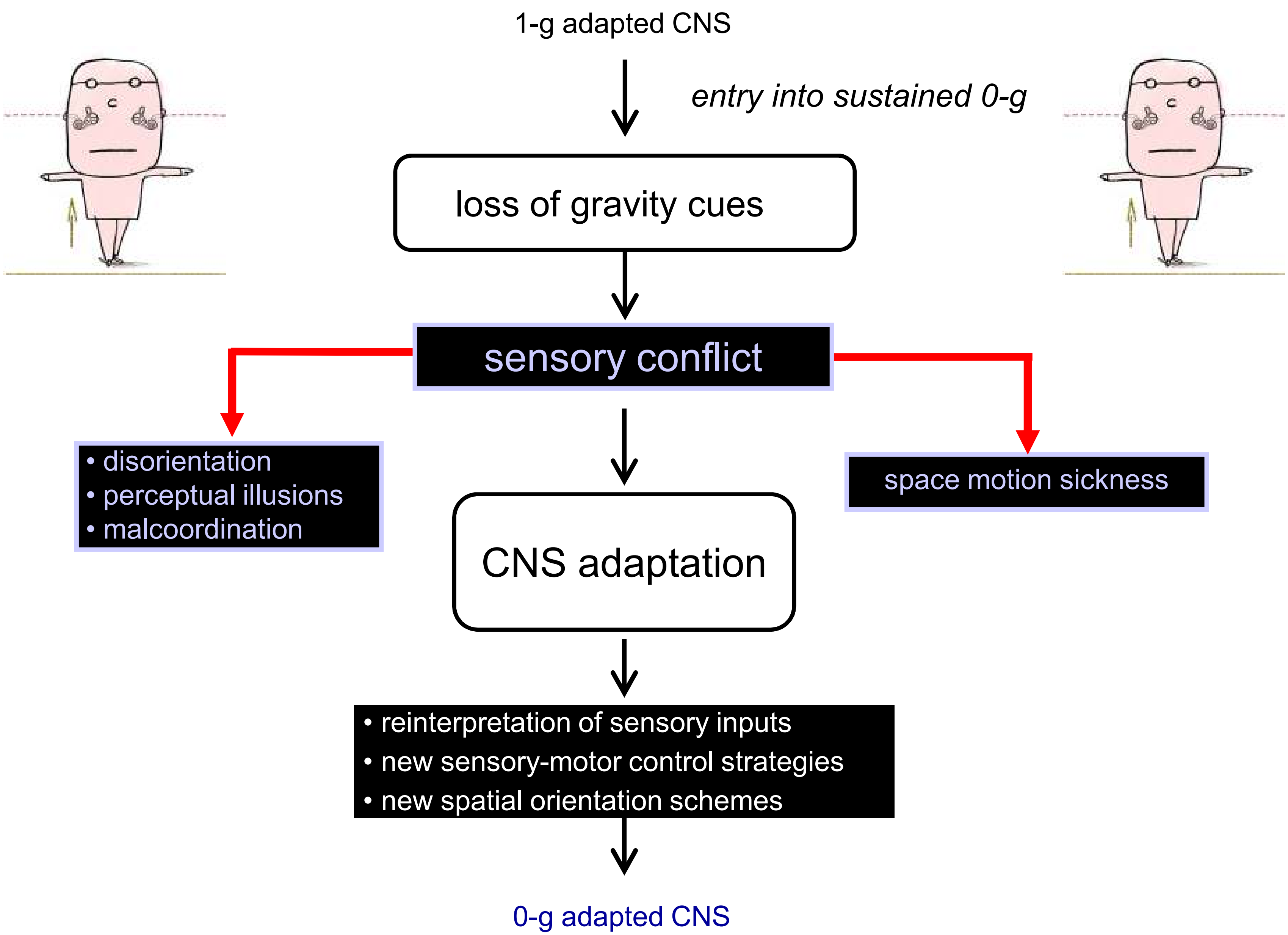
Visual Reorientation Illusion



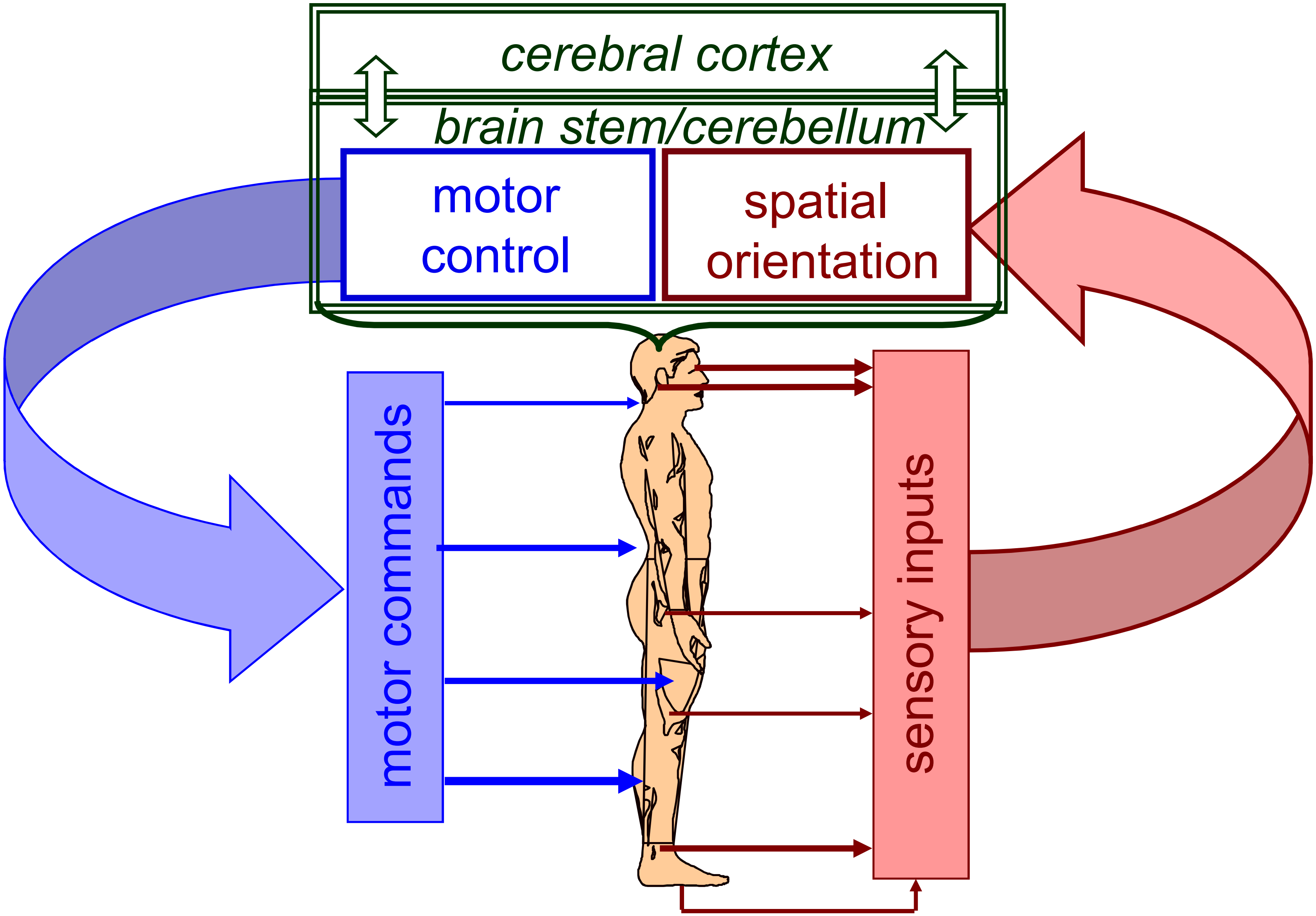
0-g Navigation Problems

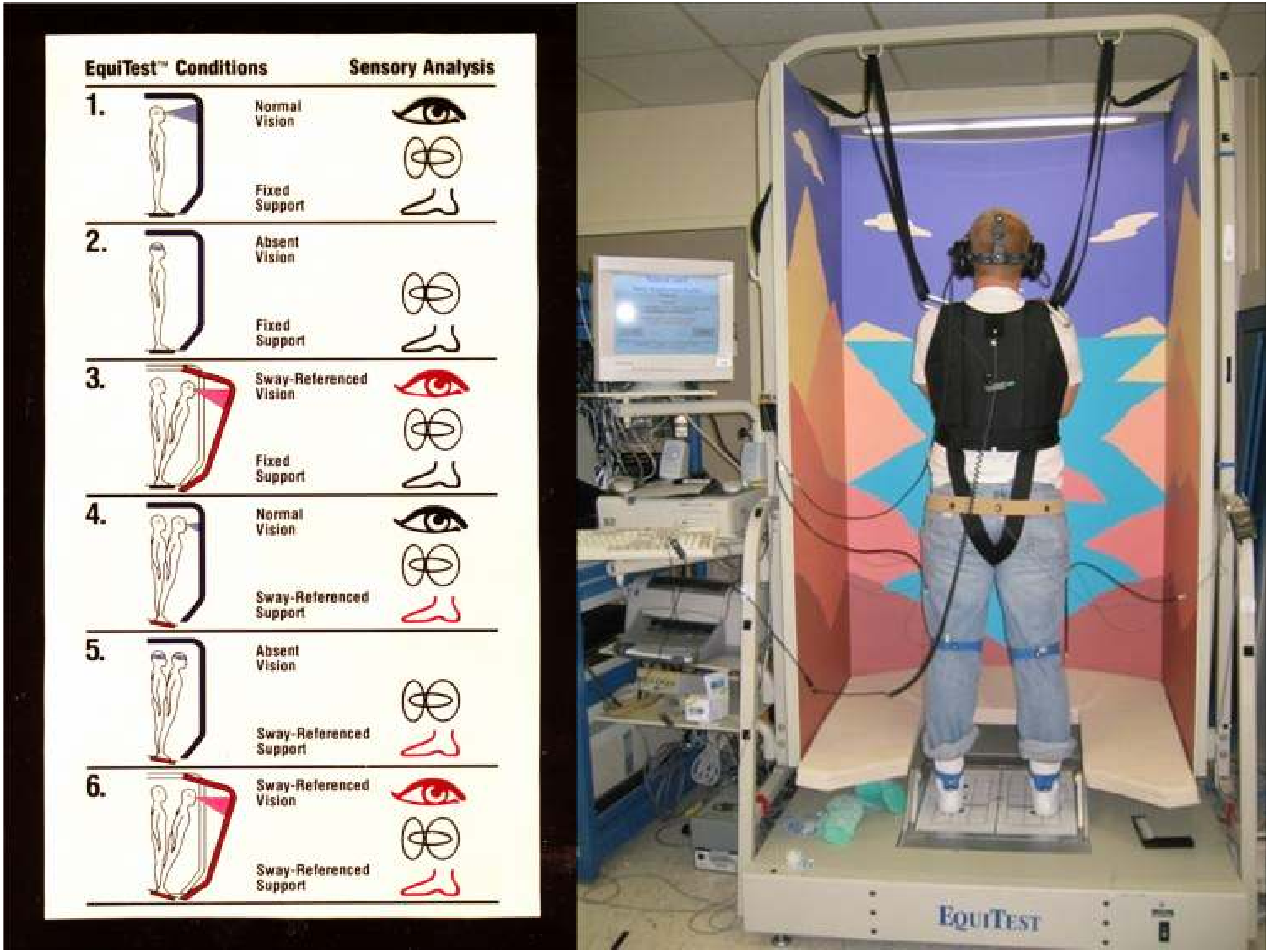
EVA Height Vertigo

CNS Response to Spaceflight



Human Sensory-Motor Balance Control

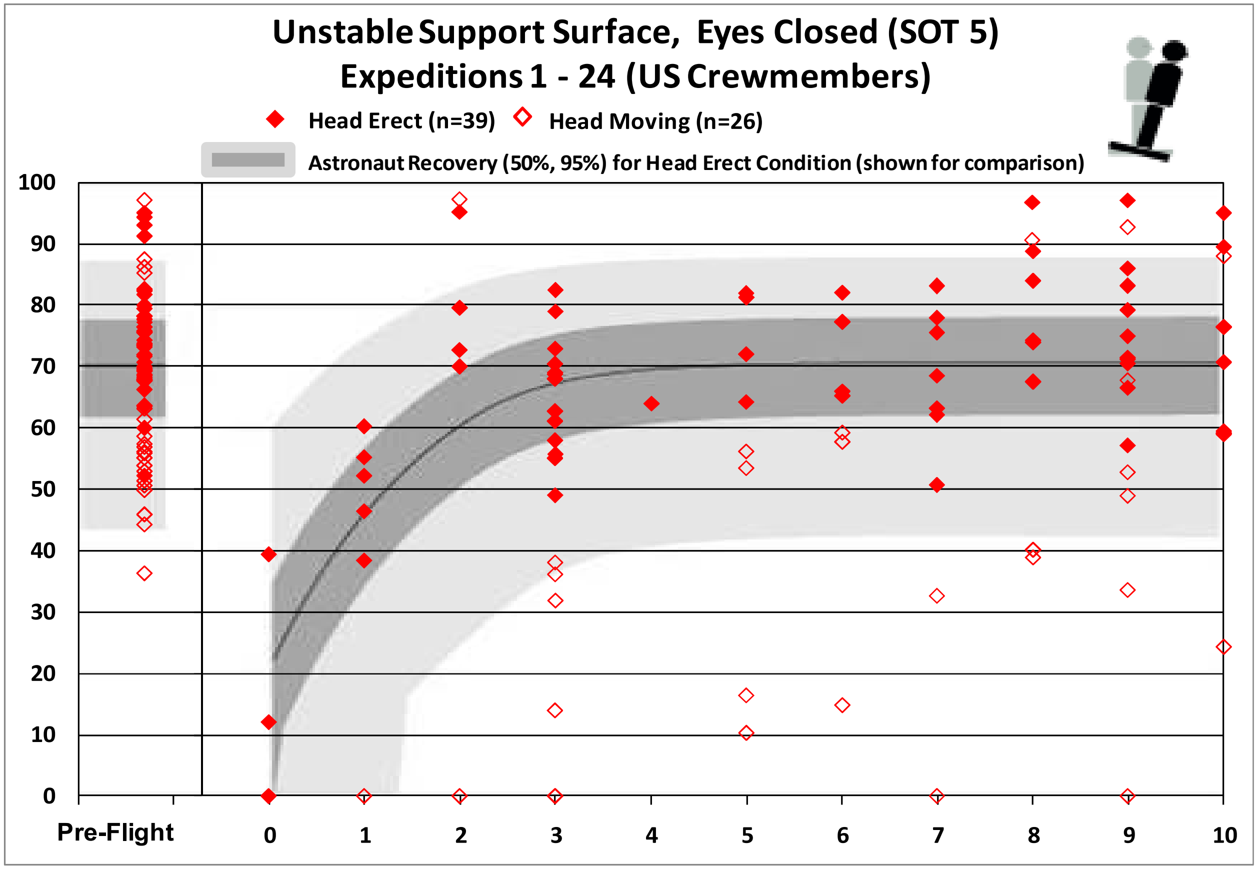



EquiTest™ Conditions
Sensory Analysis
1.
Normal Vision
Fixed Support
2.
Absent Vision
Fixed Support
3.
Sway-Referenced Vision
Fixed Support
4.
Normal Vision
Sway-Referenced Support
5.
Absent Vision
Sway-Referenced Support
6.
Sway-Referenced Vision
Sway-Referenced Support
EQUITEST

Long Duration Flight Balance Control Recovery

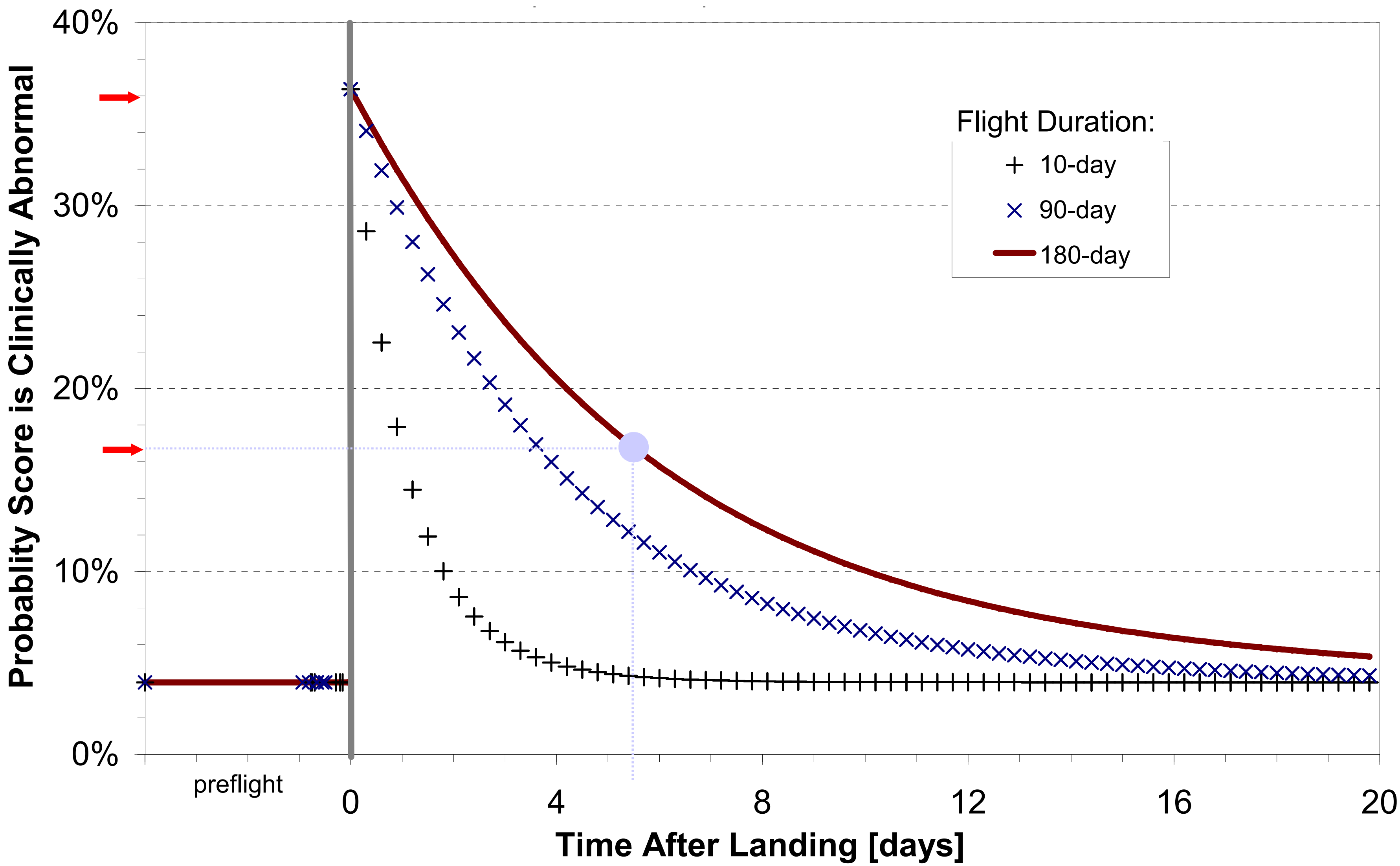
Functional Neurological Assessment

Sensory Organization Test 5 – Head Erect/Head Moving



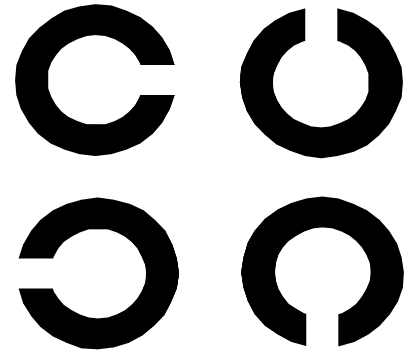
Eyes closed on unstable surface shows moderate-to-severe deficits post-flight. Addition of head movements (open symbols) reveals greater inter-subject variability with longer return to baseline conditions.

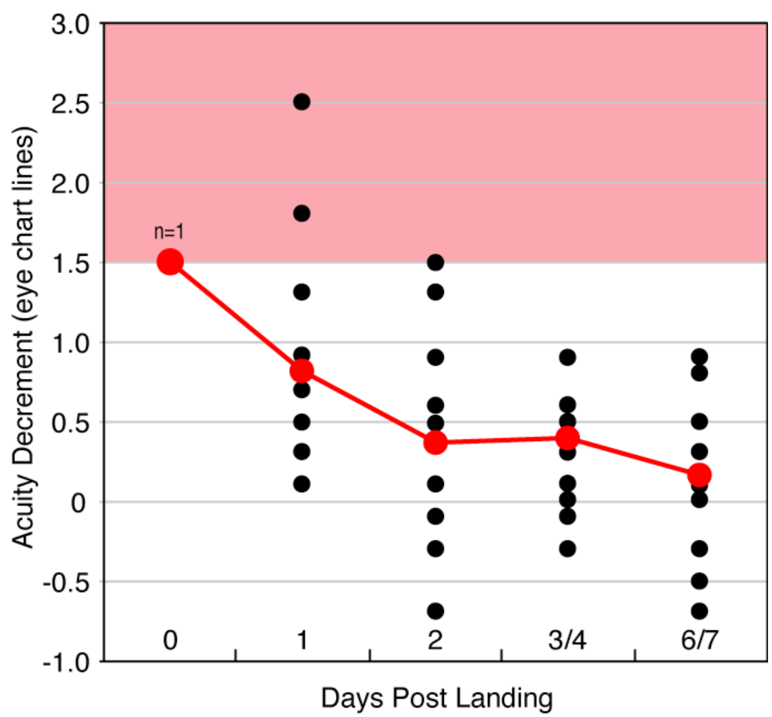
Effect of Mission Duration on Balance Recovery

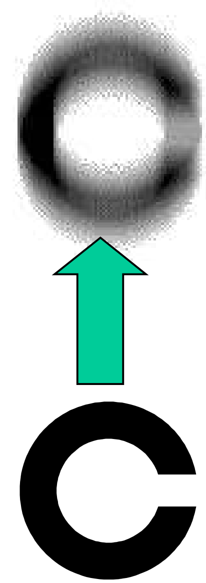


Dynamic Visual Acuity

Landolt-C







Courtesy of J. Bloomberg, NASA JSC

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

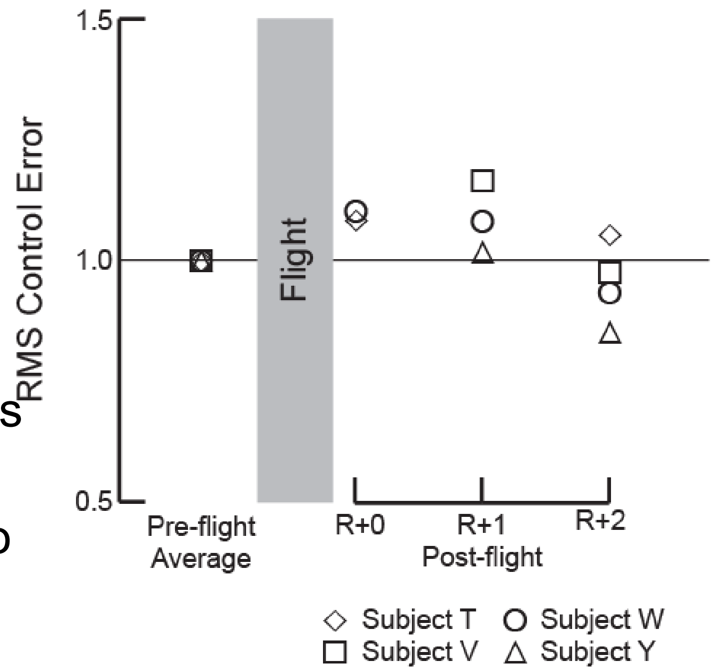
Subjects used control wheel to “keep themselves upright with respect to gravity”. Sum-of-sines motion profile (0.014 – 0.668 Hz)

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.



Merfeld et al., JAP 81((1): 50-57, 1996

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

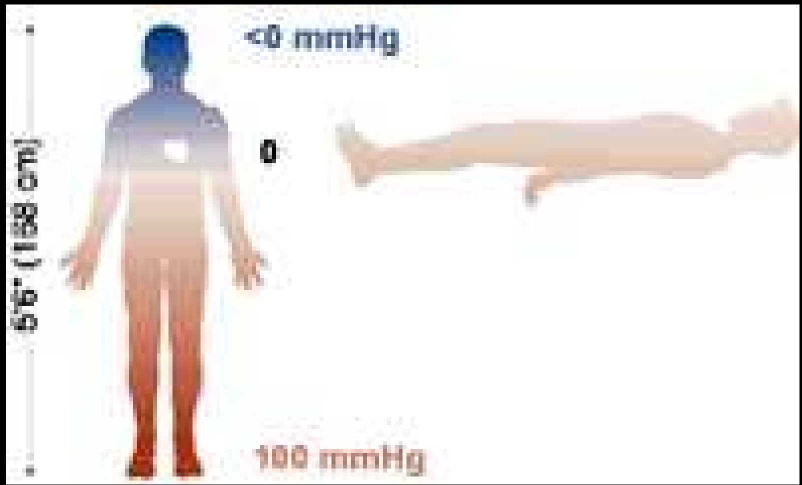
CARDIAC ISSUE FOR SPACEFLIGHT

•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.

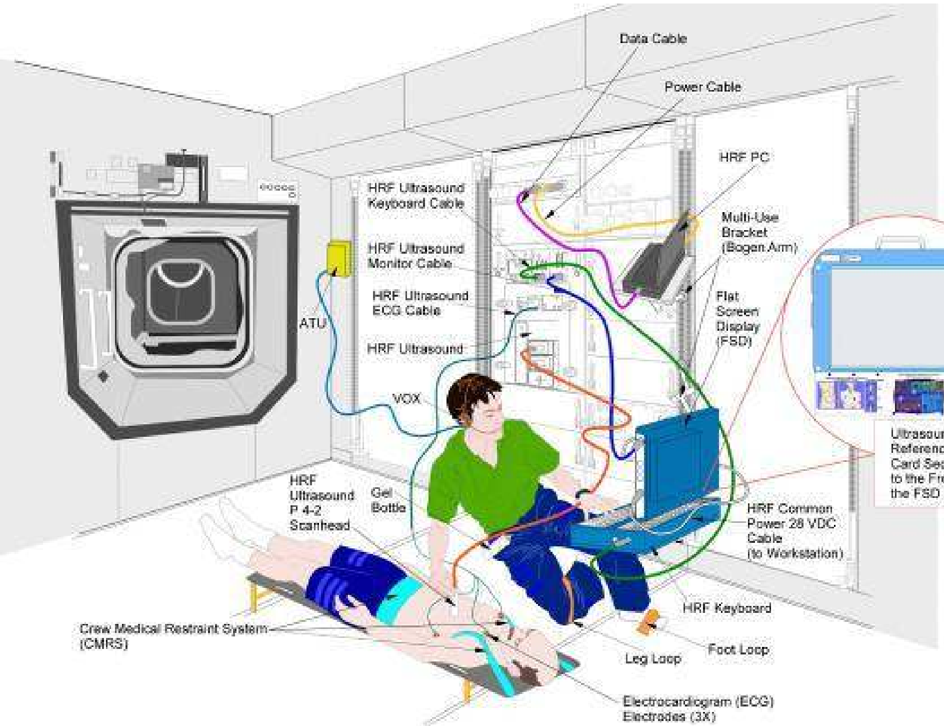
•Atrophy may result in impaired cardiac function and/or fainting (orthostatic intolerance) post-landing on the Earth, moon or Mars.



'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*.

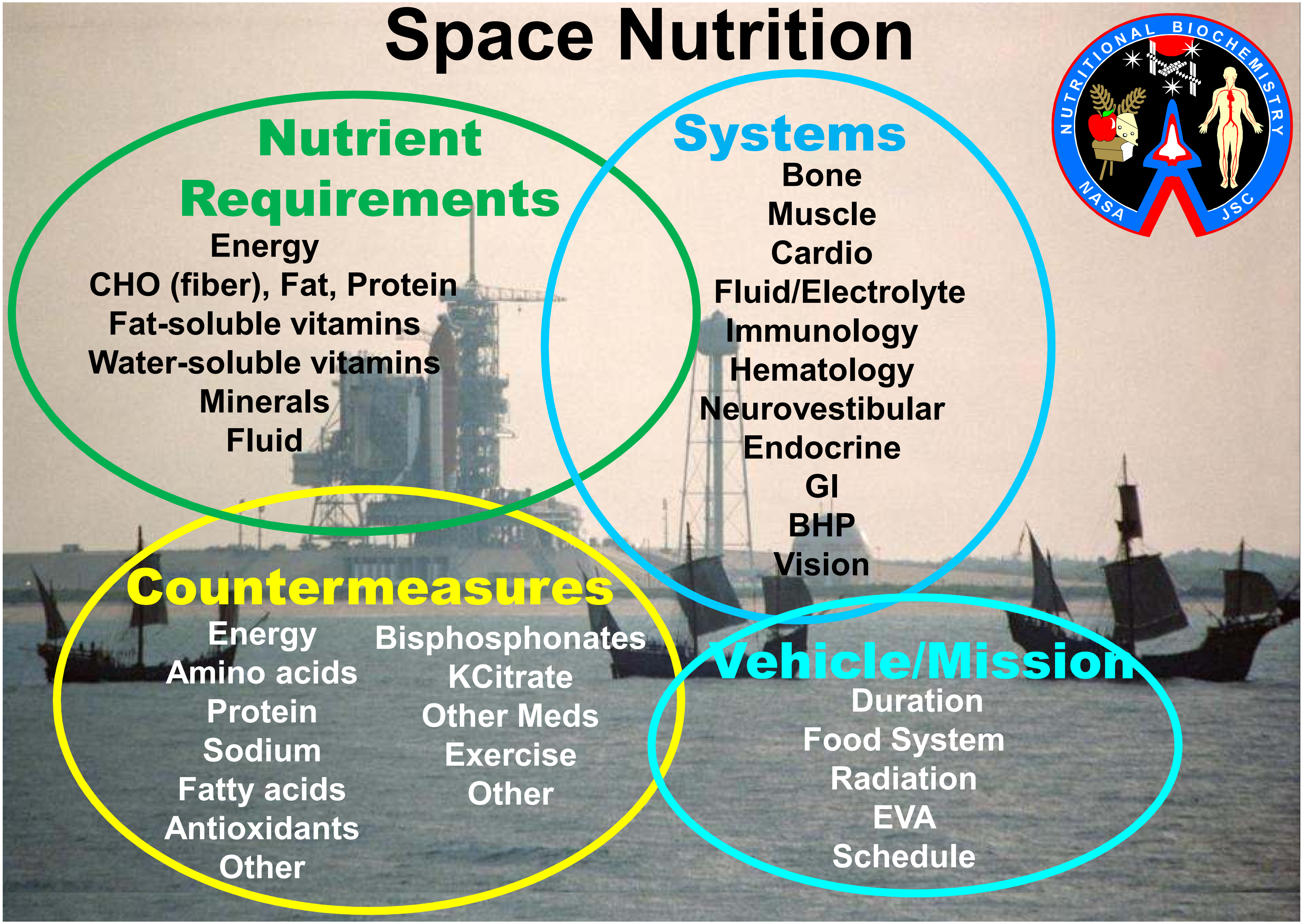


The Integrated Cardiovascular experiment investigates the magnitude of ventricular atrophy using MRI, relates this type of atrophy to measures of physical activity and cardiac work inflight, and determines the time course and pattern of the progression of cardiac atrophy cardiac ultrasound.

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).

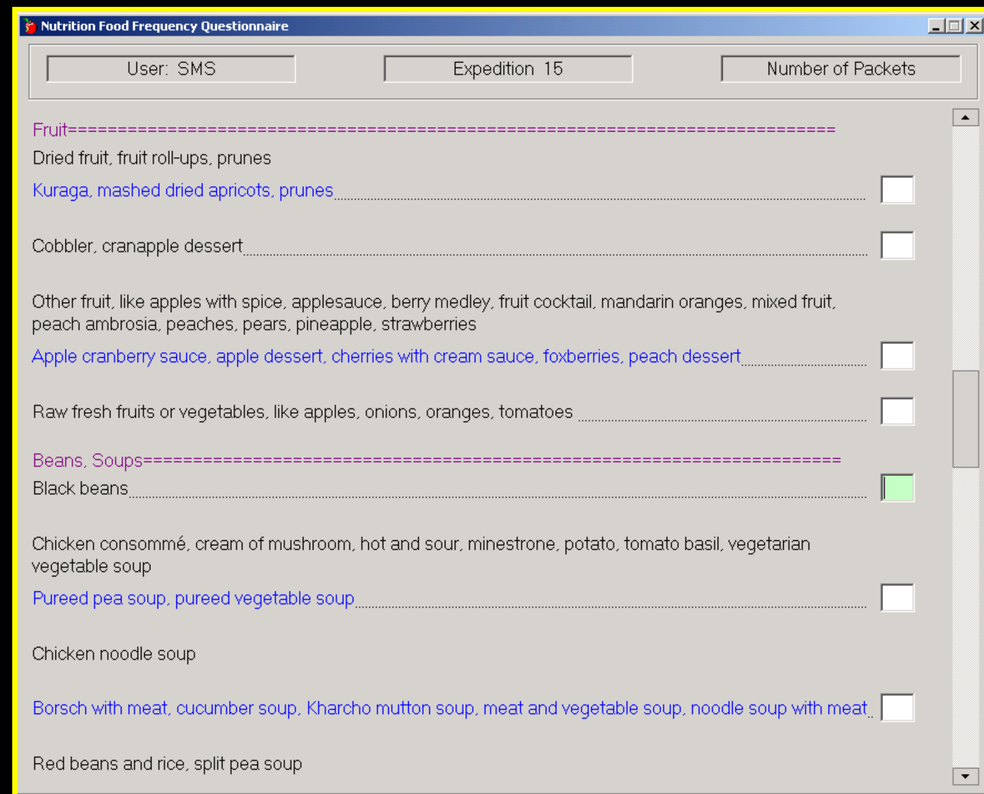
Nicole Stott performs routine tasks aboard the ISS while ECG (using the HRF Holter Monitor 2) and continuous blood pressure data (using the ESA Cardiopres) are recorded for the Integrated Cardiovascular experiment.

Nutrition



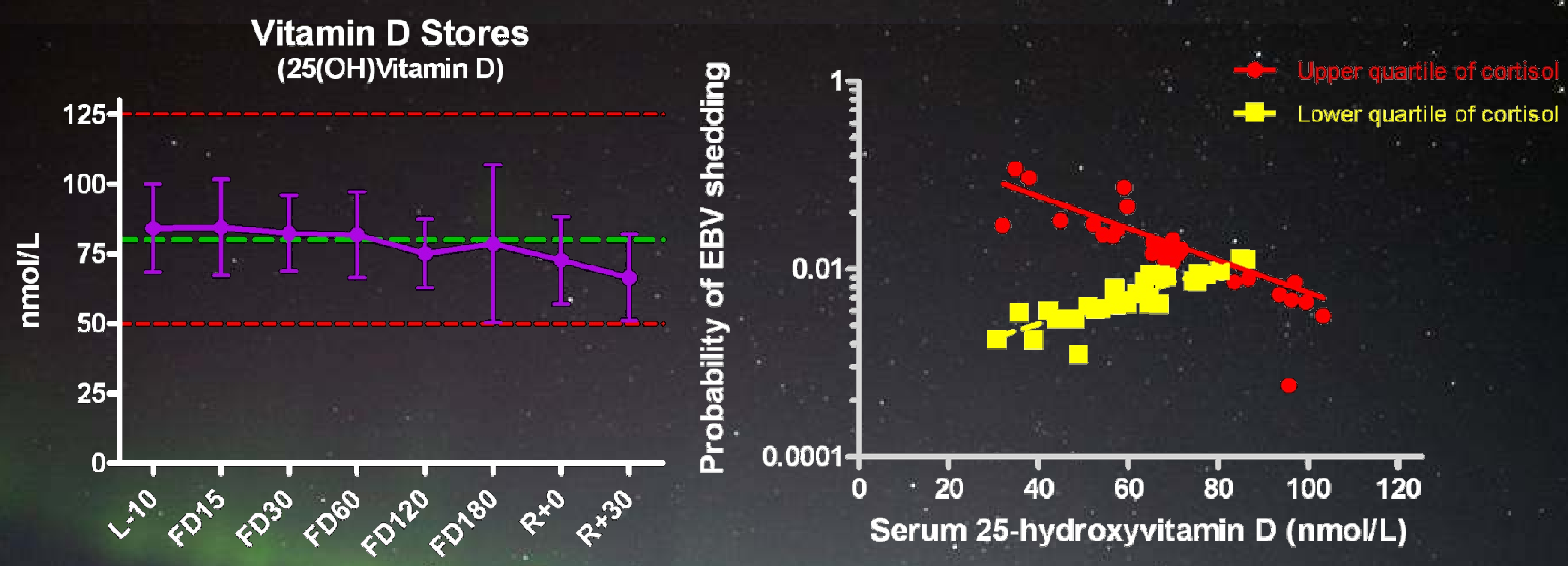
Nutrition is critical for any type of exploration mission, and is

Dietary Intake



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).

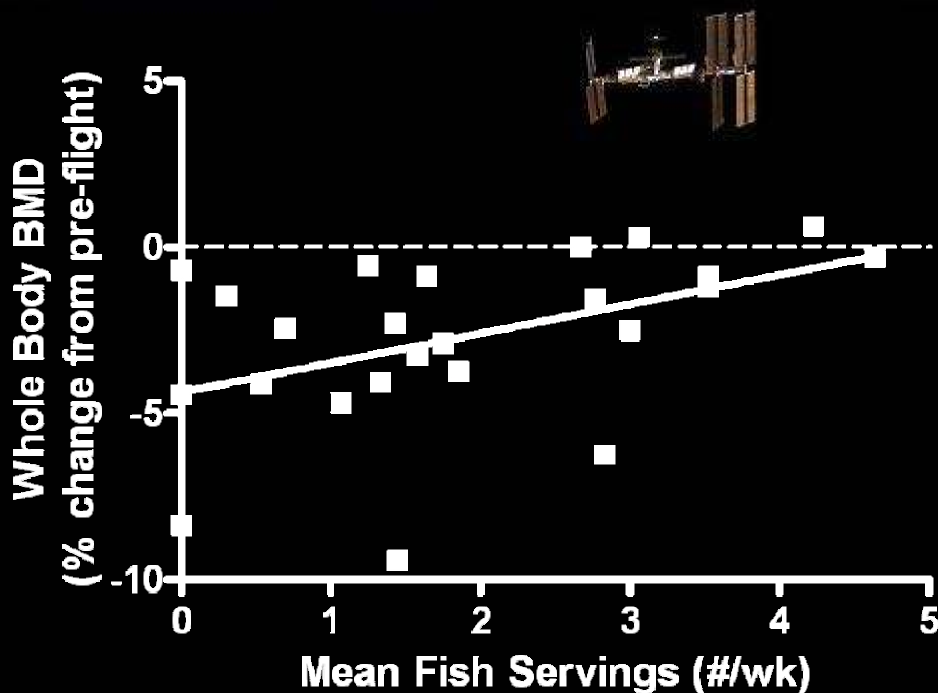
Vitamin D



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

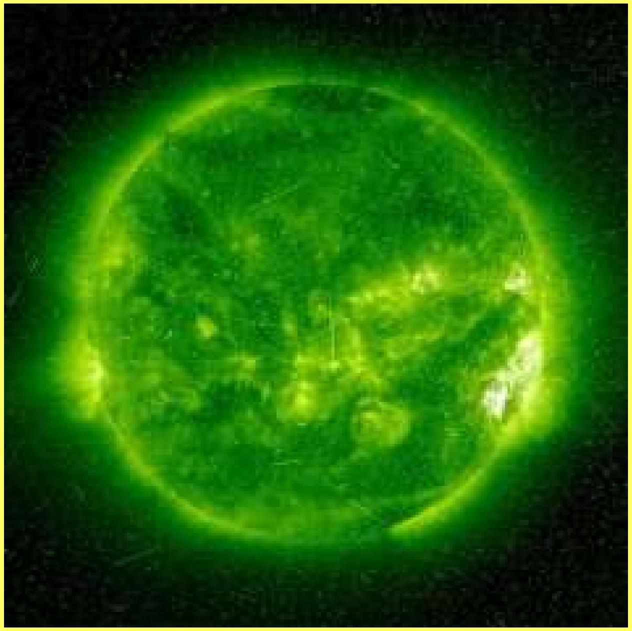
Supplementation with 800 IU vit D/day maintains status during flight (left panel). Antarctic studies show vitamin D, stress, and viral reactivation are interrelated.

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.

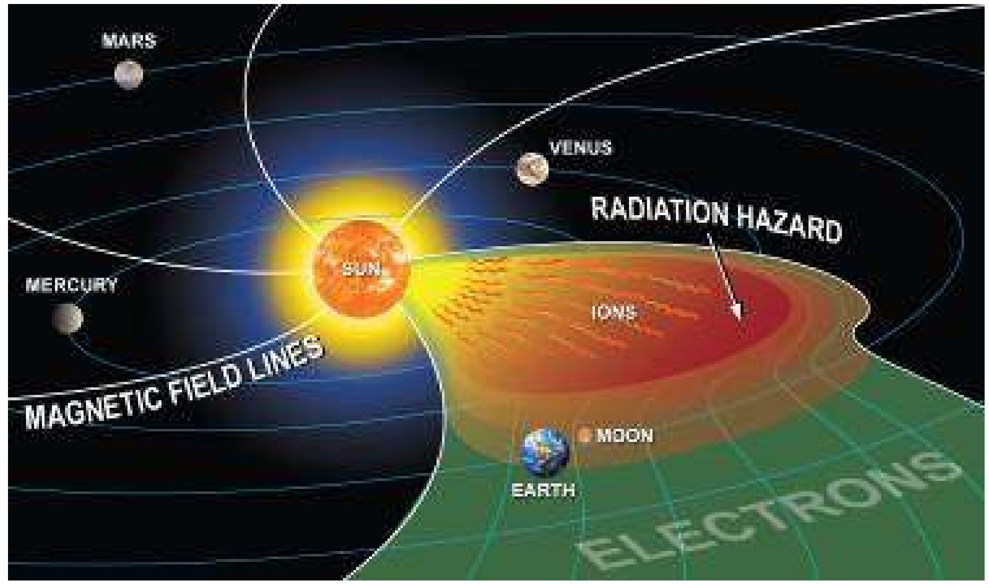
Radiation



The Space Radiation Problem

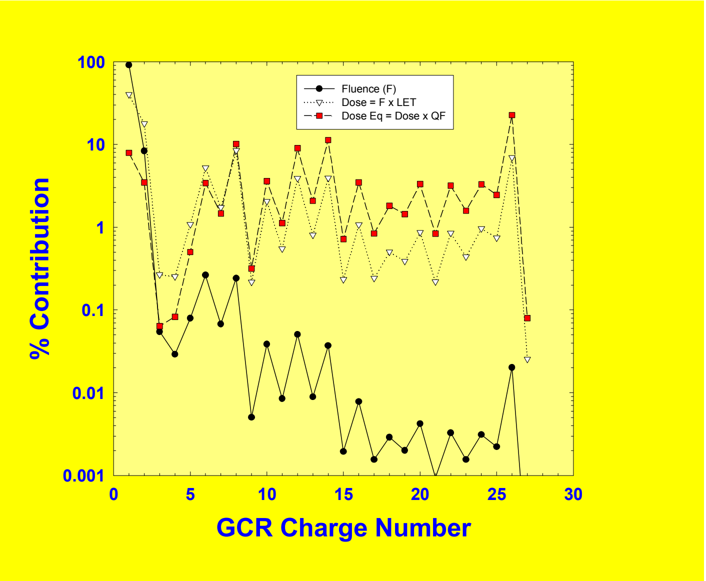
Space radiation is comprised of high-energy protons and heavy ions (HZE's) and secondary protons, neutrons, and heavy ions produced in shielding

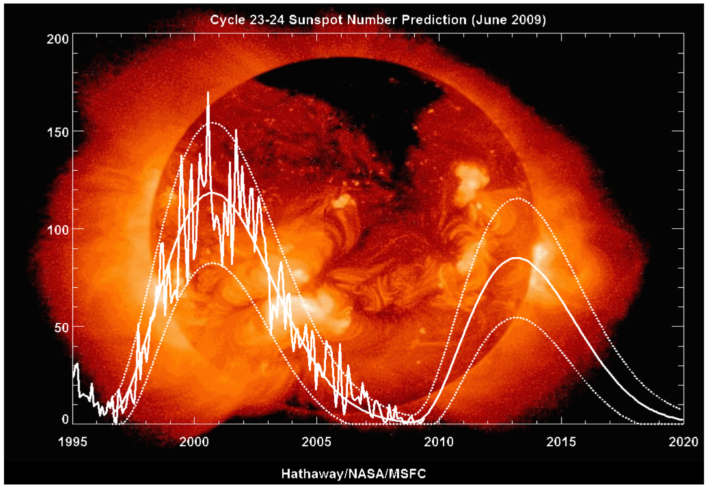
- Unique damage to biomolecules, cells, and tissues occurs from HZE ions
- No human data to estimate risk
- Expt. models must be applied or developed to estimate cancer, and other risks
- Shielding has excessive costs and will not eliminate galactic cosmic rays (GCR)



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

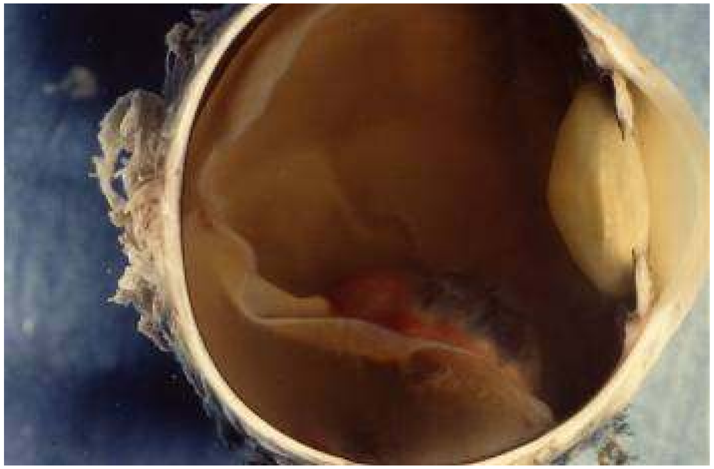




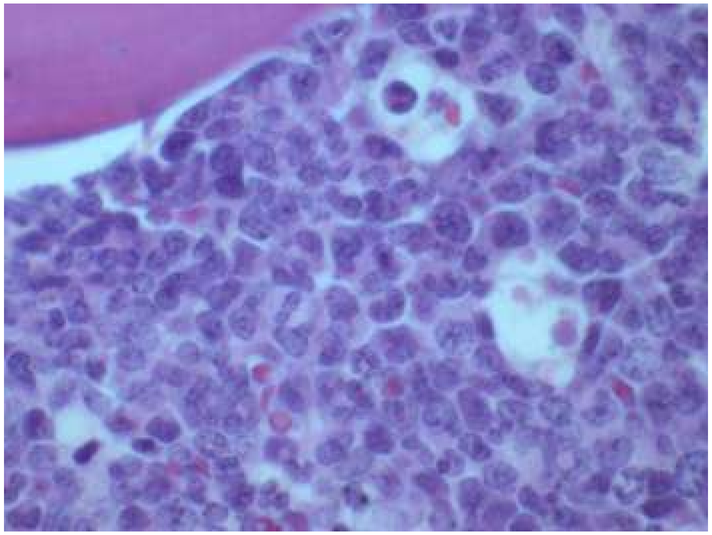
Categories of Radiation Risk

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

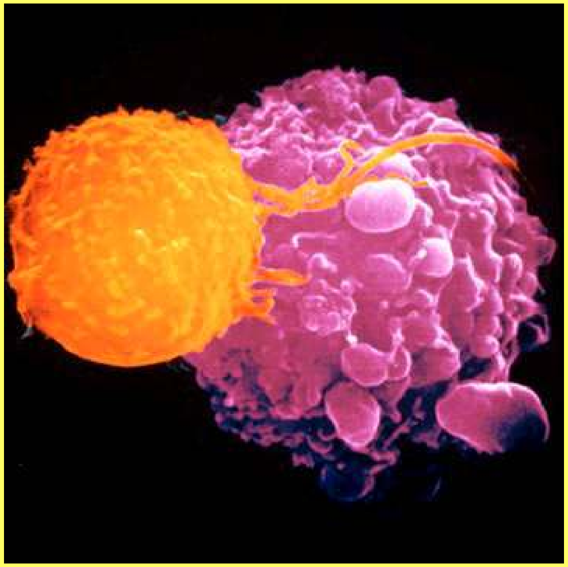


cataracts



First experiments for leukemia

IMMUNOLOGY



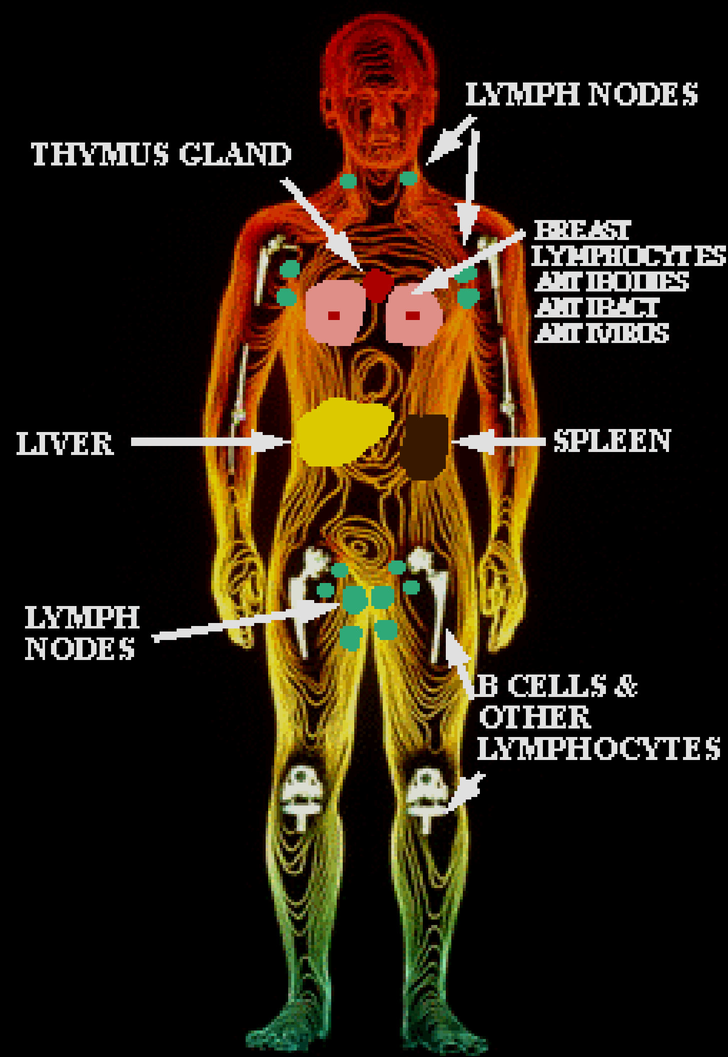
THE IMMUNE SYSTEM

•One of largest tissues in the human body, although largely in fluid state.

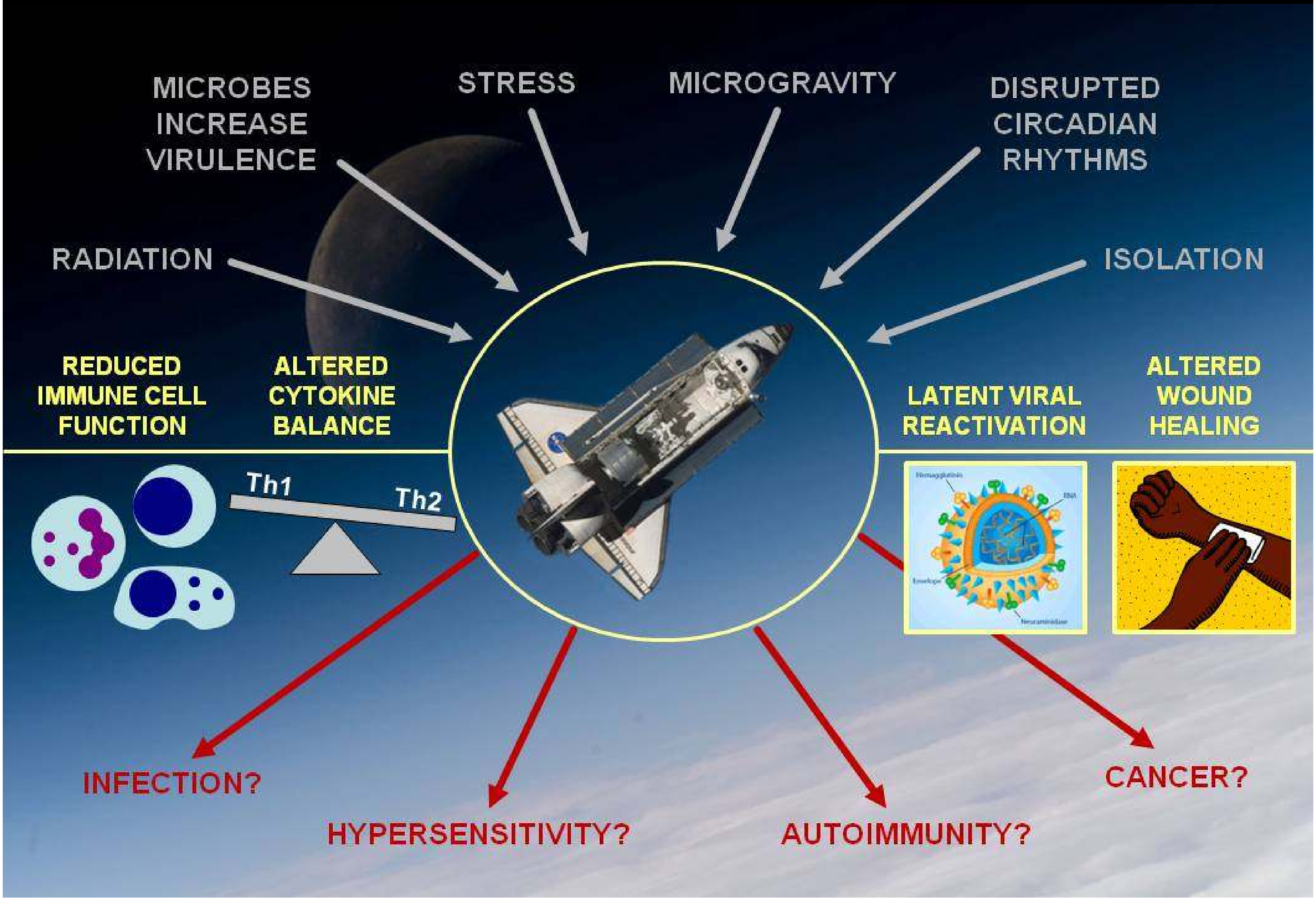
•Consists primarily of white blood cells (WBCs) located in lymph nodes and the peripheral blood.

•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.

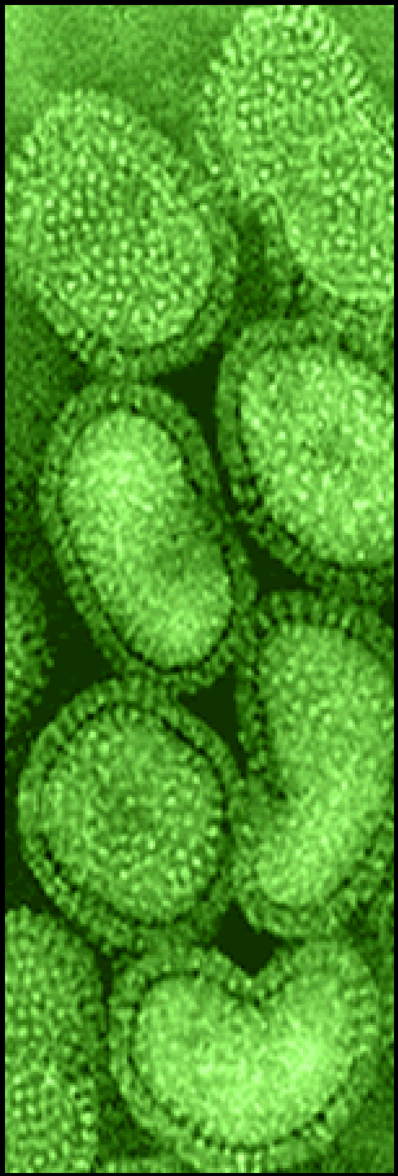


Overview: Spaceflight-Associated Immune Dysregulation



Shuttle: Incidence of In-flight Infectious Disease

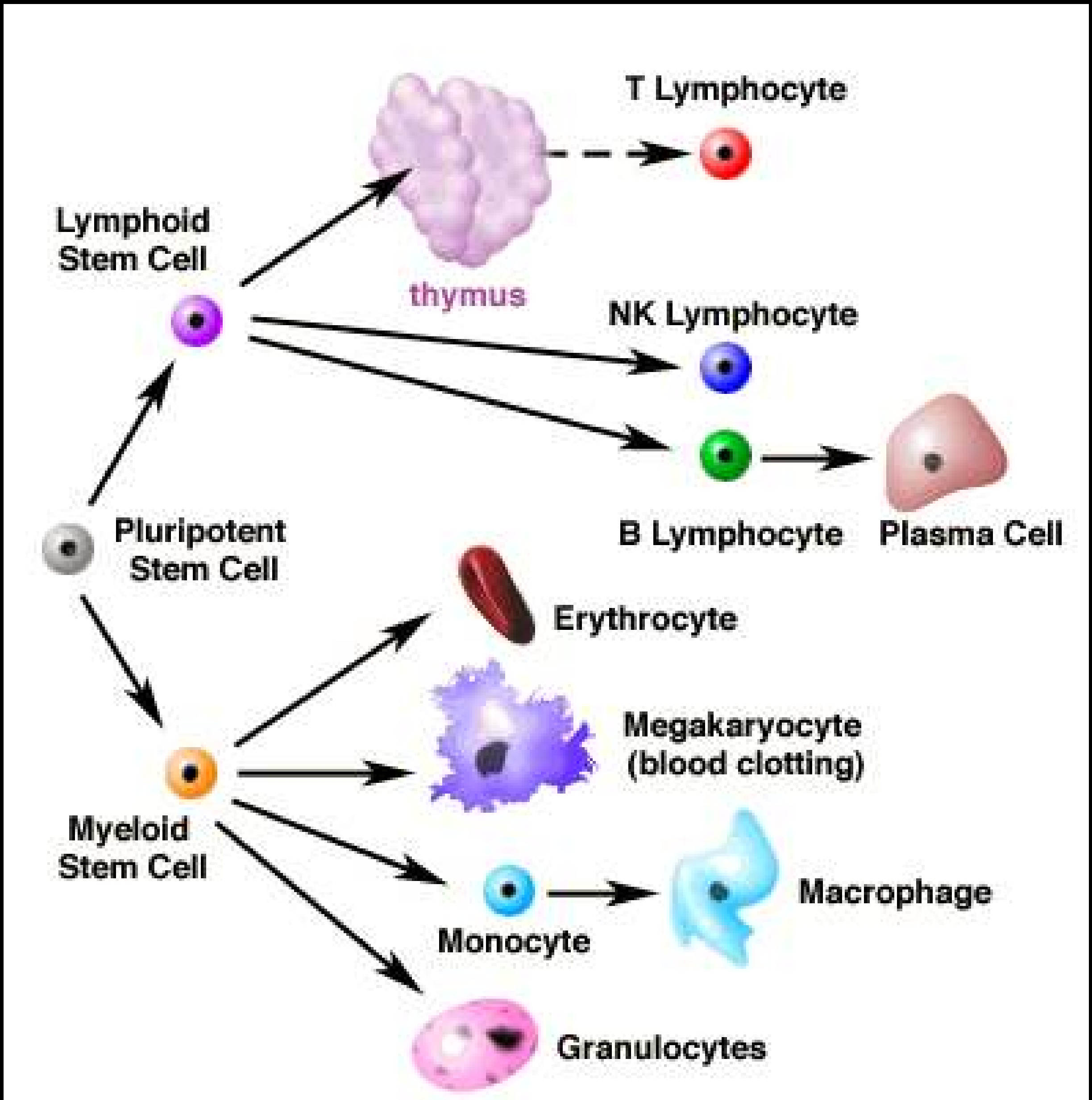
(STS-1 through STS-108)

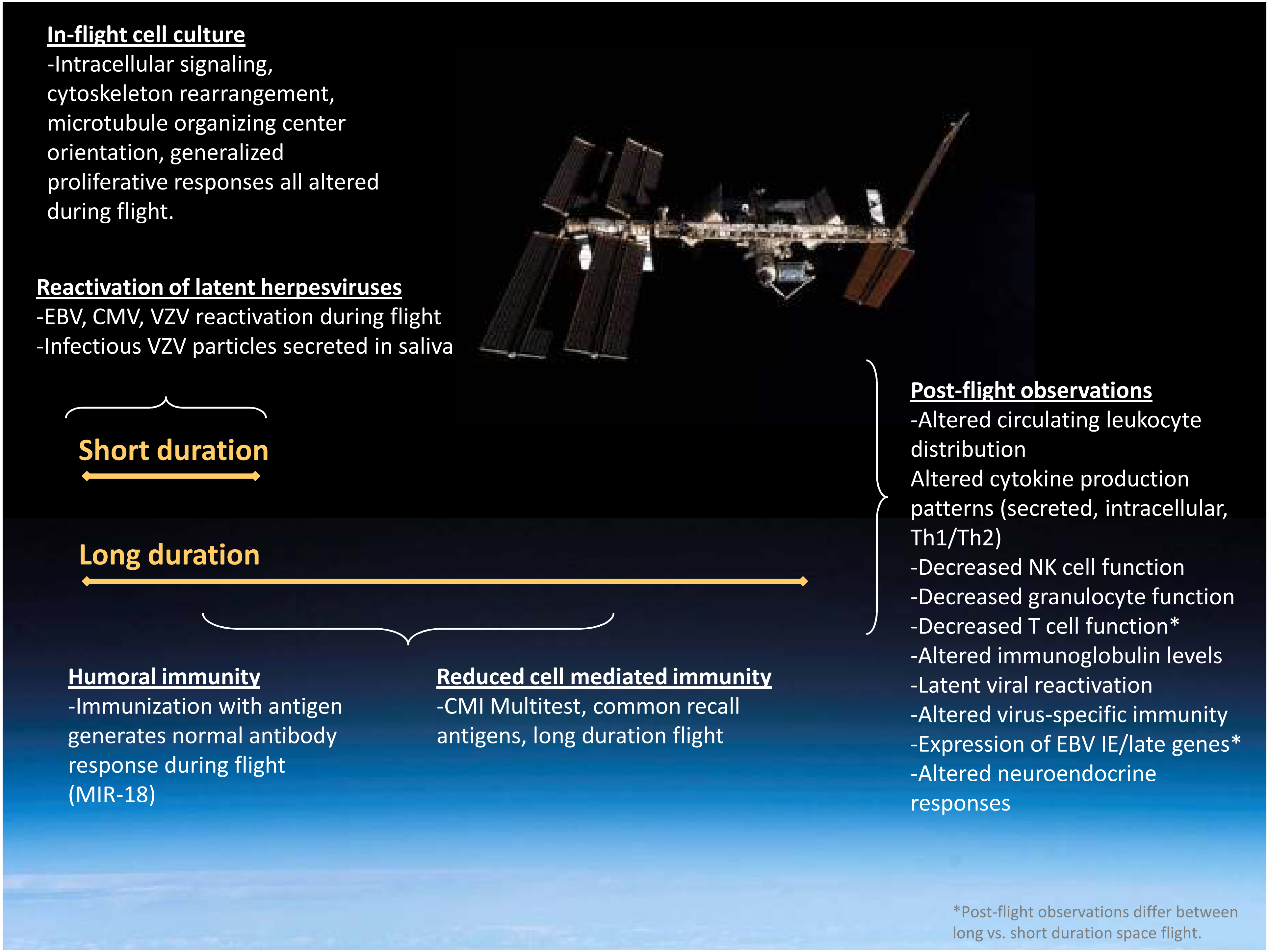


Number	Infectious Disease
8	Fever, chills
5	Fungal infection
3	Flu-like syndrome
4	Urinary tract infections
3	Aphthous stomatitis
2	Viral gastrointestinal disease
2	Subcutaneous skin infection
2	Other viral disease
29	Total incidents in 106 Shuttle flights

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

SKYLAB IMMUNE DATA - 1973

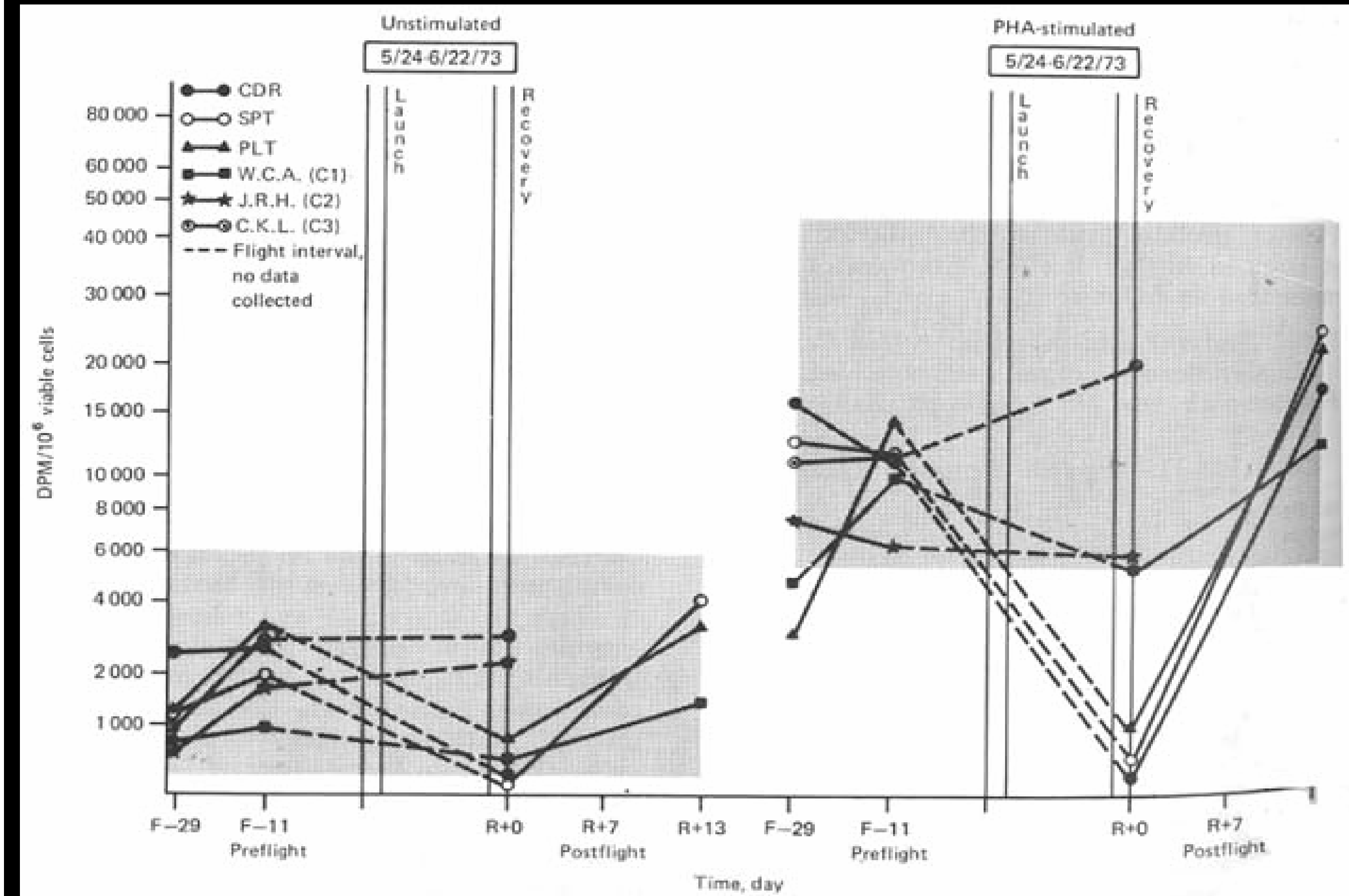
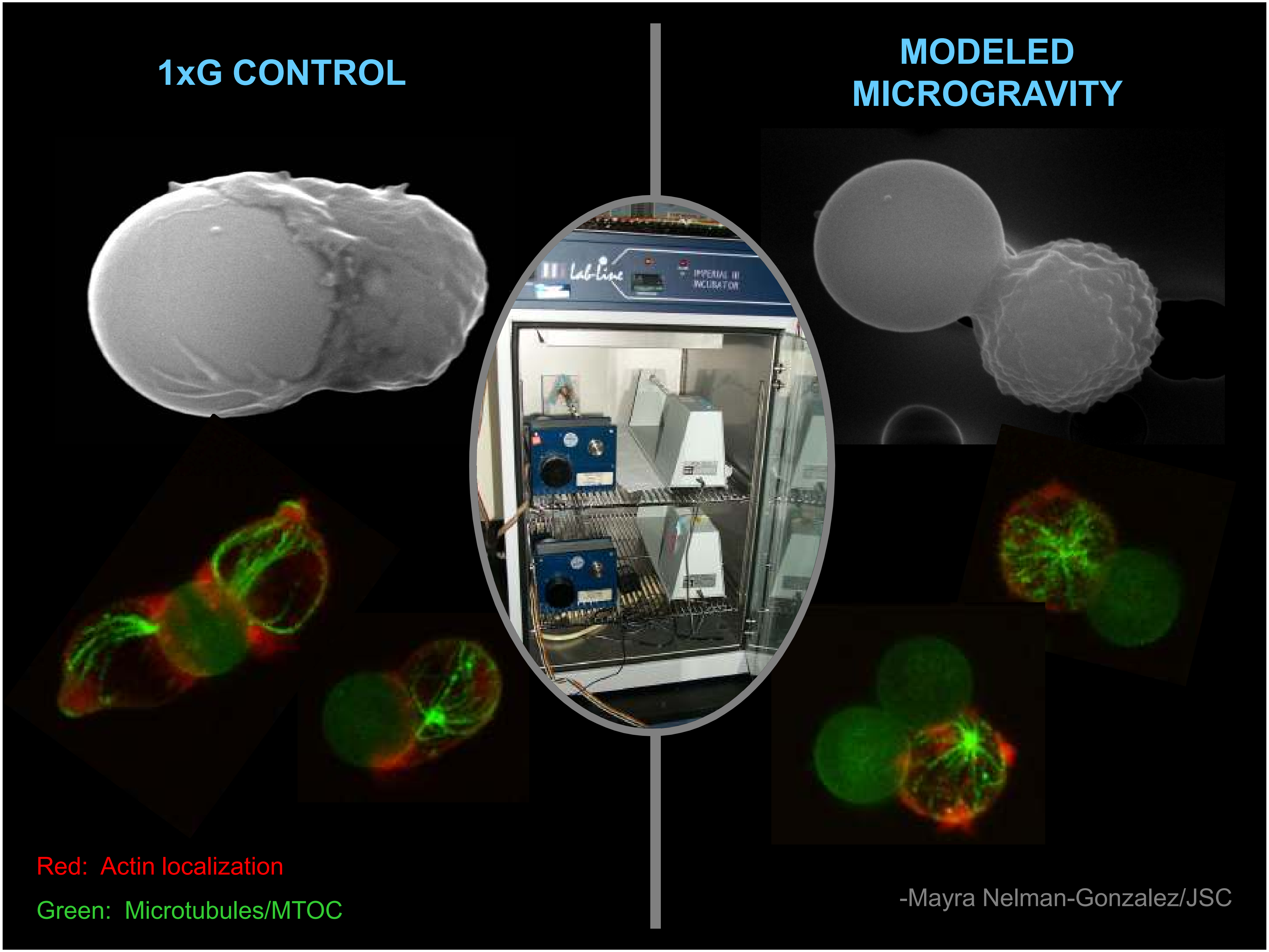
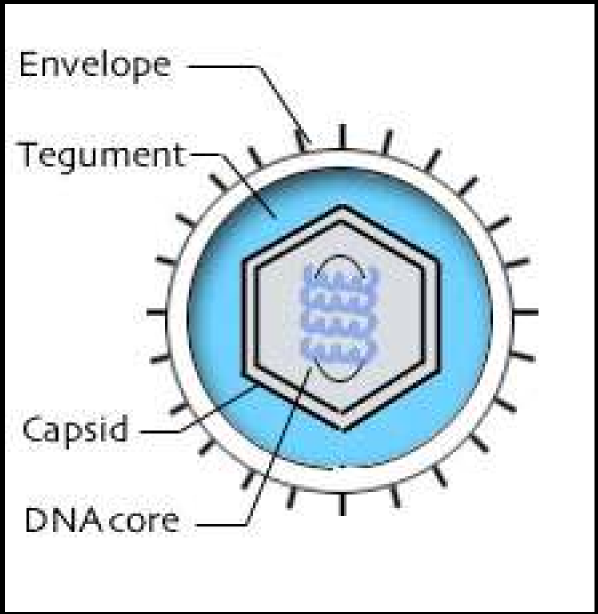


Figure 28–1a.—RNA synthesis rates in lymphocytes, cultured with and without PHA, obtained from the Skylab crews and control groups. The cells were pulsed with ^{3}H-uridine at 23 h and harvested at 24 h after initiation of the cultures.

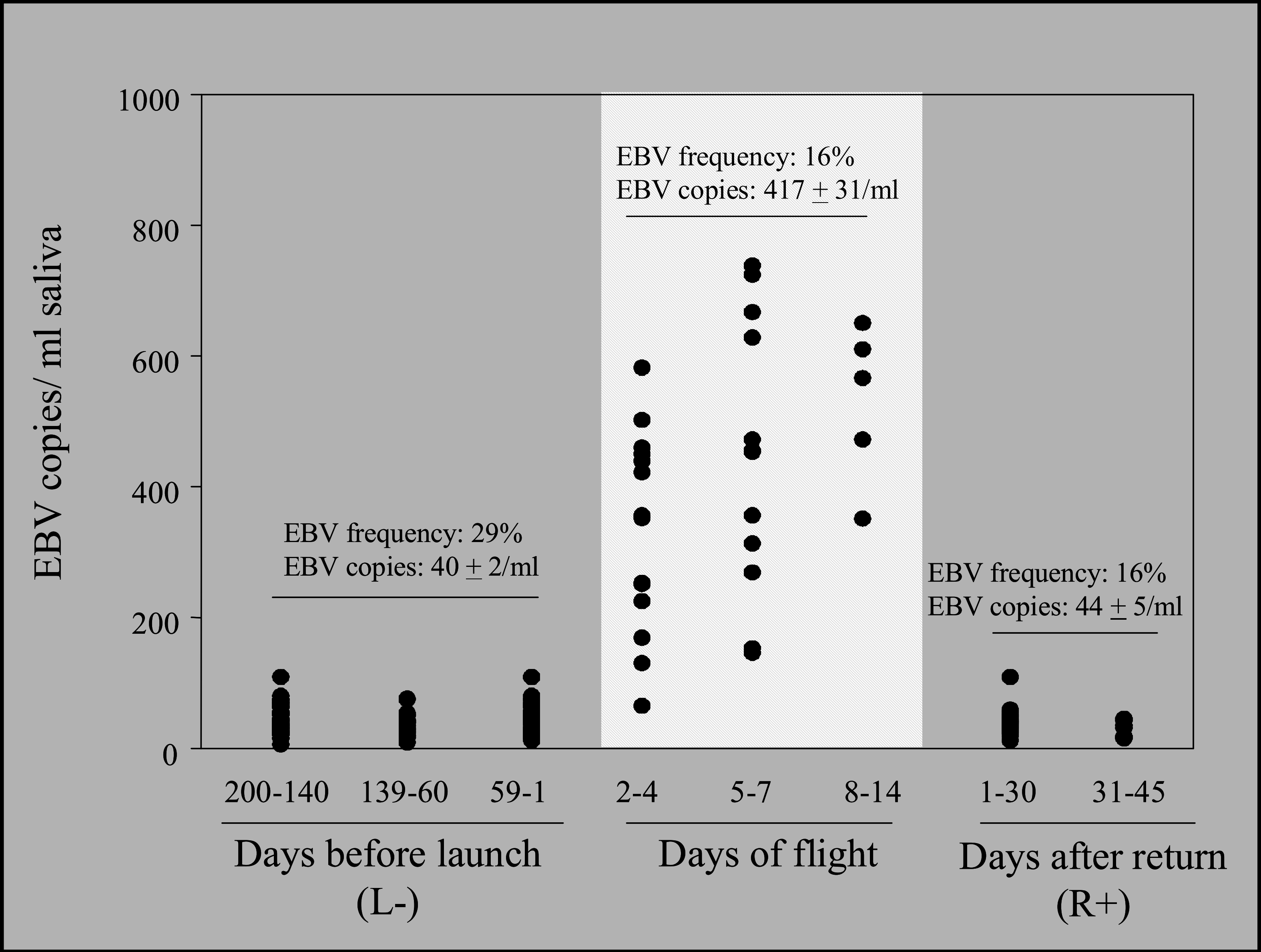

1xG CONTROL
MODELED MICROGRAVITY
Red: Actin localization
Green: Microtubules/MTOC
-Mayra Nelman-Gonzalez/JSC

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



-D. Pierson, 2003

Current Flight Study

RECENT SPACE IMMUNE STUDIES

	PRE-FLIGHT						IN-FLIGHT							POST-FLIGHT						
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**		

*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

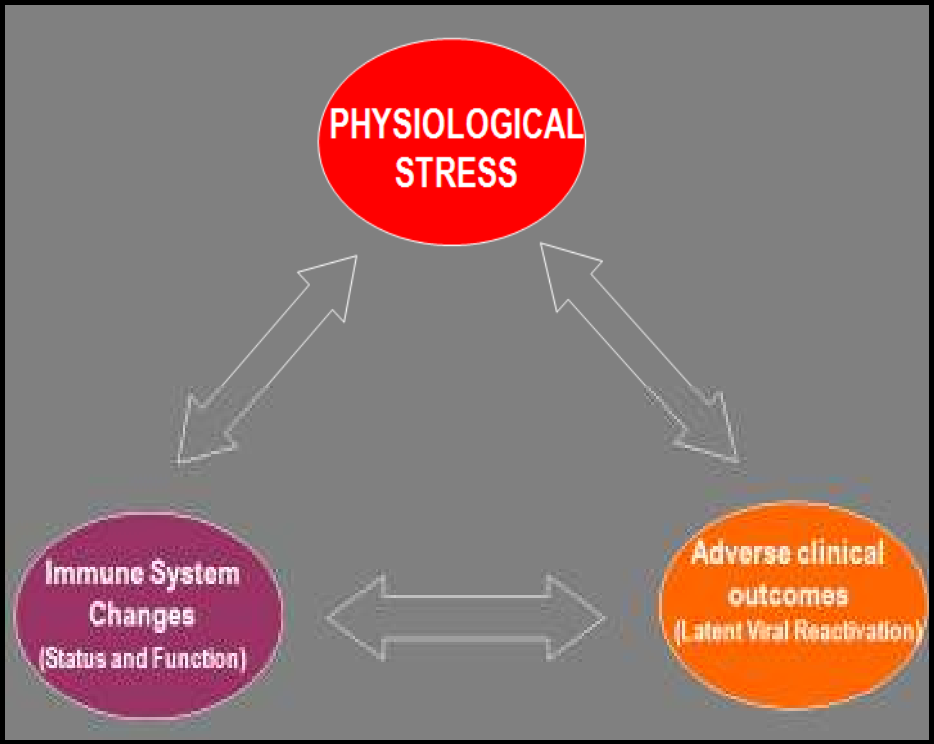
- Plasma cytokine balance
- Leukocyte cytokine RNA

Microgen Laboratories

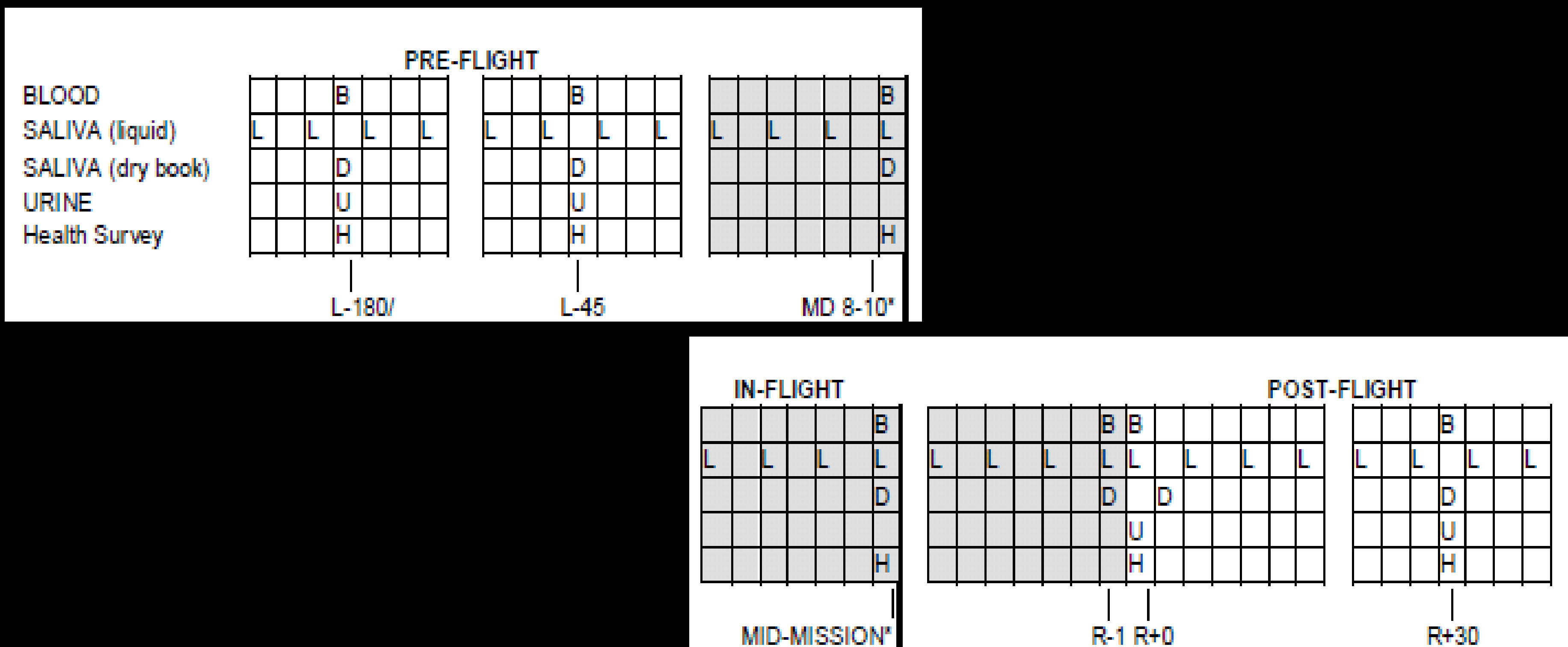
- Virus specific T cell number
- Virus specific T cell function
- Plasma stress hormones

JSC Microbiology Laboratory

- Latent herpesvirus reactivation (saliva/urine)
- Saliva/urine stress hormones
- Circadian rhythm analysis

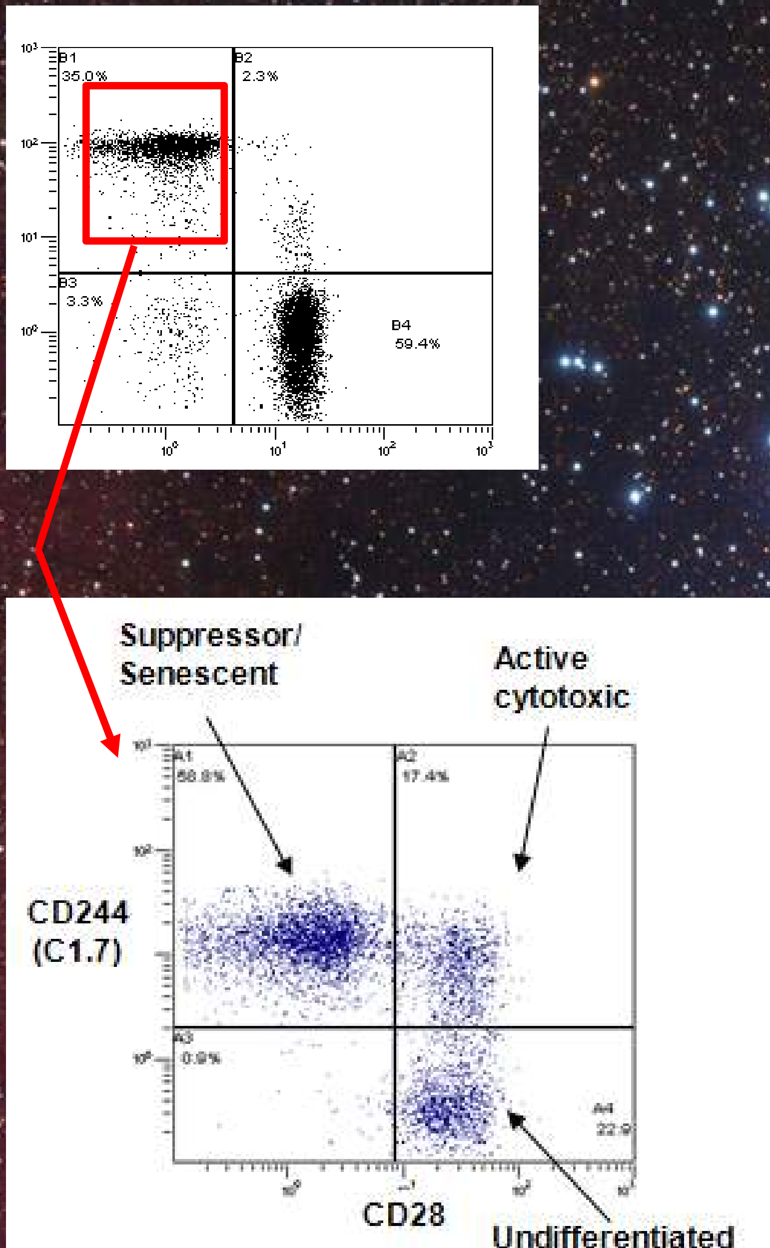


Samples - Timepoints

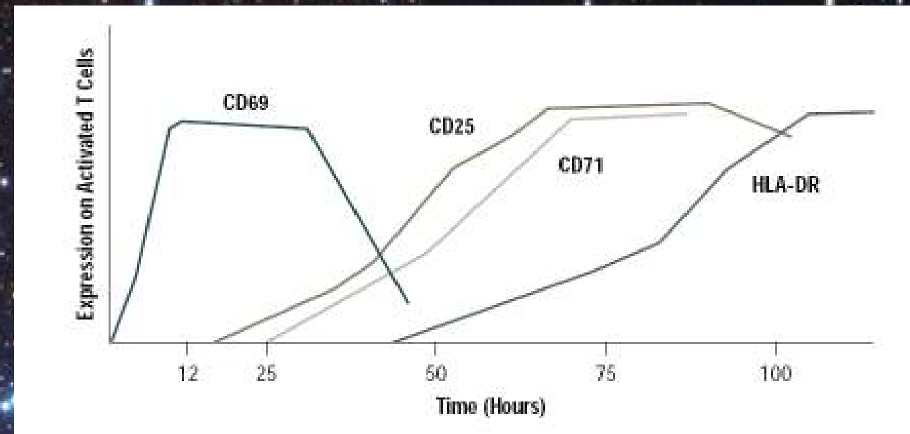


Flight Hardware

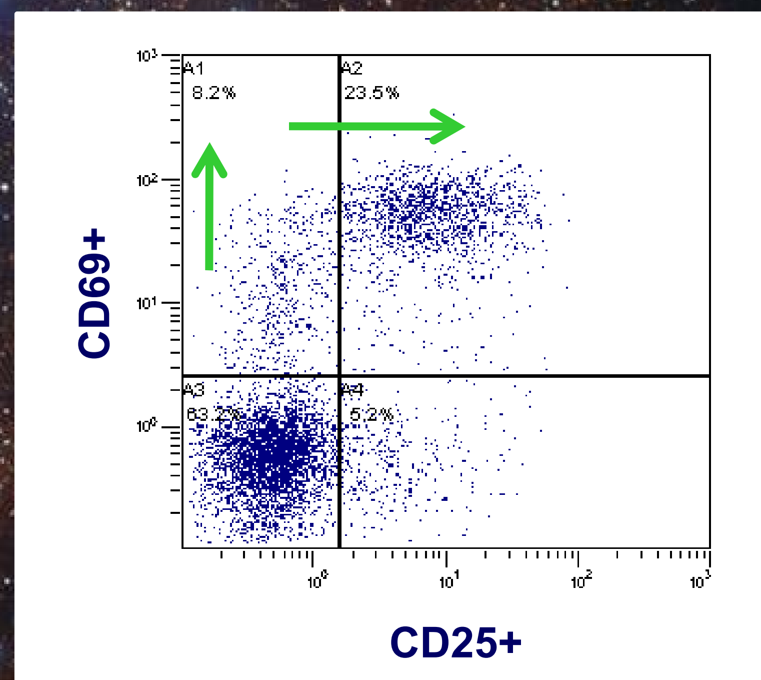
Cell Distribution

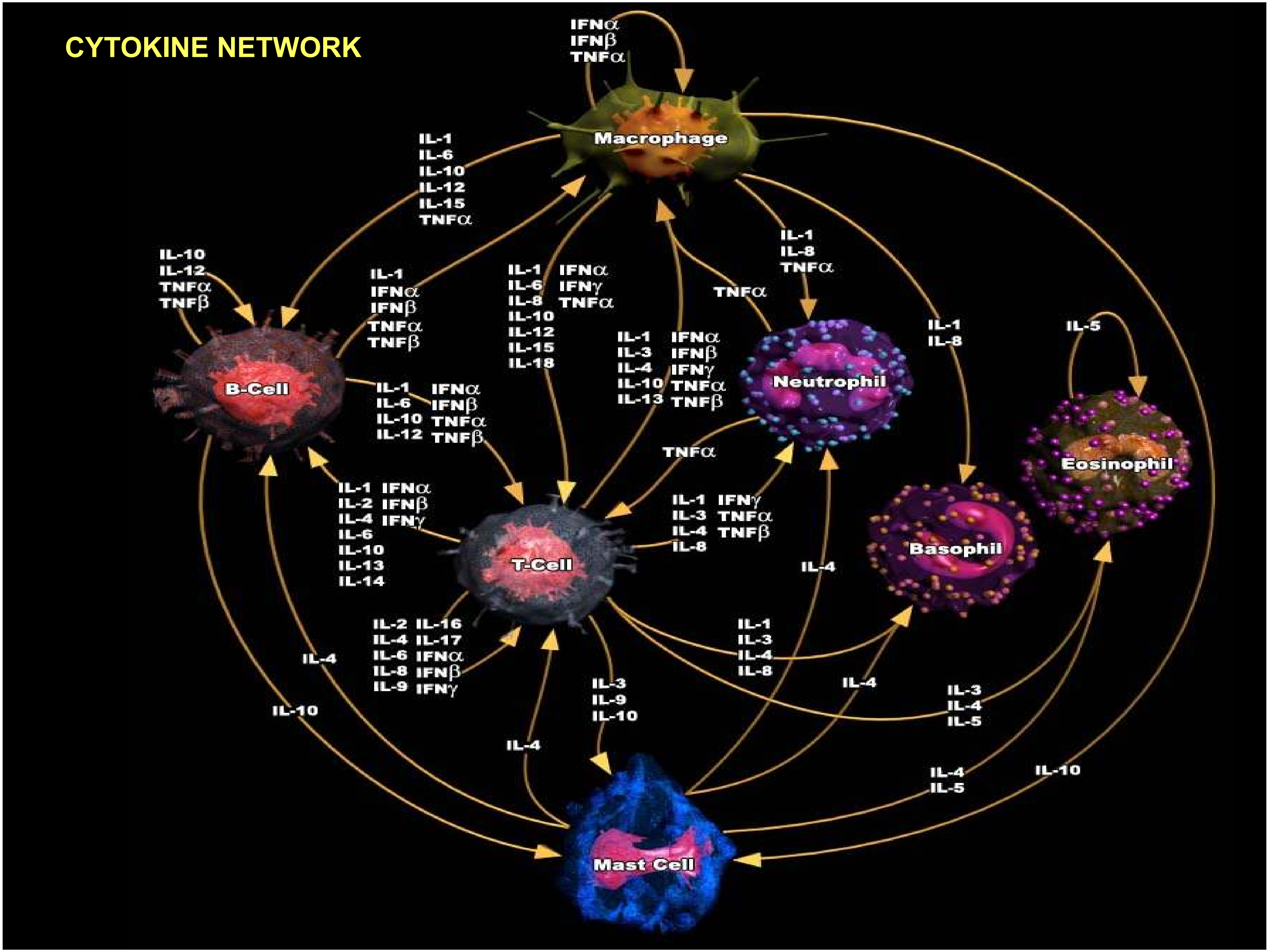


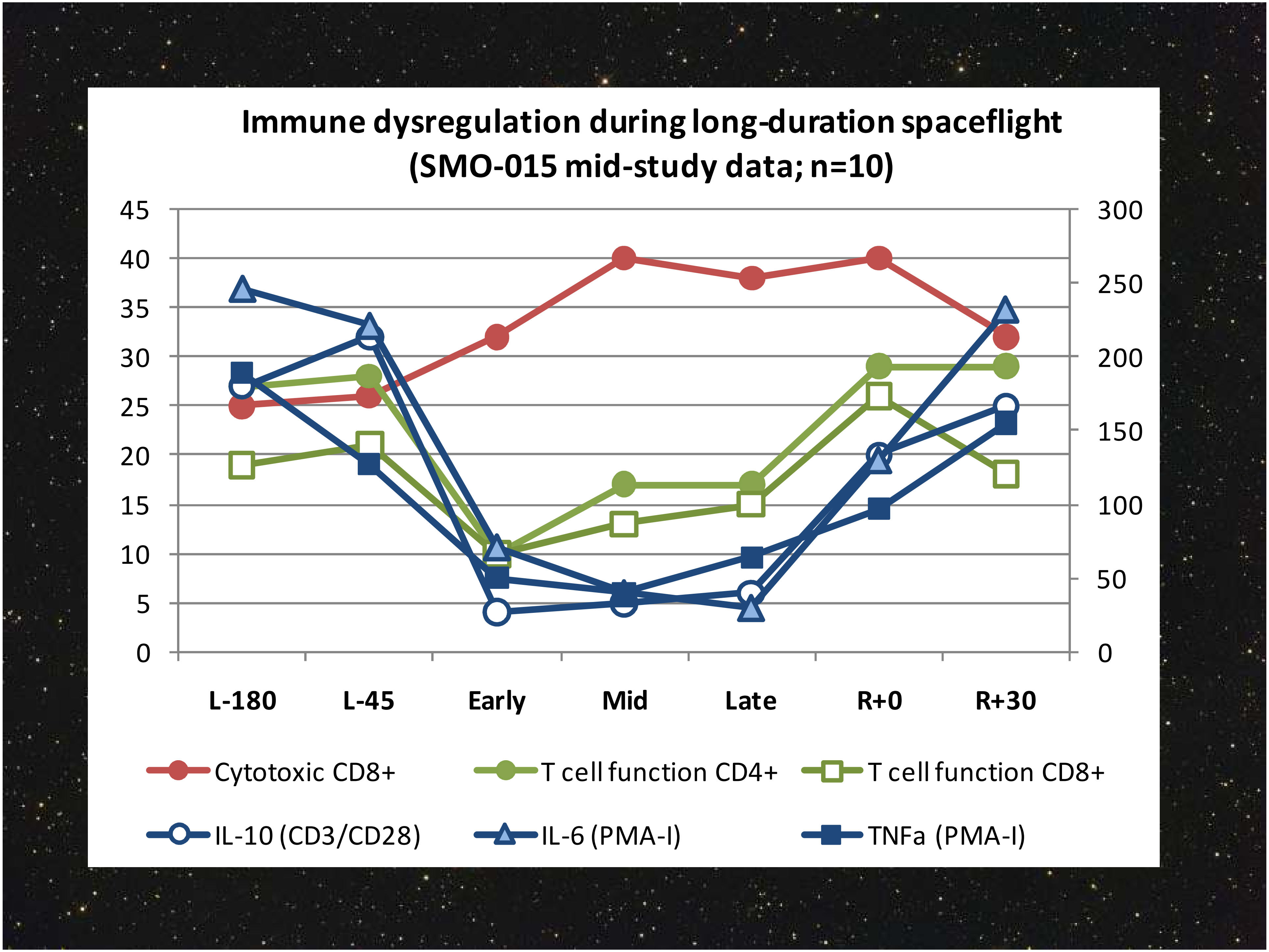
Cell Function



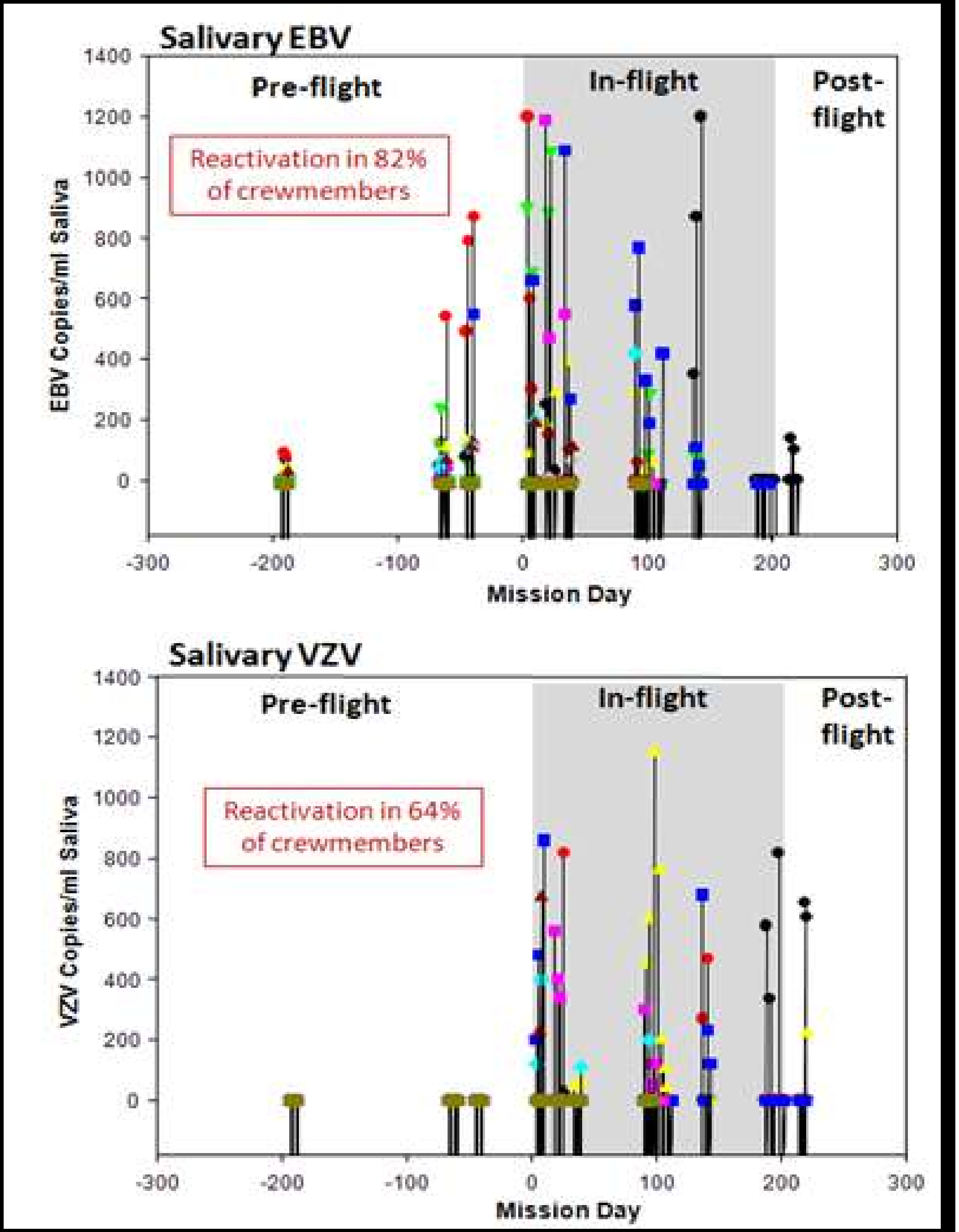
Kinetics of Expression of Activation Antigens on T Cells




CYTOKINE NETWORK
IFNα
IFNβ
TNFα
Macrophage
IL-1
IL-6
IL-10
IL-12
IL-15
TNFα
IL-10
IL-12
TNFα
TNFβ
IL-1
IFNα
IFNβ
TNFα
TNFβ
IL-1 IFNα
IL-6 IFNγ
IL-8 TNFα
IL-10
IL-12
IL-15
IL-18
IL-1
IL-8
TNFα
TNFα
IL-1 IFNα
IL-3 IFNβ
IL-4 IFNγ
IL-10 TNFα
IL-13 TNFβ
Neutrophil
IL-1
IL-8
IL-5
B-Cell
IL-1 IFNα
IL-6 IFNβ
IL-10 TNFα
IL-12 TNFβ
TNFα
Eosinophil
IL-1 IFNα
IL-2 IFNβ
IL-4 IFNγ
IL-6
IL-10
IL-13
IL-14
T-Cell
IL-1 IFNγ
IL-3 TNFα
IL-4 TNFβ
IL-8
IL-4
Basophil
IL-2 IL-16
IL-4 IL-17
IL-6 IFNα
IL-8 IFNβ
IL-9 IFNγ
IL-4
IL-1
IL-3
IL-4
IL-8
IL-4
IL-3
IL-4
IL-5
IL-10
IL-3
IL-9
IL-10
IL-4
IL-4
IL-5
IL-10
Mast Cell



Immune dysregulation during long-duration spaceflight
(SMO-015 mid-study data; n=10)
45
40
35
30
25
20
15
10
5
0
300
250
200
150
100
50
0
L-180
L-45
Early
Mid
Late
R+0
R+30
Cytotoxic CD8+
T cell function CD4+
T cell function CD8+
IL-10 (CD3/CD28)
IL-6 (PMA-I)
TNFa (PMA-I)


Salivary EBV
Pre-flight
In-flight
Post-flight
Reactivation in 82% of crewmembers
EBV Copies/ml Saliva
Mission Day
Salivary VZV
Pre-flight
In-flight
Post-flight
Reactivation in 64% of crewmembers
VZV Copies/ml Saliva
Mission Day

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)

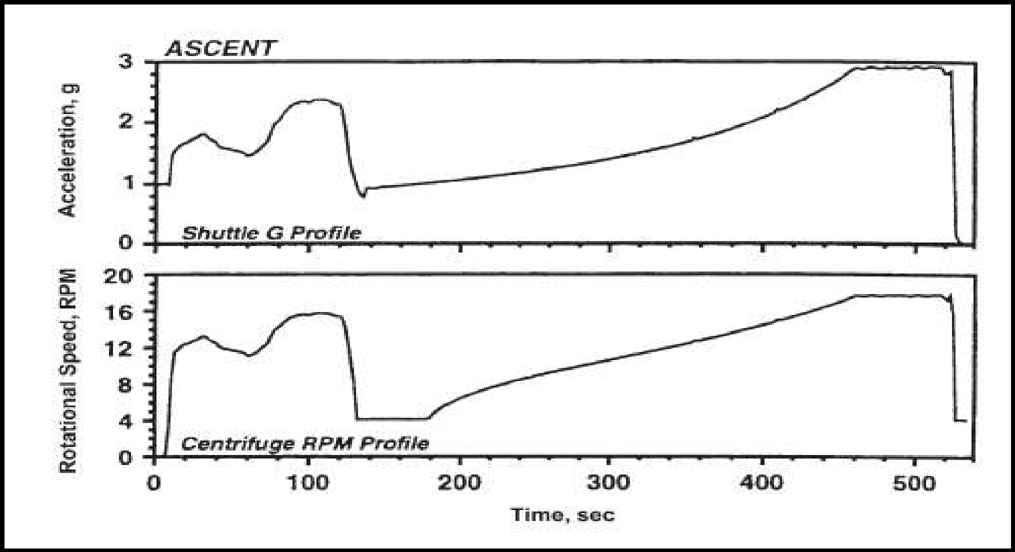
Closed Chamber Confinement

NEEMO Aquarius Station

Haughton-Mars Project

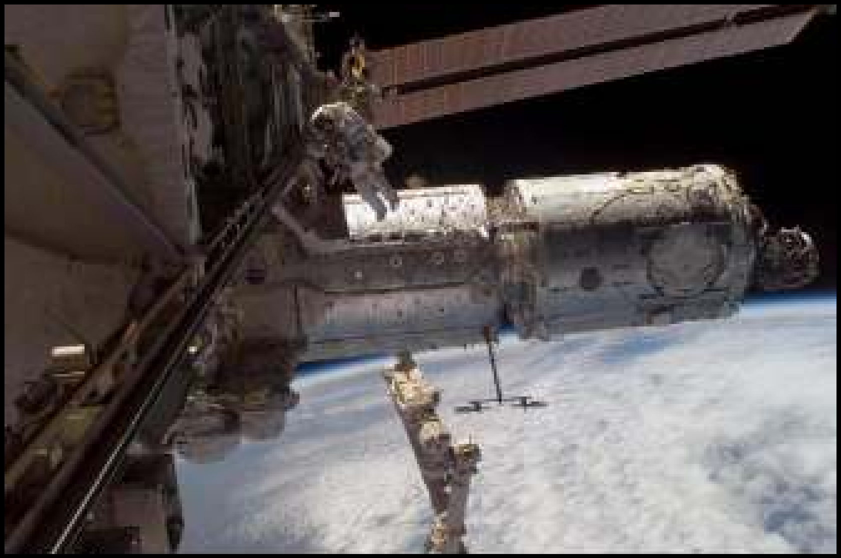
Antarctica winter over

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.

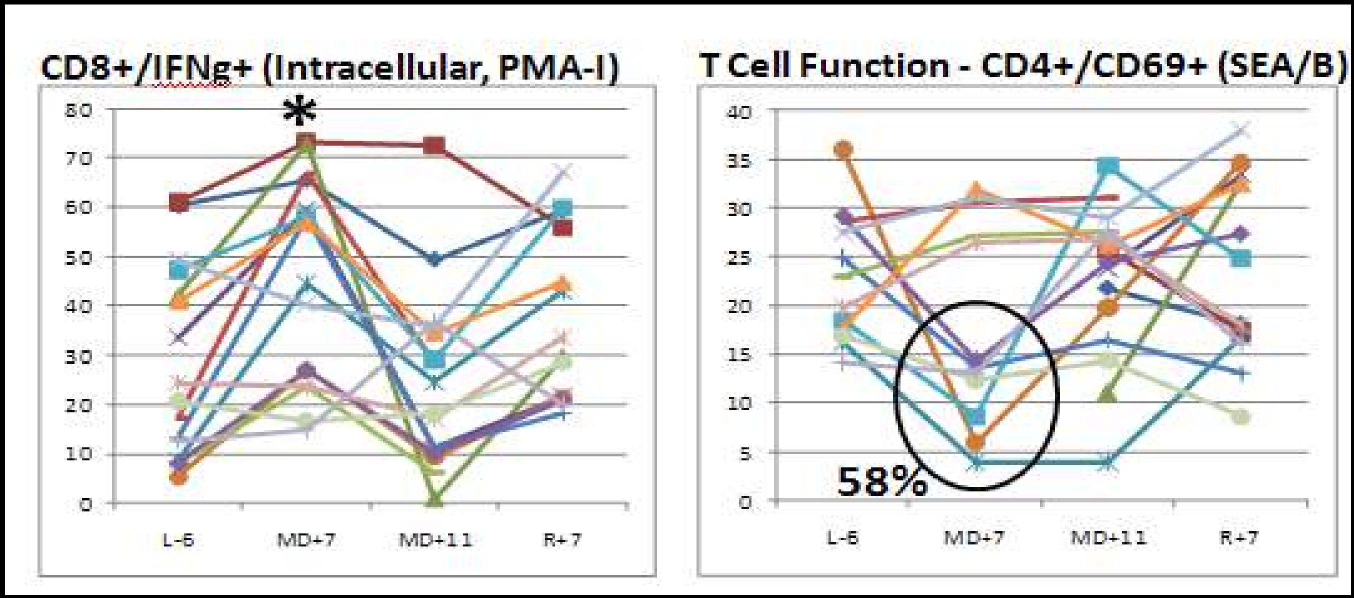
NEEMO Aquarius Station
(Key Largo - Florida)

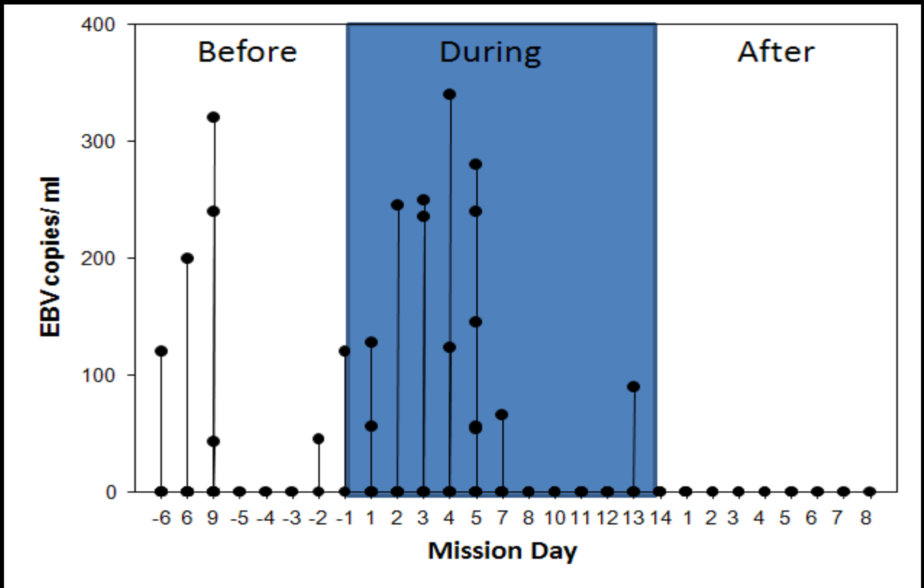

6. 30. 2003



6. 22. 2003

NEEMO Immune Data: N12, 13, 14 Pilot Study

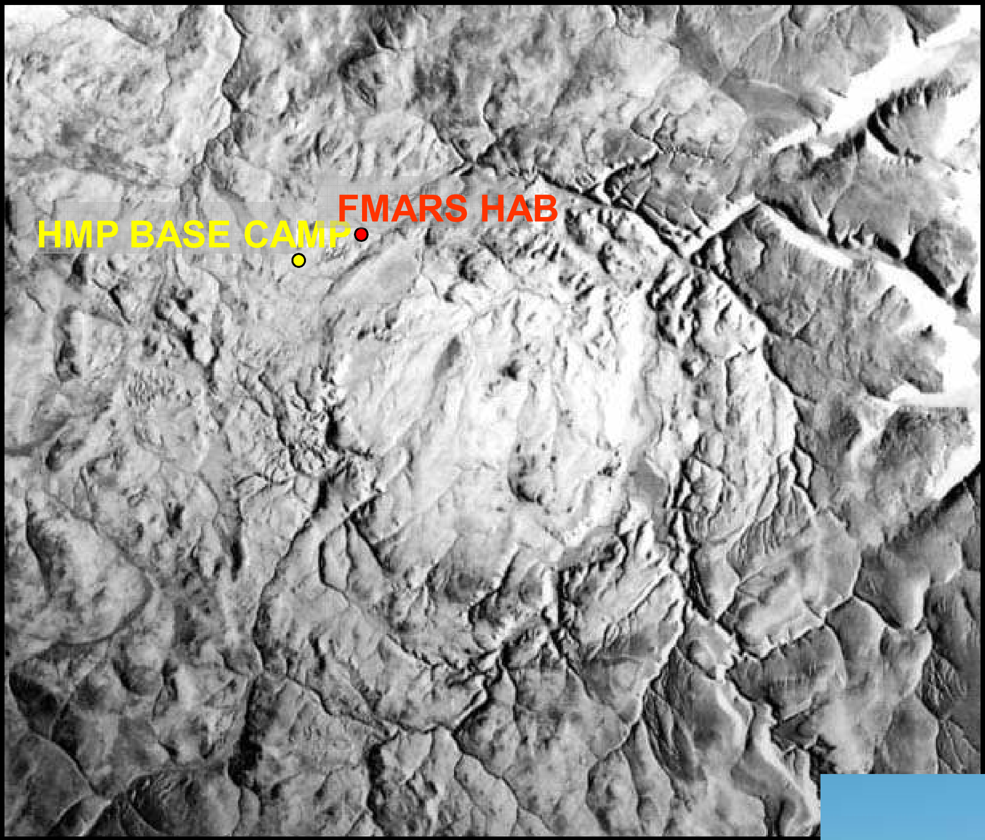




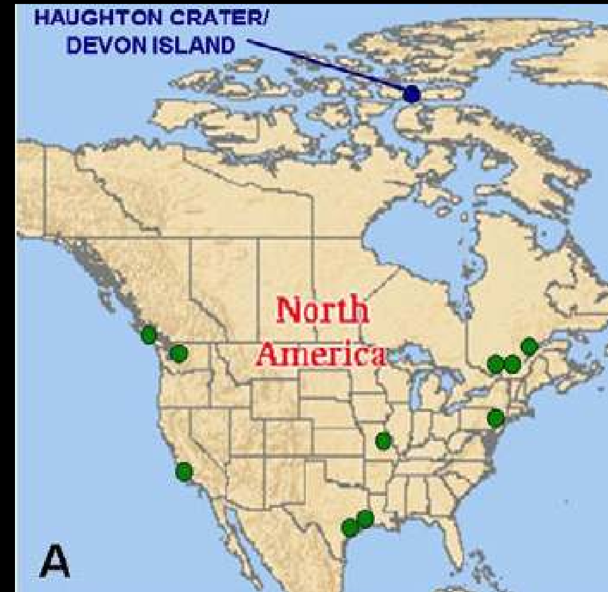
http://www.nasa.gov/mission_pages/NEEMO/index.html

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

Haughton Crater



HMP 2002 Pilot Study



HMIA 2002

SAMPLE COLLECTION vs. FIELD SEASON DATES

SUBJECT	PRE-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	POST-MISSION
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	16-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

HMIA ON-SITE ACTIVITY

▒ =subject on Devon Island

X =date of blood collection

BMC Immunology

Research article

Open Access

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

Brian Crucian*[1], Pascal Lee[2], Raymond Stowe[3], Jeff Jones[4], Rainer Effenhauser[4], Raymond Widen[5] and Clarence Sams[4]

Address: [1]Wyle Laboratories/NASA-JSC, 1290 Hercules Drive, Houston, Texas, 77058, USA, [2]Mars Institute, SETI Institute & NASA Ames Research Center, 515 N. Whisman Road, Moffett Field, CA, 94045, USA, [3]Microgen Laboratories, 903 Texas Avenue, La Marque, Texas, 77568, USA, [4]NASA-JSC, NASA Parkway, Houston, Texas, 77058, USA and [5]Tampa General Hospital, PO Box 1289, Tampa, Florida, 33601, USA

Email: Brian Crucian* - bcrucian@ems.jsc.nasa.gov; Pascal Lee - pascal.lee@marsinstitute.info; Raymond Stowe - rpstowe@microgenlabs.com; Jeff Jones - jeffrey.a.jones@nasa.gov; Rainer Effenhauser - rainer.k.effenhauser@nasa.gov; Raymond Widen - rwiden@tgh.org; Clarence Sams - csams@ems.jsc.nasa.gov

* Corresponding author

Published: 23 May 2007

BMC Immunology 2007, 8:7 doi:10.1186/1471-2172-8-7

Received: 7 December 2006
Accepted: 23 May 2007

This article is available from: http://www.biomedcentral.com/1471-2172/8/7

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.

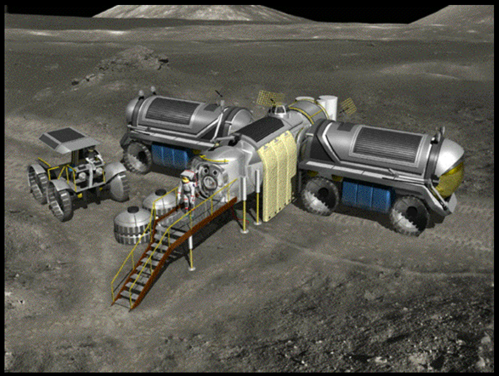
Results: The protocol developed for immune sample processing in remote field locations functioned properly. Samples were processed on Devon Island, and stabilized for subsequent analysis at the Johnson Space Center in Houston. The data indicated that some phenotype, immune function and stress hormone 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.

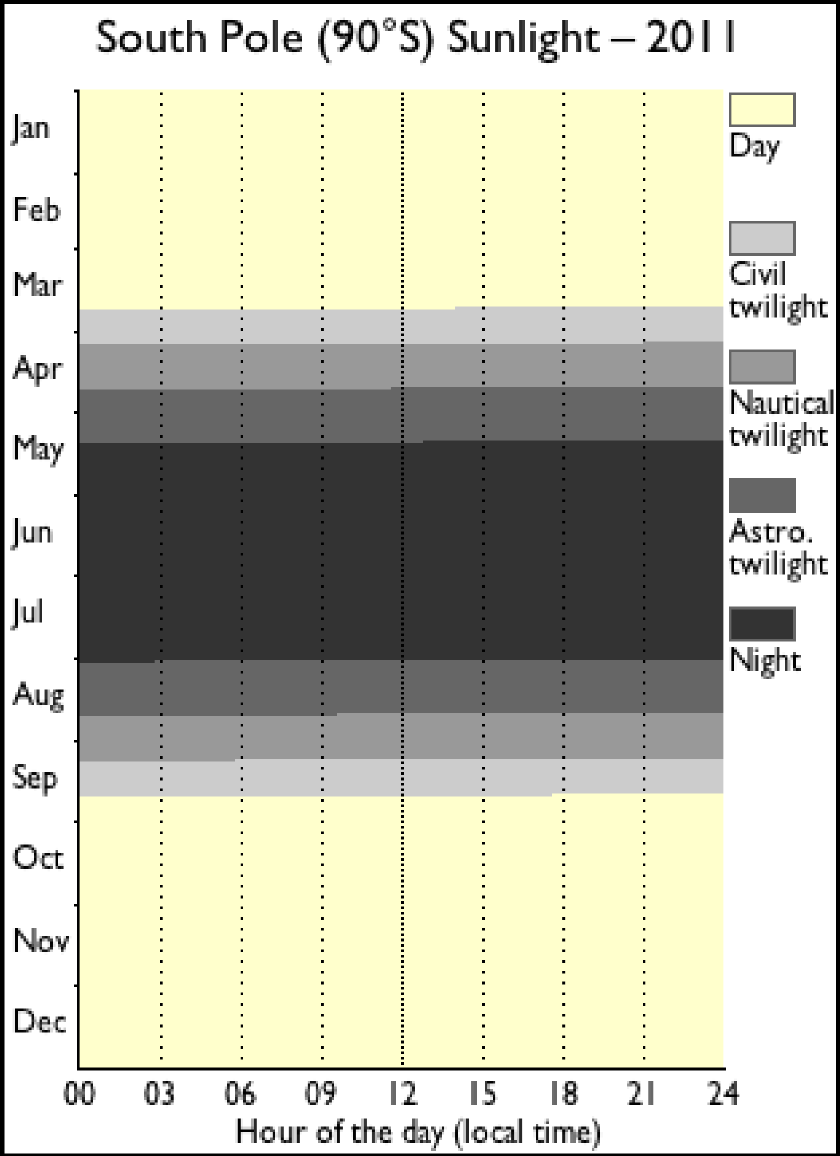

British Claim
Norwegian Claim
Indian Ocean
South Orkney Islands
Argentine Claim
Brazilian Zone of Interest
Weddell Sea
Ronne Ice Shelf
Bellingshausen Sea
Peter I Island
South Pole
Amundsen-Scott (U. S.)
Byrd (U. S.)
Ross Ice Shelf
Ross Sea
Antarctic Circle
Balleny Islands
Australian Claim
French Claim
New Zealand Claim
CHO2ICE
CONSEQUENCES OF LONGTERM-CONFINEMENT AND HYPOBARIC HYPOXIA ON IMMUNITY IN THE ANTARCTIC CONCORDIA ENVIRONMENT
esa
DLR
LMU

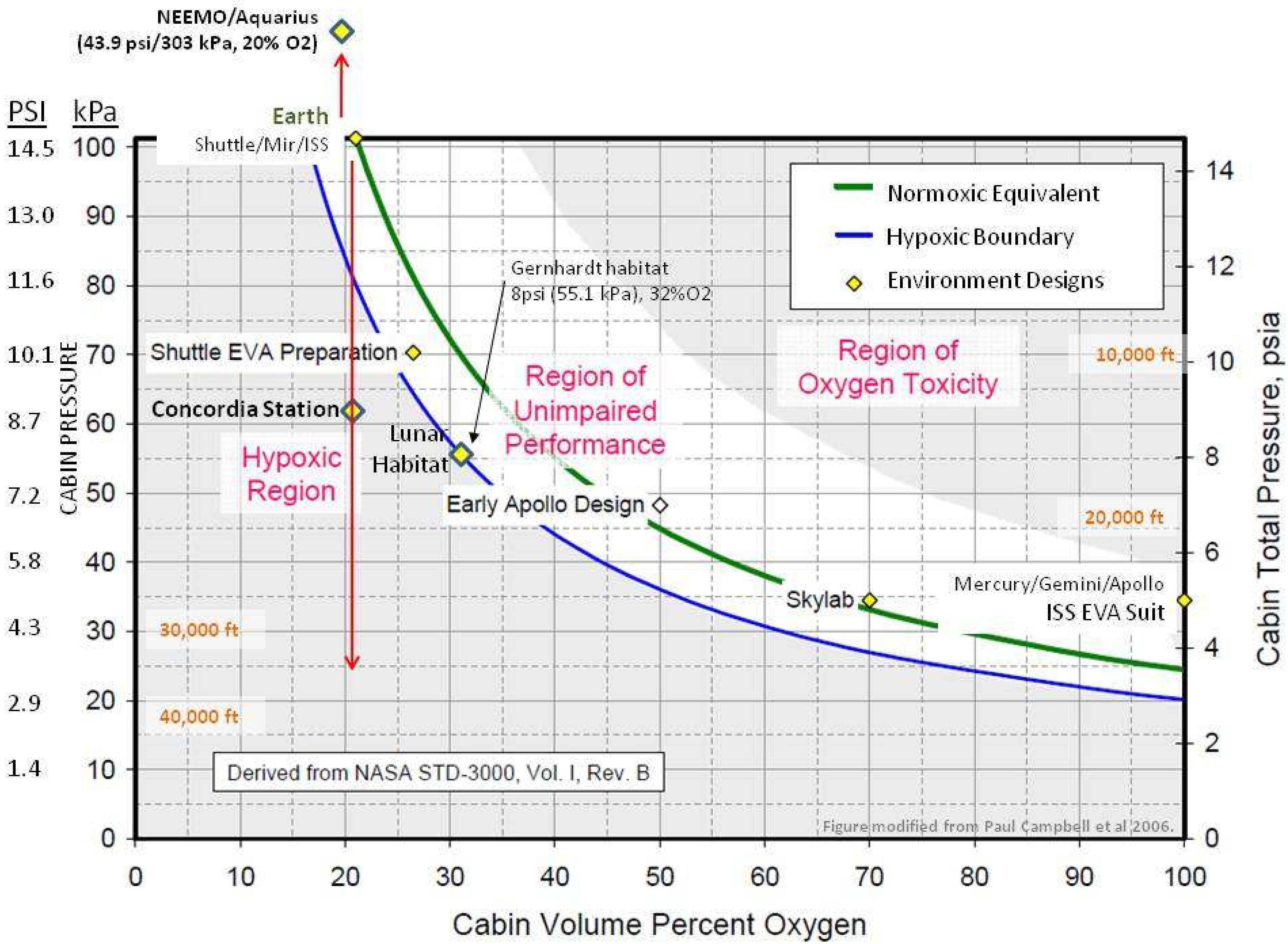
Concordia Station as Spaceflight-Planetary Exploration Analog

- 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 CO_2 in air
- Higher ionization in air (increases oxidative metabolism)



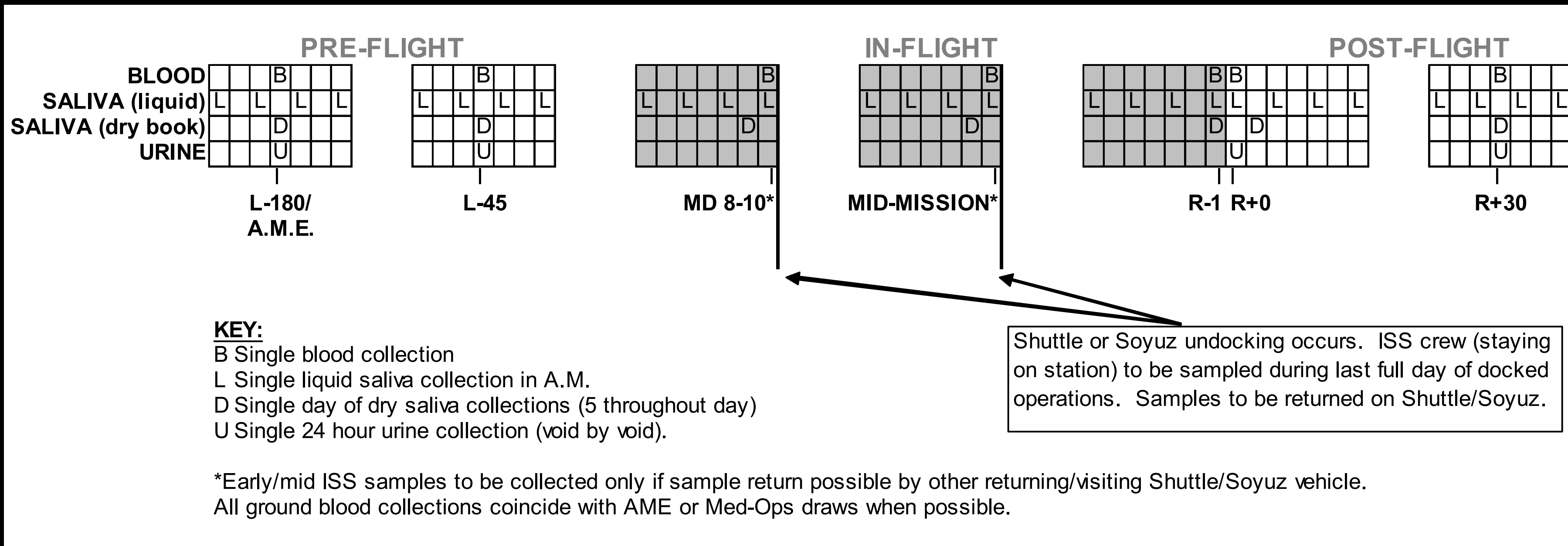
- Relative humidity 3-5%
- Snowfall ~1cm/yr
- High winds
- Elevated UV exposure (summer)
- Mean winter temperature -60 C (-72 F)
- Mean summer temperature -30 C (-22 F)
- Disrupted circadian rhythms
- Altered nutritional aspects


South Pole (90°S) Sunlight – 2011
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
00
03
06
09
12
15
18
21
24
Hour of the day (local time)
Day
Civil twilight
Nautical twilight
Astro. twilight
Night

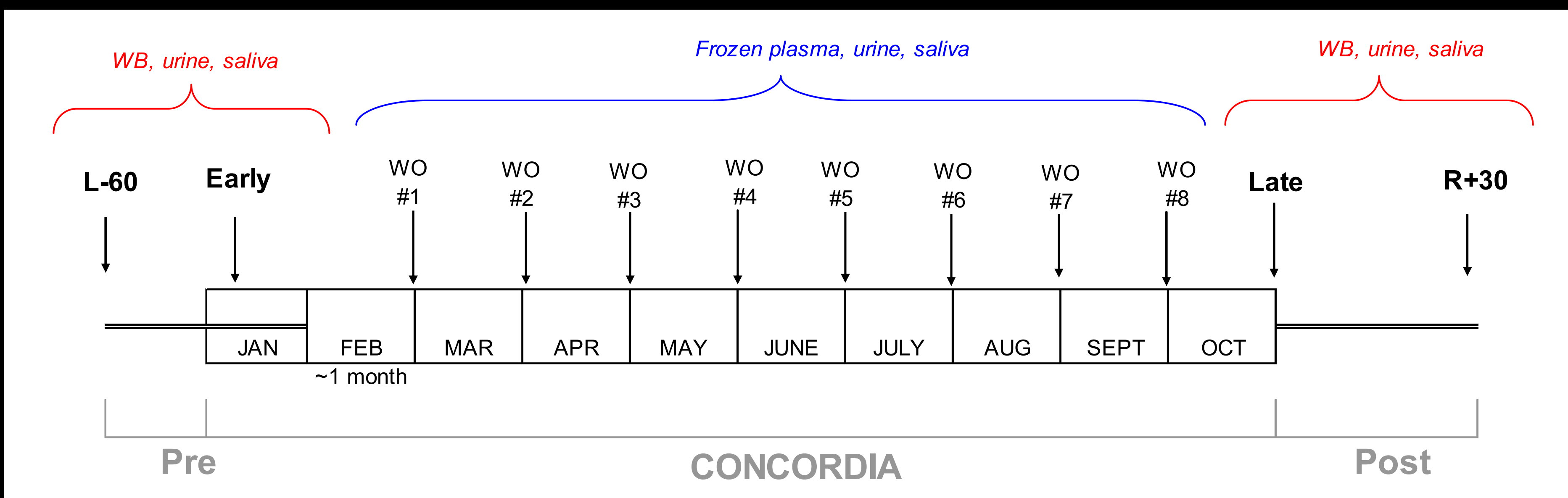


NEEMO/Aquarius
(43.9 psi/303 kPa, 20% O2)
PSI
kPa
Earth
Shuttle/Mir/ISS
14.5 100
13.0 90
11.6 80
10.1 70
8.7 60
7.2 50
5.8 40
4.3 30
2.9 20
1.4 10
0
CABIN PRESSURE
Normoxic Equivalent
Hypoxic Boundary
Environment Designs
Gernhardt habitat
8psi (55.1 kPa), 32%O2
Shuttle EVA Preparation
Concordia Station
Lunar Habitat
Hypoxic Region
Region of Unimpaired Performance
Region of Oxygen Toxicity
10,000 ft
20,000 ft
30,000 ft
40,000 ft
Early Apollo Design
Skylab
Mercury/Gemini/Apollo
ISS EVA Suit
Derived from NASA STD-3000, Vol. I, Rev. B
Figure modified from Paul Campbell et al 2006.
0 10 20 30 40 50 60 70 80 90 100
Cabin Volume Percent Oxygen
14 12 10 8 6 4 2 0
Cabin Total Pressure, psia

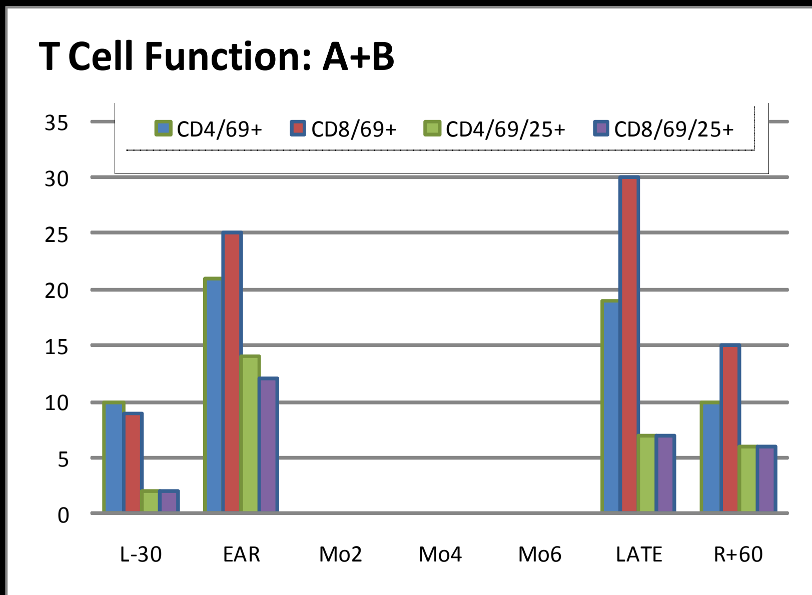
INTEGRATED IMMUNE

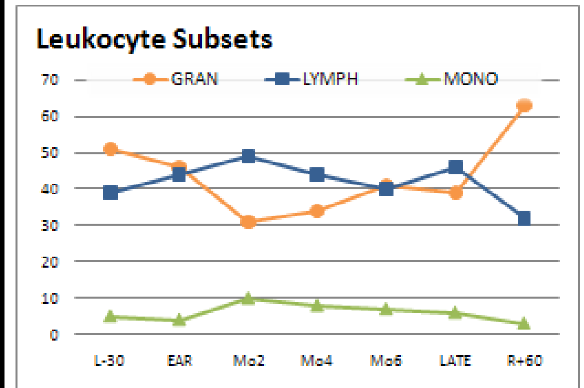


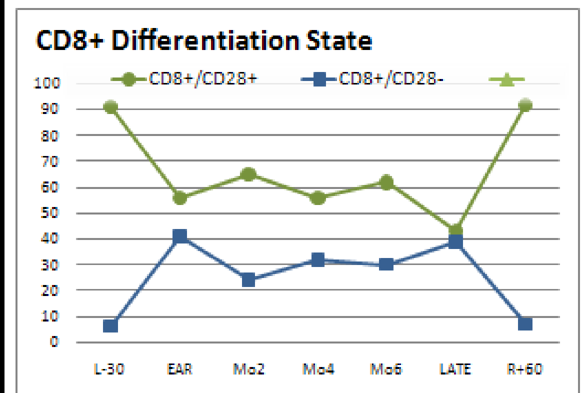
CHOICE

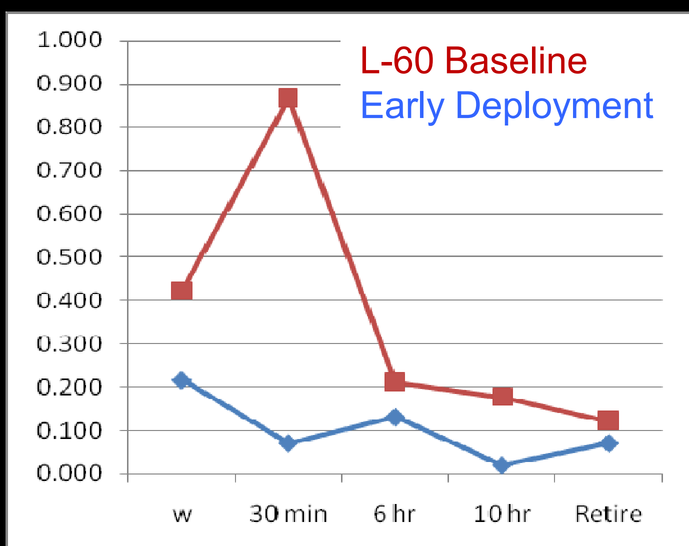


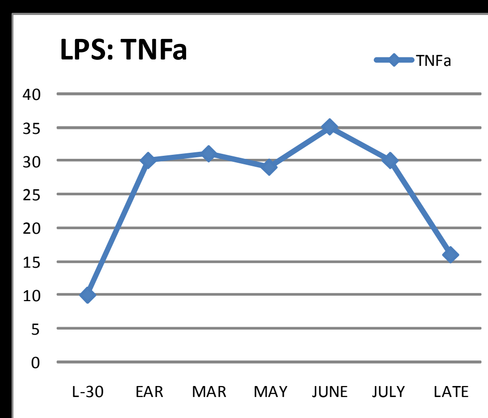
NASA/ESA Concordia/Antarctic Immune Study

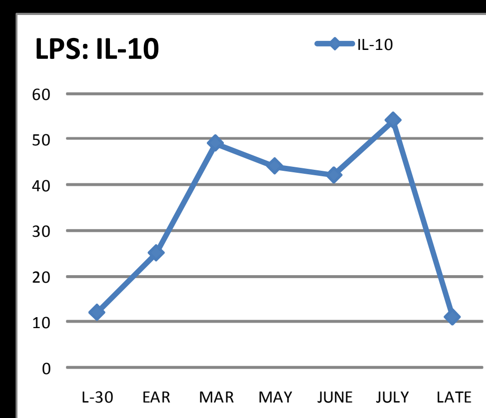


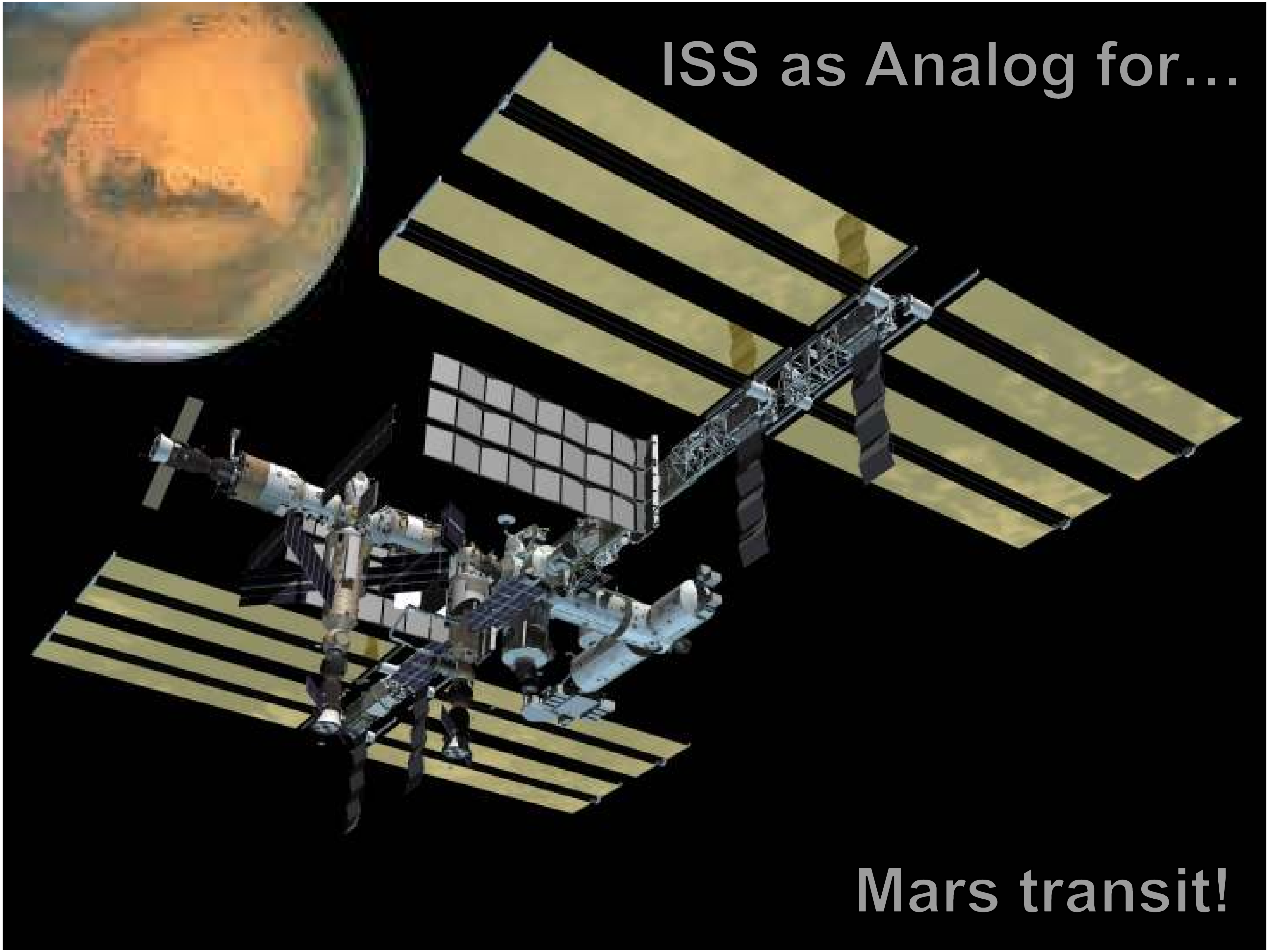











ISS as Analog for…
Mars transit!

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

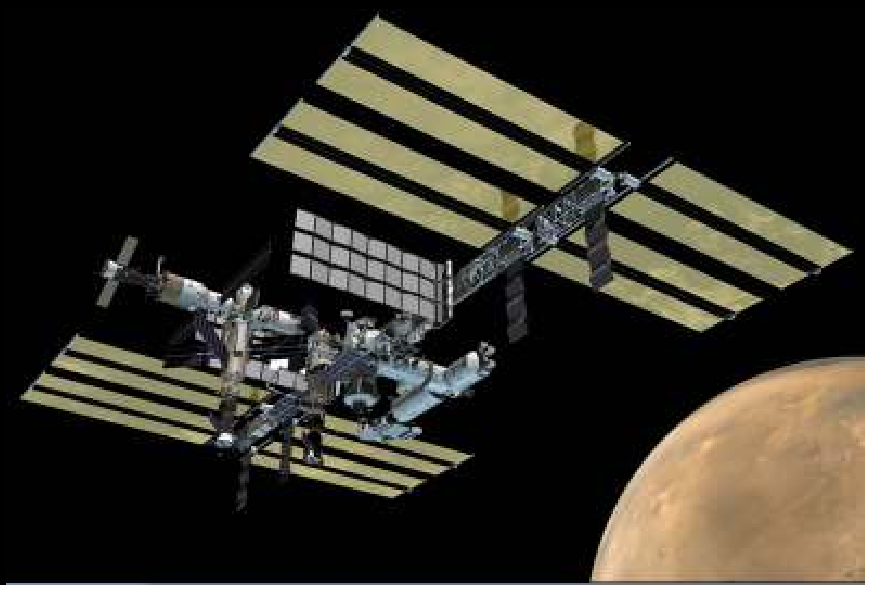
- Behavioral health and performance
- Human factors

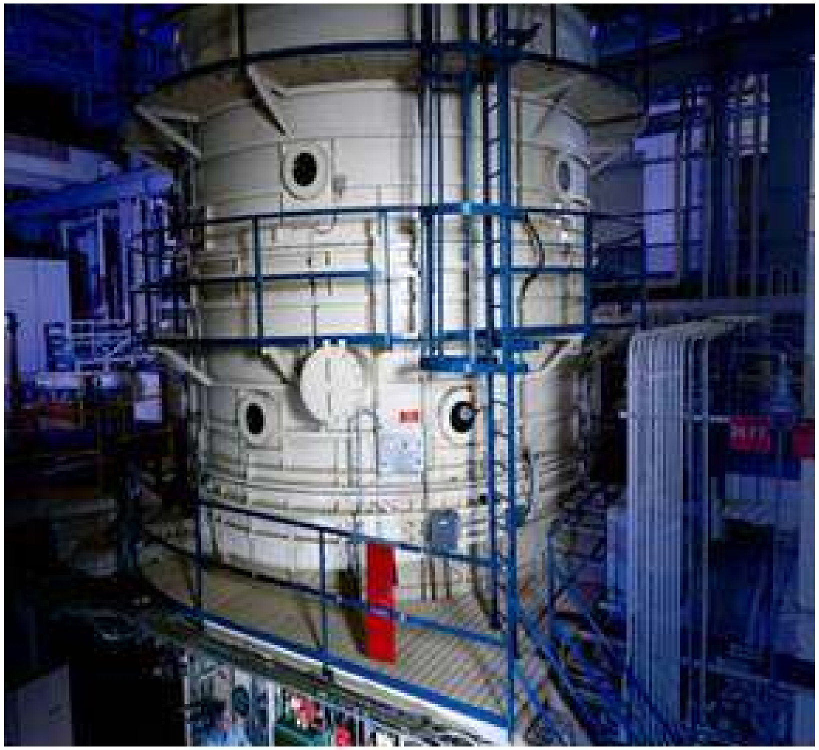
Weaknesses

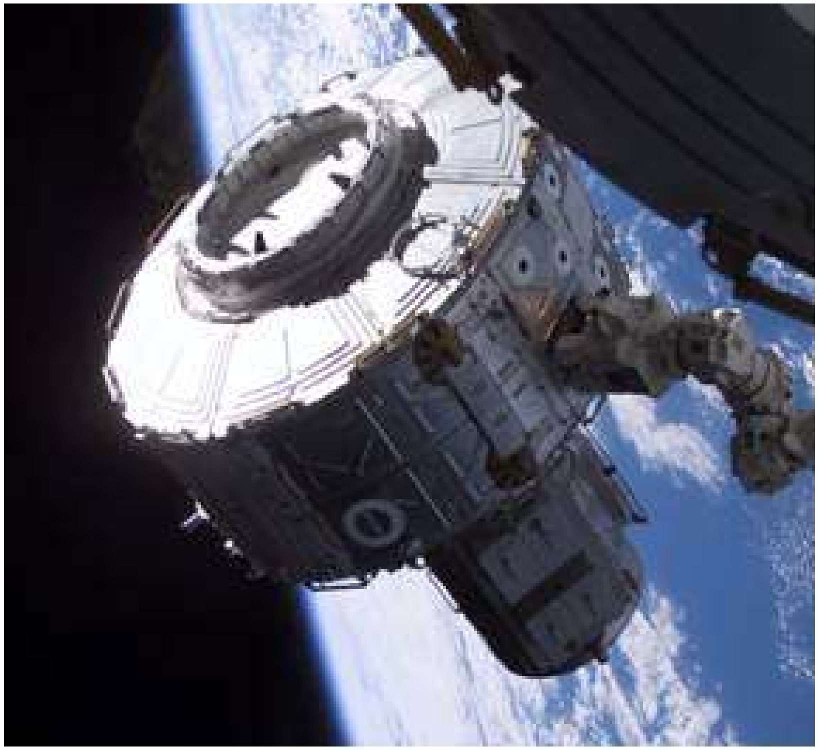
Shielded from deep-space radiation environment

Proximity to Earth

- Minimal time delay in communications
- Frequent abort opportunities
- Earth is always just outside the window



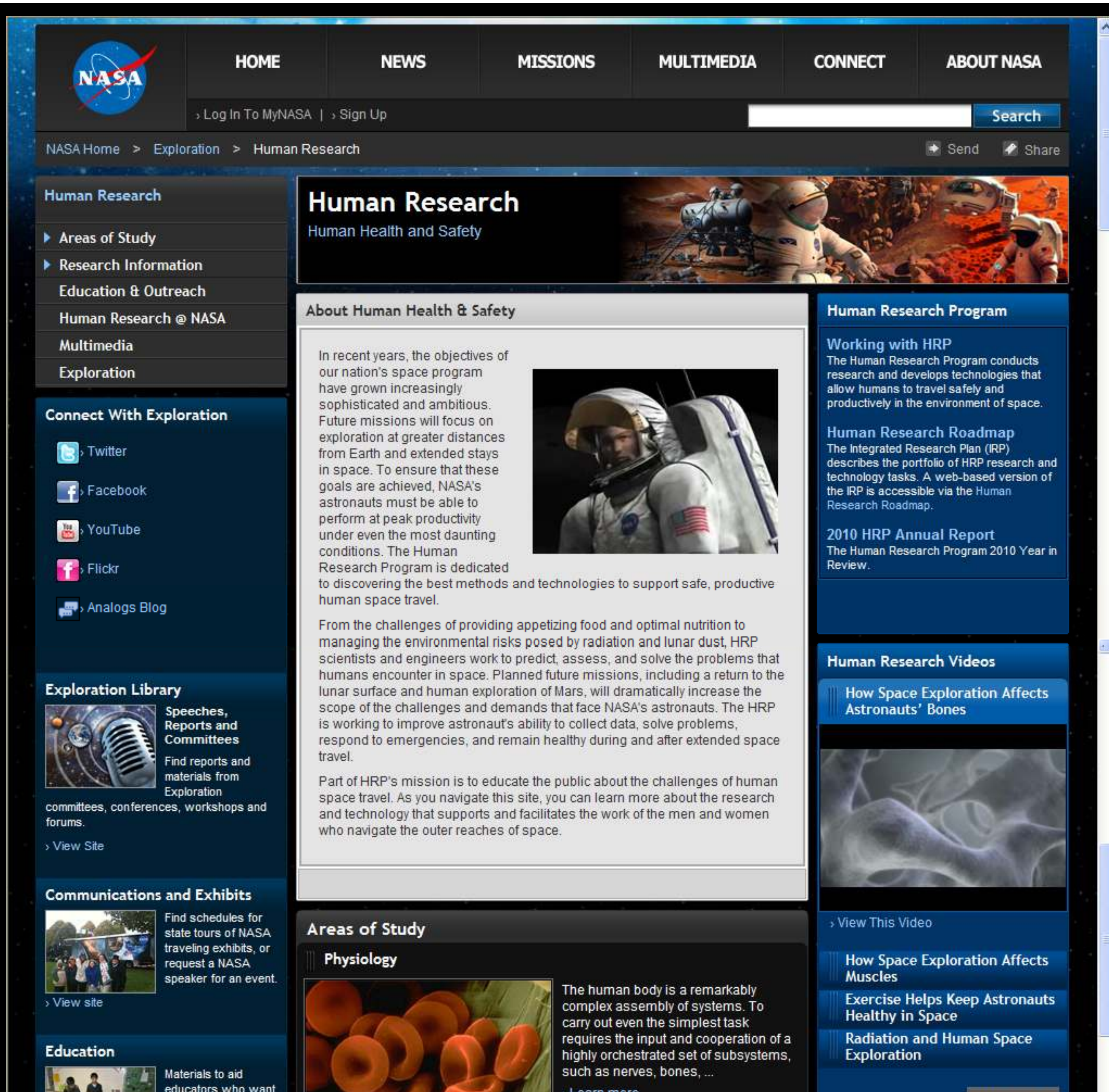




Phase 1: JSC 20ft Chamber (2012)
•30 subjects
•10d isolation/EVA activities
•8/32 atmosphere

Phase 2: ISS Airlock (2013-14)
•2 crewmembers - Expedition 35/36
•3 week isolation/EVA activities
•8/32 atmosphere

For more information…



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

HUMAN RESEARCH ROADMAP | HRP | DATA | EXPLORATION

Home | HRP Introduction | HRP Architecture | HRP Org Chart | Acronyms | Reviews | Help

EVIDENCE | RISKS | GAPS | TASKS | EXPLORE | SEARCH

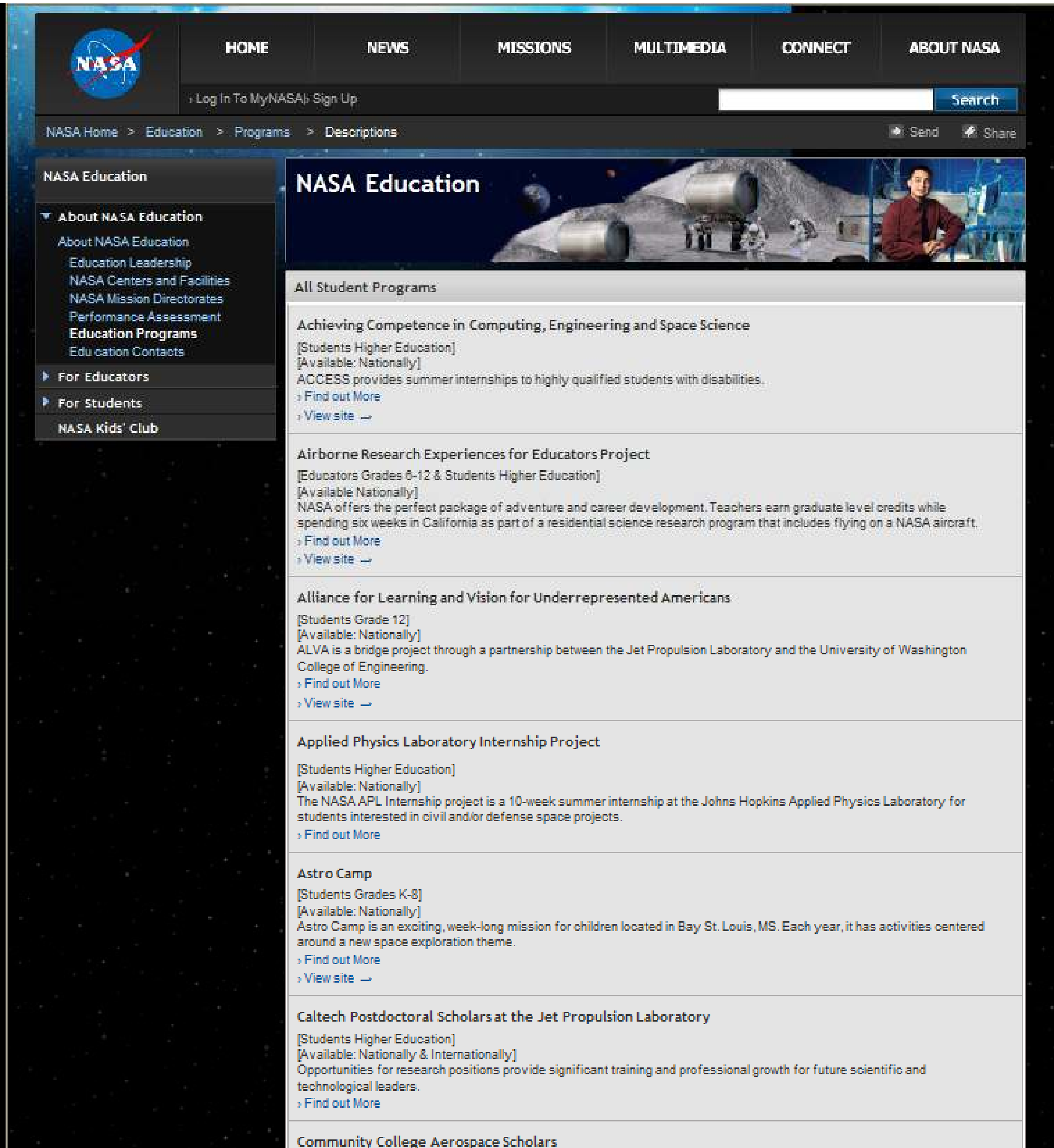
Human Research Roadmap

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/



HOME NEWS MISSIONS MULTIMEDIA CONNECT ABOUT NASA

› Log In To MyNASA› Sign Up

Search

NASA Home > Education > Programs > Descriptions

Send Share

NASA Education

- About NASA Education
  - About NASA Education
    - Education Leadership
    - NASA Centers and Facilities
    - NASA Mission Directorates
    - Performance Assessment
    - **Education Programs**
    - Edu cation Contacts
- For Educators
- For Students
- NASA Kids' Club

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
› View site →

Caltech Postdoctoral Scholars at the Jet Propulsion Laboratory
[Students Higher Education]
[Available: Nationally & Internationally]
Opportunities for research positions provide significant training and professional growth for future scientific and technological leaders.
› Find out More

Community College Aerospace Scholars

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

Questions?