Medical Concerns for Exploration Class Space Missions

Brian Crucian, Ph.D.
September 20, 2011
Microgravity Effects on the Human Body

- Fluid redistribution causes head congestion and puffy face
- Eyes become main way to sense motion
- Otoliths in inner ear respond differently to motion
- Changed sensory input confuses brain, causing occasional disorientation
- Loss of blood plasma creates temporary anemia on return to Earth
- Higher radiation doses may increase cancer risk
- Dysregulation of the immune system
- Kidney filtration rate increases; bone loss may cause kidney stones
- Fluid redistribution shrinks legs
- Weight-bearing bones and muscles deteriorate
- Touch and pressure sensors register no downward force
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

<table>
<thead>
<tr>
<th></th>
<th>Pre-2010</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Program</strong></td>
<td>Constellation</td>
</tr>
<tr>
<td><strong>Rockets</strong></td>
<td>Ares-1, Ares-V</td>
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<tr>
<td><strong>Vehicles</strong></td>
<td>Orion, Altair (Shuttle)</td>
</tr>
<tr>
<td><strong>Destination</strong></td>
<td>Moon, eventually Mars</td>
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</table>
# Recent changes to NASA vehicle plan

<table>
<thead>
<tr>
<th>Program</th>
<th>Current</th>
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<tbody>
<tr>
<td>Rockets</td>
<td>NASA - Heavy Lift Commercial: Falcon 9, Taurus 2</td>
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<tr>
<td>Vehicles</td>
<td>NASA: Orion Commercial: Dragon, Cygnus</td>
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<tr>
<td>Destination</td>
<td>TBD, Asteroids?</td>
</tr>
</tbody>
</table>
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
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 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.

PROXIMAL FEMUR

Trochanter

Femoral Neck

Cortical Bone/ "Compact Bone"

Cancellous “Spongy” Bone/Trabecular Bone

VERTEBRAL BODY
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 skeleton (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

<table>
<thead>
<tr>
<th>Region</th>
<th>% Change</th>
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<tbody>
<tr>
<td>Lumbar Spine</td>
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<tr>
<td>Femoral Neck</td>
<td></td>
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<tr>
<td>Trochanter</td>
<td></td>
</tr>
<tr>
<td>Heel</td>
<td></td>
</tr>
<tr>
<td>Pelvis</td>
<td></td>
</tr>
</tbody>
</table>
Recovery of BMD with return to gravity

\[ L_t = L_0 \cdot e^{\ln(0.5) \cdot t/HL} \]

BMD deficit (% Loss)

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
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

Courtesy of C. Oman
CNS Response to Spaceflight

1-g adapted CNS

entry into sustained 0-g

loss of gravity cues

sensory conflict

• disorientation
• perceptual illusions
• malcoordination

CNS adaptation

• reinterpretation of sensory inputs
• new sensory-motor control strategies
• new spatial orientation schemes

space motion sickness

0-g adapted CNS
Human Sensory-Motor Balance Control

- spatial orientation
- motor control
- cerebral cortex
- brain stem/cerebellum

Motor commands flow to sensory inputs and vice versa.
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

Flight Duration:
- + 10-day
- × 90-day
- 180-day

Time After Landing [days]

Probability Score is Clinically Abnormal

Probablity SOT6 Clinically Abnormal Given Flight Duration
- 20%
- 30%
- 40%

Updated after Expedition 9 return

preflight
Dynamic Visual Acuity

Landolt-C

![Dynamic Visual Acuity](image)

图表显示了不同天数后视敏度的下降情况，n=1，天数包括0、1、2、3/4、6/7。

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

*First experiments for leukemia*
IMMUNOLOGY
• One of the 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

- Microbes: Increase virulence
- Stress
- Microgravity
- Disrupted circadian rhythms
- Radiation
- Isolation
- Reduced immune cell function
- Altered cytokine balance
- Latent viral reactivation
- Altered wound healing

- Infection?
- Hypersensitivity?
- Autoimmunity?
- Cancer?
<table>
<thead>
<tr>
<th>Number</th>
<th>Infectious Disease</th>
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<tbody>
<tr>
<td>8</td>
<td>Fever, chills</td>
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<tr>
<td>5</td>
<td>Fungal infection</td>
</tr>
<tr>
<td>3</td>
<td>Flu-like syndrome</td>
</tr>
<tr>
<td>4</td>
<td>Urinary tract infections</td>
</tr>
<tr>
<td>3</td>
<td>Aphthous stomatitis</td>
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<tr>
<td>2</td>
<td>Viral gastrointestinal disease</td>
</tr>
<tr>
<td>2</td>
<td>Subcutaneous skin infection</td>
</tr>
<tr>
<td>2</td>
<td>Other viral disease</td>
</tr>
</tbody>
</table>

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

- Lymphoid Stem Cell
  - thymus
  - NK Lymphocyte
  - B Lymphocyte
  - Plasma Cell

- Pluripotent Stem Cell
  - Erythrocyte
  - Megakaryocyte (blood clotting)
  - Monocyte

- Myeloid Stem Cell
  - Macrophage
  - Granulocytes
**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

**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 ³H-uridine at 23 h and harvested at 24 h after initiation of the cultures.
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

EBV frequency: 16%
EBV copies: 417 ± 31/ml

EBV frequency: 29%
EBV copies: 40 ± 2/ml

EBV frequency: 16%
EBV copies: 44 ± 5/ml

Days before launch (L-): 200-140, 139-60, 59-1
Days of flight: 2-4, 5-7, 8-14
Days after return (R+): 1-30, 31-45

-D. Pierson, 2003
### RECENT SPACE IMMUNE STUDIES

<table>
<thead>
<tr>
<th>Study Type</th>
<th>Start L</th>
<th>Start L+30</th>
<th>Start L+90</th>
<th>Start L+120</th>
<th>Return R</th>
<th>Return R+3</th>
<th>Return R+7</th>
<th>Return R+14</th>
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<tr>
<td>Russian Med-Ops/CYTOKINE DSO-501 (ISS)</td>
<td>L-60</td>
<td>L-10</td>
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<td>R+0</td>
<td>R+7</td>
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<td>Latent Virus/DSO-493 (SHUTTLE)</td>
<td>L-180</td>
<td>L-10</td>
<td>saliva</td>
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<td>Japan Immunology/DSO-206 (SHUTTLE)</td>
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<td>L-30</td>
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<td>R+0</td>
<td>R+3</td>
<td>R+7</td>
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<td>Epstein Barr/DSO-500 (SHUTTLE)</td>
<td>L-120</td>
<td>L-65</td>
<td>L-10</td>
<td>L-3/2</td>
<td>R+0</td>
<td>R+3</td>
<td>R+14</td>
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<td>Epstein Barr/E129 (ISS)</td>
<td>AME/ L-180</td>
<td>L-60</td>
<td>L-10</td>
<td>L-3/2</td>
<td>R+0</td>
<td>R+3</td>
<td>R+14</td>
<td>AME/ R+180</td>
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<td>Immuno-ESA/(ISS/SOYUZ)</td>
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<td>L+90 to L+120</td>
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<td>R-15 to R-7</td>
<td>R+1</td>
<td>R+7</td>
<td>R+28</td>
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<td>Integrated Immune/SDBI-1900 (SHUTTLE)</td>
<td>AME** L-180</td>
<td>L-10**</td>
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<td></td>
<td>R-1</td>
<td>R+0**</td>
<td>R+14</td>
<td></td>
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<tr>
<td>Integrated Immune/SMO-015 (ISS)</td>
<td>AME** L-180</td>
<td>L-30**</td>
<td>MD 8-10</td>
<td>MD*</td>
<td>R-1</td>
<td>R+0**</td>
<td>R+30**</td>
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*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

<table>
<thead>
<tr>
<th>BLOOD</th>
<th>PRE-FLIGHT</th>
<th>POST-FLIGHT</th>
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<td>L L L L B</td>
<td>L L L L L</td>
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<td>L-180</td>
<td>L-45</td>
<td>MD 8-10</td>
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<table>
<thead>
<tr>
<th>SALIVA (liquid)</th>
<th>IN-FLIGHT</th>
<th>R-1 R+0</th>
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<tbody>
<tr>
<td>U U U D D D D</td>
<td>U U U U U</td>
<td>U U U</td>
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</table>

<table>
<thead>
<tr>
<th>SALIVA (dry book)</th>
<th>MID-MISSION°</th>
<th>R+30</th>
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<tr>
<td>H H H D D D D D</td>
<td>H H H U U U</td>
<td>H H H</td>
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</table>
Flight Hardware
Cell Distribution

Cell Function

Kinetics of Expression of Activation Antigens on T Cells
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

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)
NEEMO Immune Data: N12, 13, 14 Pilot Study

Haughton-Mars Project
(High Canadian Arctic – Devon Island)
## HMP 2002 Pilot Study

### Map of North America

[Map of North America with Haughton Crater/Devon Island highlighted]

### Sample Collection vs. Field Season Dates

<table>
<thead>
<tr>
<th>SUBJECT</th>
<th>PRE-MISSION</th>
<th>POST-MISSION</th>
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<td>18-Oct-02</td>
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<td>2</td>
<td>10-Jun-02</td>
<td>23-Sep-02</td>
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<tr>
<td>10</td>
<td><em>(---)</em></td>
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</tr>
</tbody>
</table>

*Note: X = subject on Devon Island  
  X = date of blood collection*
Immune system changes during simulated planetary exploration on Devon Island, high arctic

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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 technique for processing immune samples in remote field locations was required. Ten HMP 2002 participants volunteered for this study. A field protocol was developed at NASA-JSC for performing sample collection, blood staining/processing for immunophenotype analysis, whole-blood nitrogen culture for functional assessments and cult-sample preservation on-location at Devon Island. Specific assays included peripheral monocyte 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 stabalized 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.
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
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).

*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.

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.
NASA/ESA Concordia/Antarctic Immune Study

**T Cell Function: A+B**

- CD4/69+
- CD8/69+
- CD4/69/25+
- CD8/69/25+

**Leukocyte Subsets**

- GRAN
- LYMPH
- MONO

**CD8+ Differentiation State**

- CD8+/CD28+
- CD8+/CD28−

**L-60 Baseline**

**Early Deployment**

**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
For more information…
Human Research

Human Health and 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 ever 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 astronauts' 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, muscles, exercise helps keep astronauts healthy in space.

Radiation and Human Space Exploration

http://www.nasa.gov/exploration/humanresearch/
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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<td>[Students: Higher Education]</td>
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<tr>
<td>[Available Nationally]</td>
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<tr>
<td>ACCESS provides summer internships to highly qualified students with disabilities.</td>
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| 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 |
| [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, MO. 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 technology leaders. |
| Find out More |

| Community College Aerospace Scholars |

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