NASA Utilization of the International Space Station and the Vision for Space Exploration

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On January 14, 2004, the focus of NASA research on ISS was fundamentally changed with President Bush’s *Vision for U.S. Space Exploration*

- ISS Focus for NASA before Exploration Vision: Diverse, multi-discipline research
  - Human Life Sciences
  - Biological Sciences
  - Materials Science
  - Fluids Science
  - Combustion Science
  - And all other sciences!
On January 14, 2004, the focus of NASA research on ISS was fundamentally changed with President Bush’s *Vision for U.S. Space Exploration*

- **NEW ISS Focus for NASA**
  - Astronaut health and countermeasure development to protect crews from the space environment during long duration voyages
  - Testing research and technology developments for future exploration missions
  - Developing and validating operational procedures for long-duration space missions
Outline

- Research on Astronaut Health
- Research and Technology Development
- Learn Lessons from ISS Operations
- Life and Physical Sciences in Microgravity

Plans AND Accomplishments
ISS Medical Project
The Challenge

- ISS is the only long-duration microgravity environment for studies of health effects/countermeasures for Mars transit.
- To get reasonable numbers of human subjects, studies must begin NOW—about 1/3 of planned expeditions are complete!
- Most utilization resources are limited during assembly, and with 3 crew through 2009.
Experiments on ISS can address countermeasures & risk reduction.

**SPACE SYSTEM**
- Advanced life support
- Exercise systems
- Clinical capabilities
- Radiation
- Dust

**HUMAN SYSTEM**
- Integrated physiology
- Cardiovascular
- Bone & Muscle
- Neurovestibular
- Food and nutrition
- Immunology & infection
- Human behavior & performance
Distribution of bone loss
- Bone lost: 0.9%/month spine, 1.4%/month in femoral neck (a menopausal woman loses ~1% per year)
- In the hip, trabecular (interior) bone is lost at a rate 2.5%/month, compared to 0.5%/month for cortical (outer) bone
- Risk of fracture on return to Earth higher than estimated from average bone loss

1-Year Postflight:
- Bone has substantially recovered
- However, volumetric cortical bone mass and bone strength only partially recovered; affects risk assessments

Next Steps:
- Upcoming studies of biomarkers for bone resorption, bisphosphonate trials

Sub-Regional Assessment of Bone Loss in the Axial Skeleton in Long-Term Spaceflight, PI: Thomas F. Lang, University of California, San Francisco
Completed—Quantitative Measurement of Forces for Exercise Countermeasures

- **Bone and muscle loss vs. exercise countermeasures**

- **Results:**
  - Preliminary—much less force was experienced than would be experienced when exercising on Earth.
  - Knee-joint motion in space is reduced compared to that on Earth, and this has an effect on muscle action.
  - Detailed data were collected on the loads across all exercise hardware settings during Expeditions 11 and 12.

- **Application to Exercise Operations**
  - Force/bone loss connection for determining “prescriptions”
  - Harness/load devices
  - Resistive exercise vs. aerobic exercise

*Foot/Ground Reaction Forces During Space Flight, PI: Peter Cavanagh, The Cleveland Clinic, Cleveland, OH*
Completed—Interactions

- **Standard mood and interpersonal group climate questionnaires**

- **Results:**
  - No evidence of 3rd quarter or 2nd half effects
  - Displacement of negative feelings from the crew to the ground, and from ground personnel to outside supervisors
  - Differences between Americans and Russians and between crew and ground
  - Salutogenic effects of being in space

- **Application to Operations**
  - Use of measures in upcoming test of crew autonomy
  - Discussion within the operations community about phasing effects and displacement

*Crewmember and Crew-Ground Interaction During International Space Station Missions, PI: Nick A. Kanas, University of California-San Francisco, CA*
Other recent ISS human research results with key applications for Exploration missions

Clinical Medicine and Telemedicine:
Advanced Ultrasound

Renal Stone Prevention

Chromosome investigation and ongoing radiation monitoring
ISS Medical Project

- ISSMP has been developed to maximize the utilization of ISS to obtain solutions to the human health and performance problems and the associated mission risks of exploration class missions.
- Complete programmatic review with medical operations (space medicine/flight surgeons) to identify:
  - Evidence base on risks
  - Gap analysis
- Rapid implementation of key studies to optimize human research return
  - First two of these implemented via fast track during 2006
  - Ongoing process to identify and develop the most critical studies
Now Begun: Nutrition & Physiological Status

- Medical Requirement observations “Clinical Nutrition Assessment” (MR016L)
- Results:
  - Body weight, total bone mineral content, and bone mineral density decreased during flight.
  - Antioxidant capacity decreased during flight, leading to increased susceptibility to genetic damage from radiation.
  - Vitamin D concentration in crew bone was decreased, and bone resorption increased, by long exposure to microgravity.
- New In-flight Study (the most comprehensive to date):
  - Biomarkers for bone loss process
  - Stress hormones
  - Oxidative Stress
  - B-vitamin status
MELFI— -80°C freezer capability on ISS
Analysis of returned foods and drugs from ISS

Results:
- Some pharmaceuticals and vitamins are significantly degraded in space
  - Antibiotics
  - Antihistaminies
  - Vitamin D

New In-flight Study:
- Controlled exposure of food and pharmaceuticals to spaceflight
- Four identical sample kits (containing pharmaceuticals, food, dosimeter and a temperature sensor) will be transported to ISS
- Stored for 0, 6, 12, and 18 months and returned for analysis
- Identical kit in Orbital Environmental Simulator

Stability of Pharmacotherapeutic and Nutritional Compounds, PI: Scott Smith and Lakshmi Putcha, NASA Johnson Space Center
“Slam Shifting” on ISS used to align communications with ground sites for EVA, dockings

Results:
- Crewmembers go through significant shifts in sleep to meet operational requirements—sometimes equivalent to multiple transoceanic flights per month
- Auditory and light environments on ISS can also impact sleep
- Short duration (Shuttle) crewmembers experience significant disruption in sleep patterns that would be expected to produce decrements to performance

New In-flight Study:
- Automatic measurement of sleep patterns
- Automatic measurement of light exposure
- Sleep logging captures subjective elements

Sleep-Wake Actigraphy and Light Exposure During Spaceflight-Long, PI: Charles A. Czeisler, Harvard Medical School
Near Term Human Research on ISS

**Physiology in Microgravity**
- Bone resorption (Nutrition Status Assessment, Bisphosphonates)
- Stress reactivation of viruses (Epstein-Barr, Latent Virus)
- Clinical risks from immune system changes in space, and a flight-compatible immune monitoring strategy (Integrated Immune)
- Cardiovascular (Oxygen uptake assessment, Dysrhythmia, CCISS, Cardiac)

**Physiology in Microgravity: Adaptation to Gravity Changes**
- Mitigate post-flight locomotor dysfunction (Mobility)
- Prevent post-flight orthostatic intolerance (Midodrine)
- Space motion sickness drug uptake study (PMZ)

**Behavior and Performance**
- Evaluate the most important factors for coping with isolation and long duration space flight (Journals)
- Whether sleep-wake cycles are disrupted on long-duration flight as they are during short-duration space flight (Sleep)

All studies at http://exploration.nasa.gov/programs/station
Technology Development
Current Smoke Detectors, adapted from 1 g
- Shuttle: Ionization smoke detectors (<1 micron)
- ISS: Photoelectric smoke detectors (>0.6 microns)
- Orion: upcoming design decision

Dust and Aerosol Feasibility Test (DAFT)—Completed
- Proved the accuracy of COTS dust and particle counters for use in future experiments
- Documented the excellent performance of the ISS HEPA filtration system

Next Step: Smoke and Aerosol Measurement Experiment
- Quantify smoke particulate and aerosol components from on-orbit combustion
- Compare the performance of existing smoke detection systems
- Guide future design decisions

Dust and Aerosol Feasibility Test (DAFT) and Smoke and Aerosol Measurement Experiment (SAME)
PI: David Urban, NASA Glenn Research Center
Completed and Ongoing—Materials Investigations for the Space Environment

- **External Exposure to the space environment**
  - Radiation, atomic oxygen, micrometeoroids, temperature, vacuum
  - Importance for satellites of all types and human spaceflight

- **MISSE 1/2 Spent 4 years exposed**
  - Tested 400 materials
  - Optical changes in thermal control materials
  - Mechanisms of atomic oxygen degradation of multilayer materials

- **MISSE 5**
  - Test performance of advanced generation solar cells with amateur satellite communication
  - Tested 200 materials

- **Next Step: MISSE 3/4 on orbit, and 6A/6B planned 2007**
  - Includes seals for Orion advanced docking and berthing system (with and without removable cover, and with/without a metallic coating)

Materials on the ISS Experiment, PIs: William Kinard, NASA Langley Research Center (MISSE 1/2, 3/4, 6A/6B); Robert Walters, Naval research Laboratory (MISSE-5)
Near Term Technology Research on ISS

Environmental Control
- ANITA (Analyzing Interferometer for Ambient Air)
- eNOSE (Electronic Nose)
- VCAM (Vehicle Cabin Air Monitor)

Fluid Flows
- Capillary Flow Experiment (Vane gap applications to propellant tank design)

Heat Transfer
- Microheater Array Boiling Experiment
- Nucleate Pool Boiling Experiment

Spacecraft Materials & Systems
- Elastic memory composites for hinges (EMCH)
- Rigidized structure assembly (RIGEX)
- Formation flying, guidance, and navigation (SPHERES)
- Picosatellites (STP-H2-MEPSI, ANDE, RAFT)

Microfluidic Analysis
- Lab-on-a-chip Technologies (LOCAD-PTS)

All studies at http://exploration.nasa.gov/programs/station
Lessons Learned from ISS Operations
Environmental monitoring is performed operationally to insure the health of the spacecraft and crew.

**Water system results:**
- 12 bacterial strains cultured, met safe drinking water standards
- Biocide treatments and other preventative measures are working

**Air quality results:**
- HEPA filters are effective in controlling trace contaminants
- Performance and repair of Volatile Organics Analyzer
- Lessons learned from regeneration of Metox cannisters—disruption of airflows and temporary formaldehyde accumulations

**Just begun: SWAB investigation**
- 90% of microbes cannot be cultured
- *Legionella, Cryptosporidium*, dust mites, endotoxins
- Modern genetic approaches to follow changes in microbial communities on ISS
- Surfaces, Air, Water
Life and Physical Sciences in Microgravity:
Examples Completed and Ongoing

Root Phototropism (*Tropi*)

*InSpace*(Magnetorheological Fluids)

Binary Colloidal Alloy Models of Critical Point Behavior (*BCAT-3*)
1. Complete assembly of the ISS
2. Develop Orion (Crew Exploration Vehicle)
3. Utilize ISS
Summary:
NASA ISS Research

- Recognize that, in the near term, completion of ISS limits the amount of research that can be completed (budget, upmass, crewtime)
  - Shuttle retirement in 2010
  - Preparation for 6-person crew by 2009
- Continue, with limited budget, to conduct high priority ISS research that
  - Supports the Exploration Vision
  - Takes maximum advantage of facilities/opportunities provided by ISS
- Partner researchers in international teams to investigate areas of mutual interest
- Focus on ISS utilization once assembly is complete
  - Expect significant (two- to three-fold) increase in U.S. crewtime for research with 6-person crew
ISS & CEV
Lunar Sortie
Lunar Outpost
Humans to Mars
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