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

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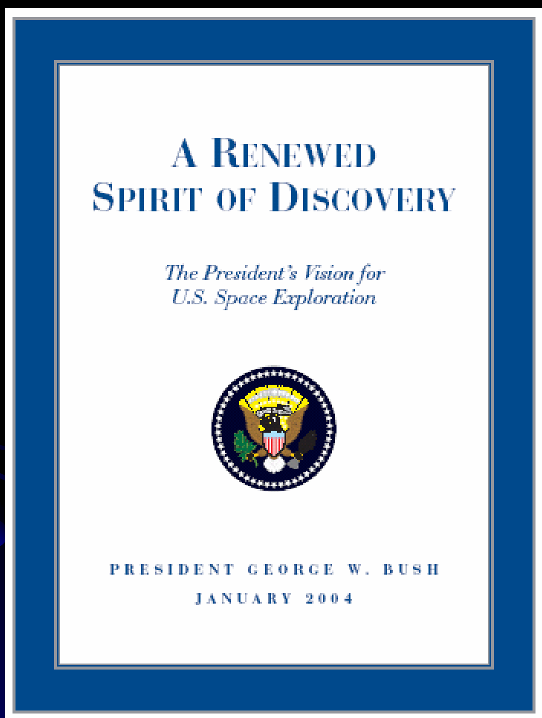
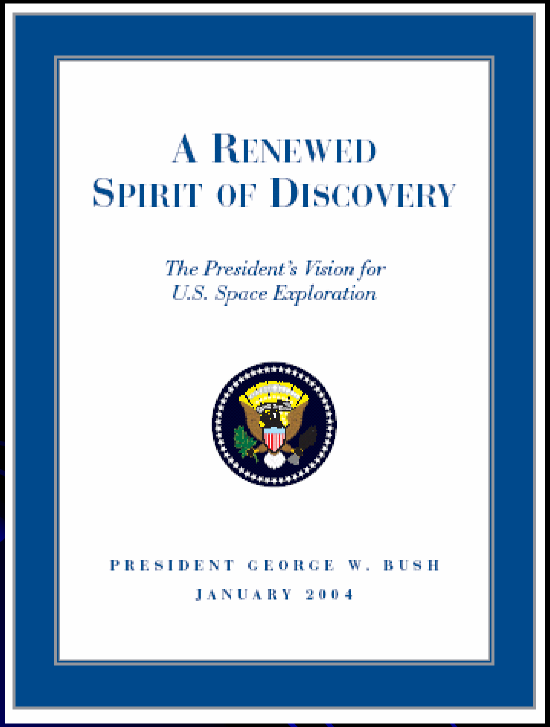
The Vision for Space Exploration



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!

The Vision for Space Exploration


A RENEWED SPIRIT OF DISCOVERY

The President's Vision for U.S. Space Exploration

PRESIDENT GEORGE W. BUSH

JANUARY 2004

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

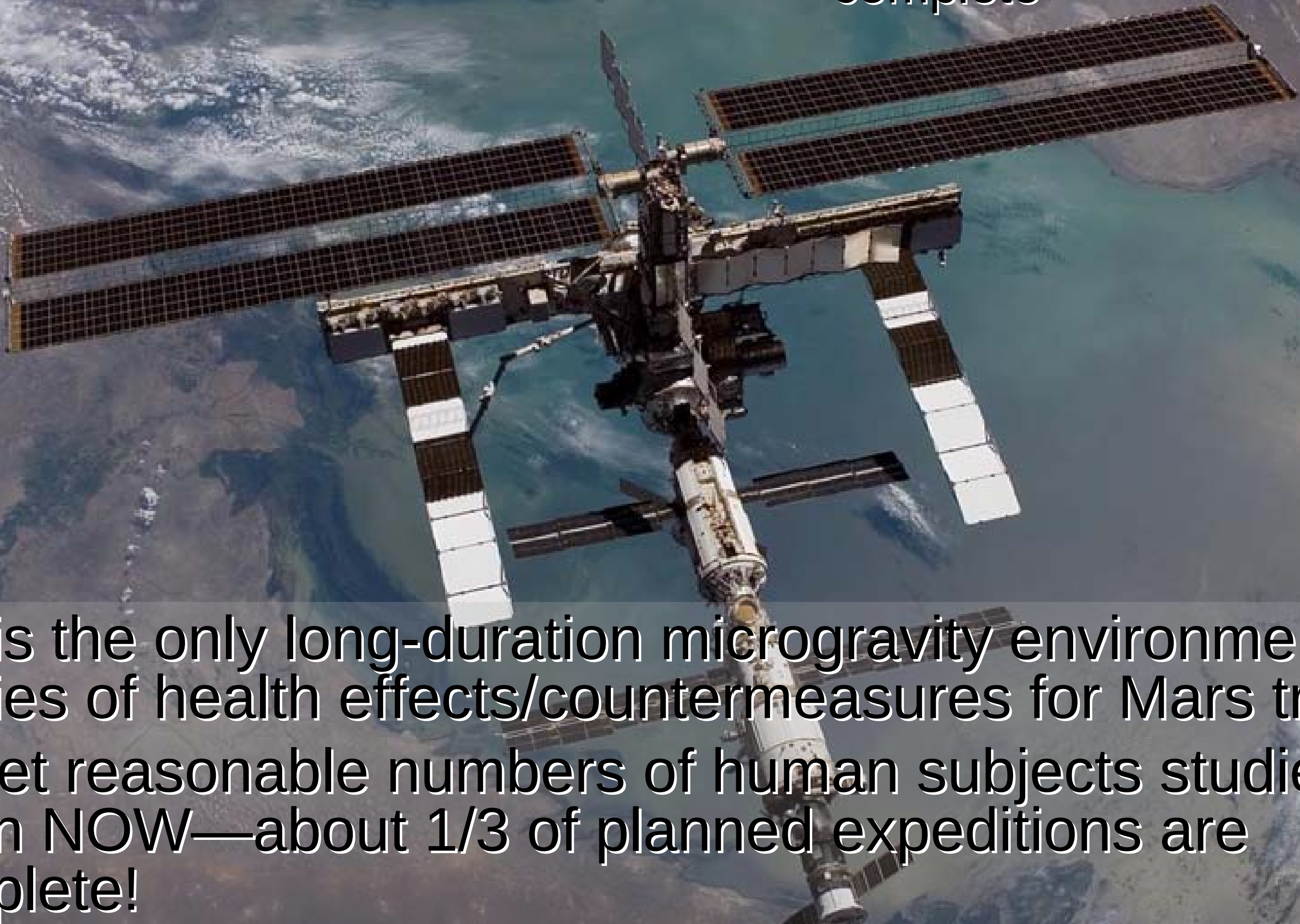
- Research on Astronaut Health
- Research and Technology Development
- Learn Lessons from ISS Operations
- Life and Physical Sciences in Microgravity

Plans AND Accomplishments

ISS Medical Project

The Challenge

2000	2006	2009	2011	2016
ISS crewed	Today	6-crew	Assembly complete	U.S. Research horizon



- 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

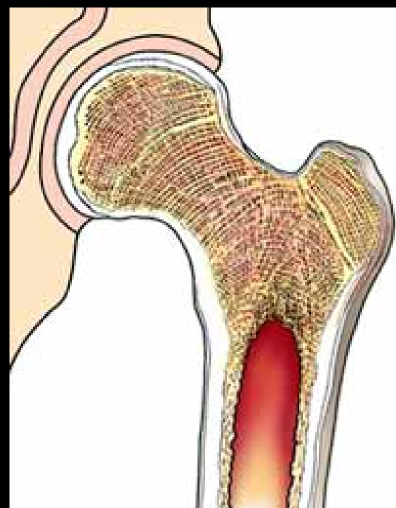
HUMAN SYSTEM

- Integrated physiology
- Cardiovascular
- Bone & Muscle
- Neurovestibular
- Food and nutrition
- Immunology & infection
- Human behavior & performance

Completed—Distribution of Loss and Recovery of Bone in Microgravity

Normal bone

Osteoporitic bone



Images: MRC Research Updates

Sub-Regional Assessment of Bone Loss in the Axial Skeleton in Long-Term Spaceflight , PI: Thomas F. Lang, University of California, San Francisco

- **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, bisphosphinate trials

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

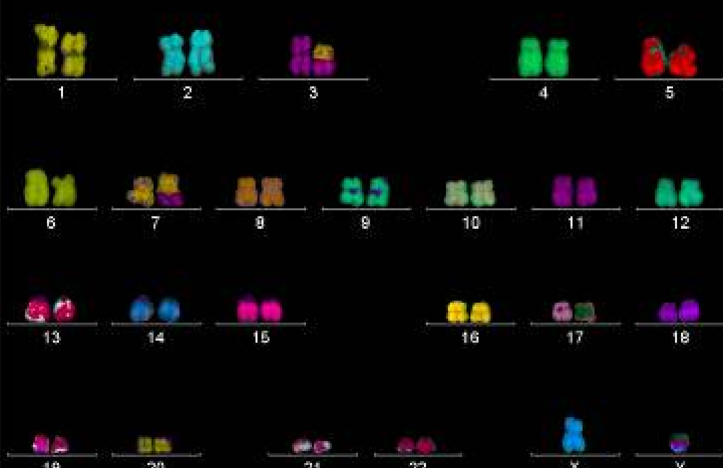
Foot/Ground Reaction Forces During Space Flight , PI: Peter Cavanagh, The Cleveland Clinic, Cleveland, OH

Completed–Interactions

Crewmember and Crew-Ground Interaction During International Space Station Missions , PI: Nick A. Kanas, University of California-San Francisco, CA

- **Standard mood and interpersonal group climate questionnaires**
- **Results:**
  - No evidence of 3^{rd} quarter or 2^{nd} 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

Other recent ISS human research results with key applications for Exploration missions



Chromosome investigation and ongoing radiation monitoring

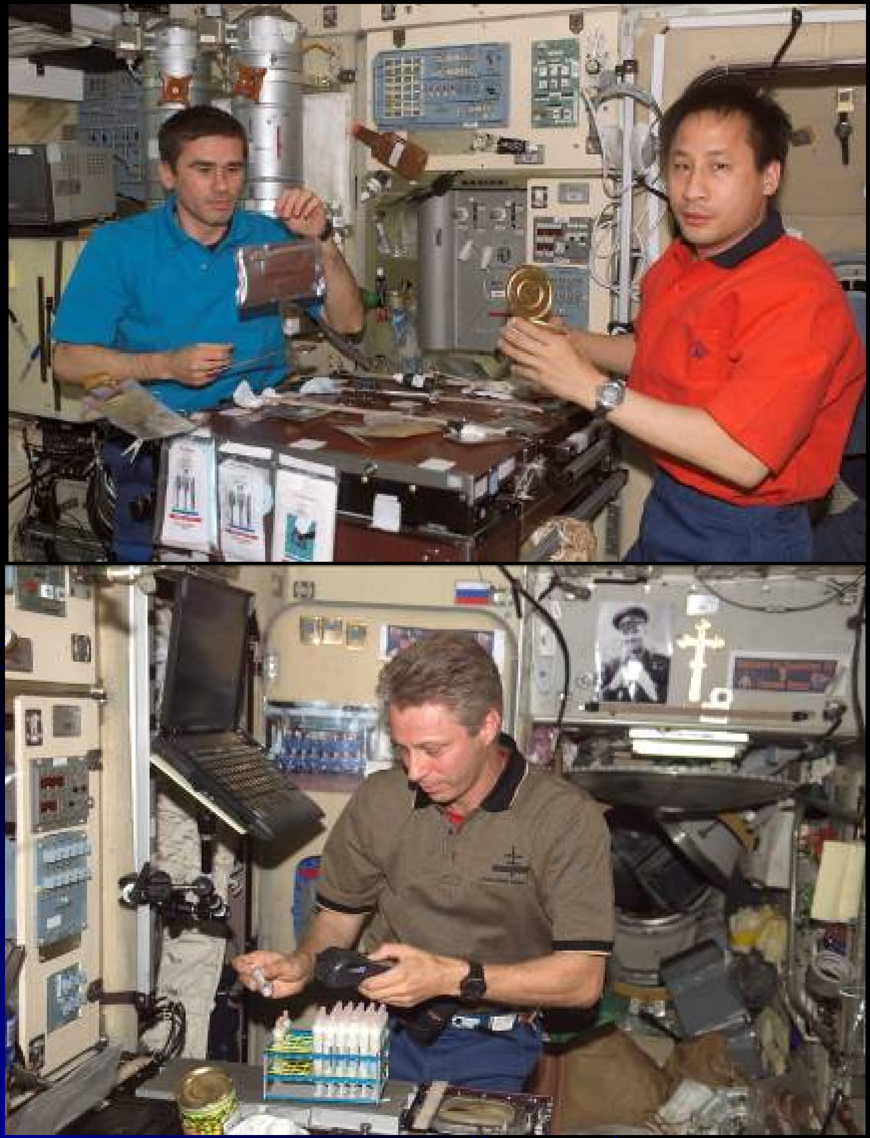
Clinical Medicine and Telemedicine: *Advanced Ultrasound*

Renal Stone Prevention

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



Nutrition Status Assessment, PI: Scott Smith, NASA Johnson Space Center

- **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

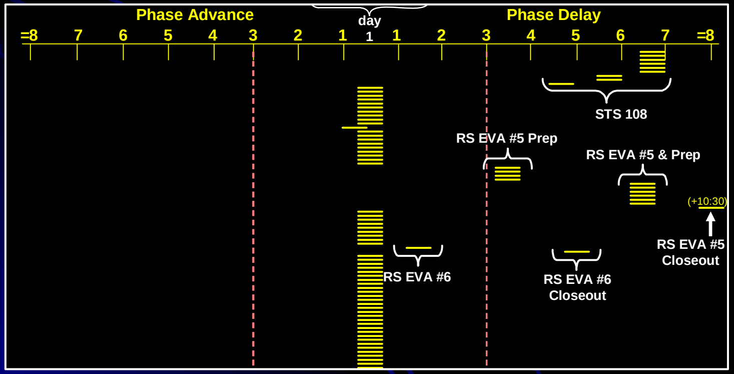
MELFI— -80°C freezer capability on ISS

In progress:
Vitamin and Drug Stability

- **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

Now Begun: Sleep-Wake Actigraphy



Sleep-Wake Actigraphy and Light Exposure During Spaceflight-Long , PI: Charles A. Czeisler, Harvard Medical School

- **"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

Near Term Human Research on ISS

Physiology in Microgravity

- Bone resorption (Nutrition Status Assessment, Bisphosphenates)
- 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

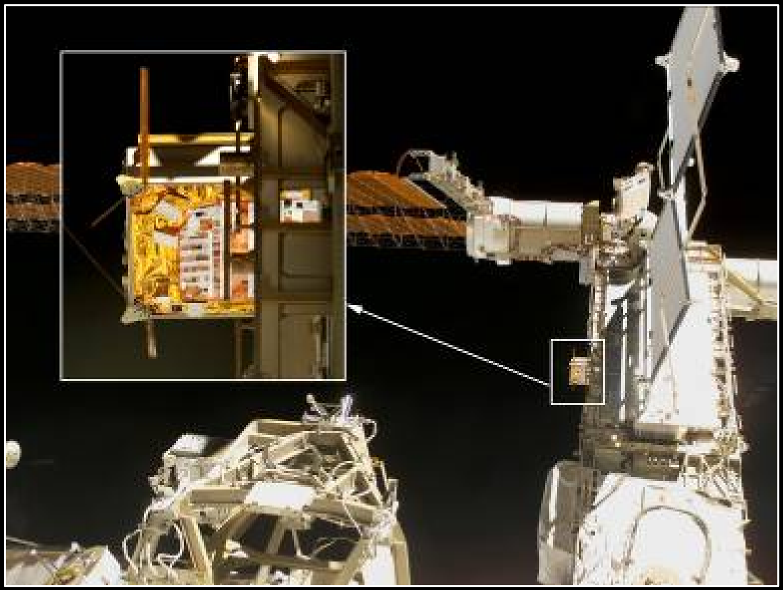
Technology Development

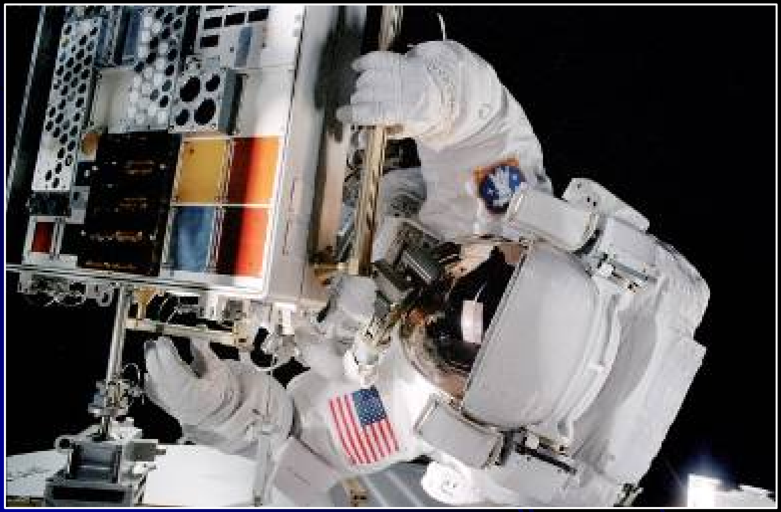
Completed and Forthcoming—Smoke Detection and Aerosol Measurement

- **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

Example—Environmental Monitoring

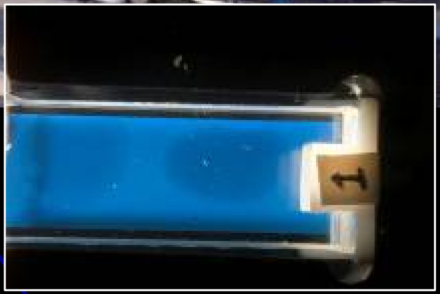
- **Environmental monitoring is performed operationally to insure the health of the spacecraft and crew**
- **Water system results:**
  - 12 bacterial strains cultured, met safe drinking water standards
  - Biocide treatments and other preventative measures are working
- **Air quality results:**
  - 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

Surface, Water and Air Biocharacterization - A Comprehensive Characterization of Microorganisms and Allergens in Spacecraft Environment , PI: Duane L. Pierson, NASA Johnson Space Center

Microgravity

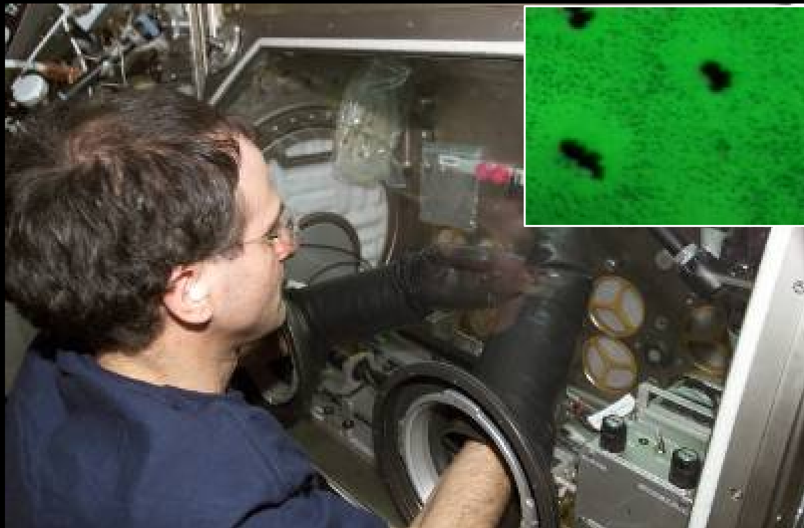
Life and Physical Sciences in Microgravity:
Examples Completed and Ongoing

Root Phototropism *(Tropi)*



Binary Colloidal Alloy Models of Critical Point Behavior (*BCAT-3*)

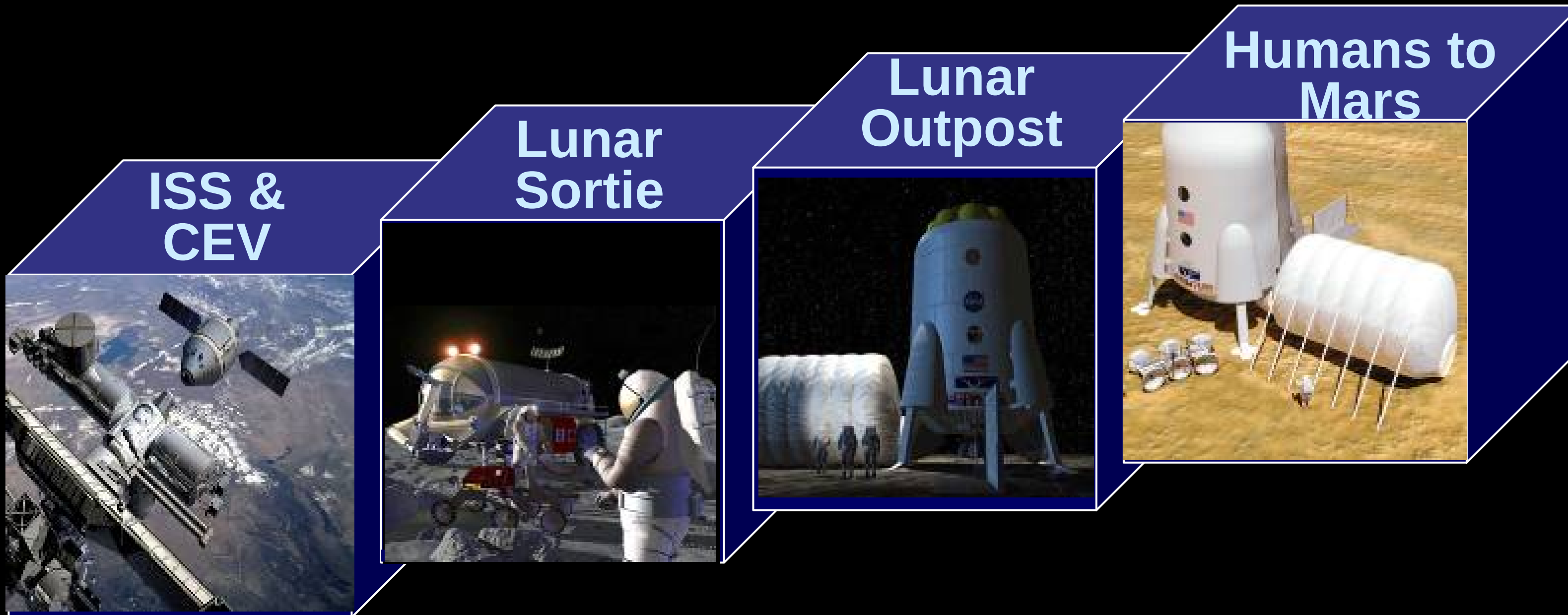
InSpace
*(*Magnetorheological Fluids*)*



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