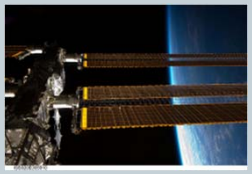
RECAPTURING A FUTURE FOR SPACE EXPLORATION: LIFE AND PHYSICAL SCIENCES RESEARCH FOR A NEW ERA



WHAT ARE THE KEY SCIENTIFIC CHALLENGES THAT LIFE AND PHYSICAL SCIENCES RESEARCH IN SPACE CAN AND MUST ADDRESS?

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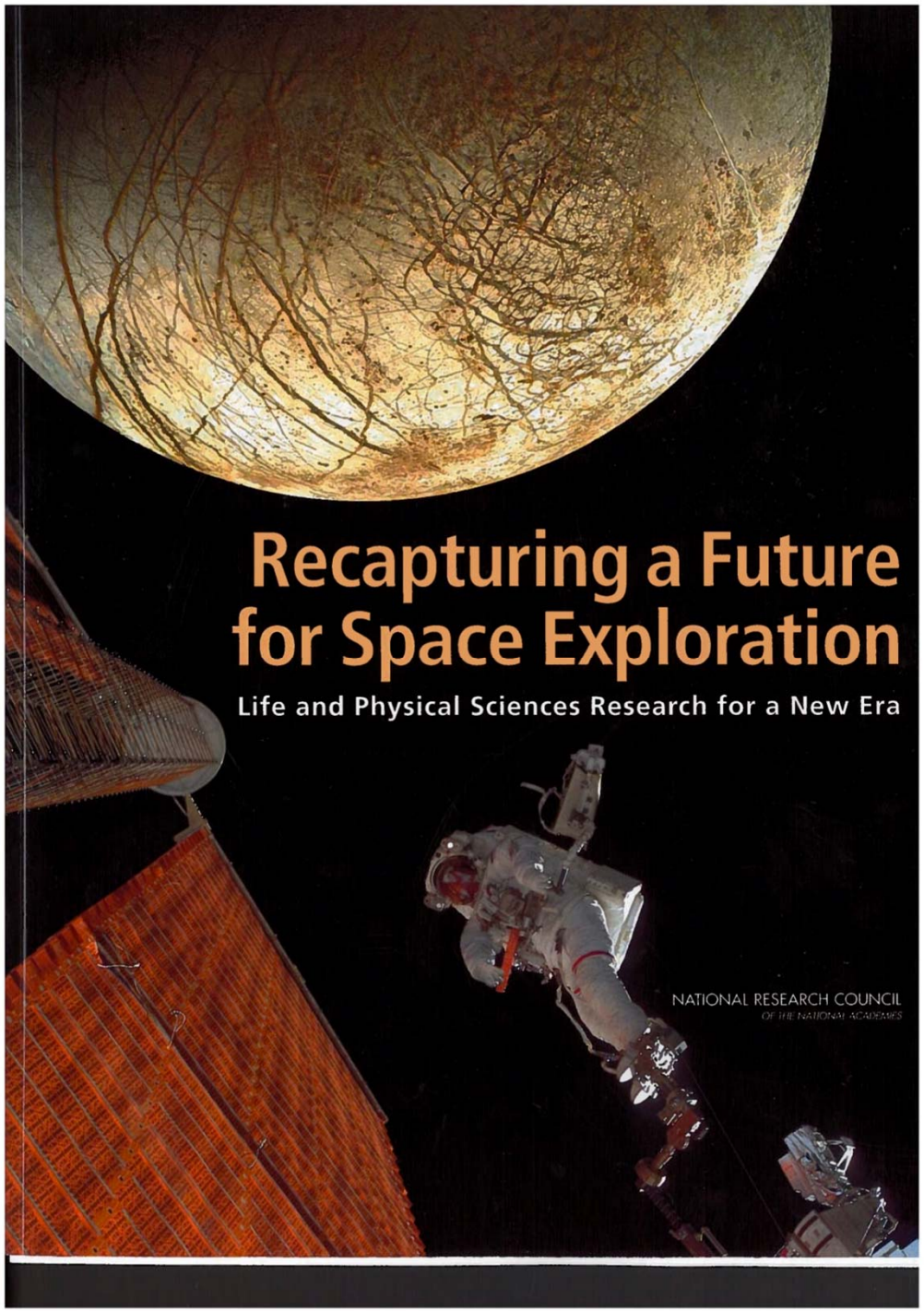
DECADAL SURVEY ON BIOLOGICAL AND PHYSICAL SCIENCES IN SPACE
NATIONAL ACADEMY OF SCIENCES

ISS SYMPOSIUM 2012
BERLIN, GERMANY

The Dec hysical

- NASA often en Research Council (NRC).
  - Decadal survey ce, heliophysics, and Earth science
- This Decadal S 9
- Community in had turned away
  - Received app
  - Meetings wit
- A major challe s in the face of change and ur

Issues:
- ✓**No clear national p**
- ✓**Organizing scientifi**
- ✓**Integrating life and**
- ✓**Enhancing the tran**



The Tasks for this Decadal Survey

- NASA asked the National Academy of Sciences to define research areas that:

Enable exploration missions

Are enabled by exploration missions

Define and prioritize an integrated life and physical sciences research portfolio and associated objectives;

Develop a timeline for the next decade for these research objectives and identify dependencies between the objectives;

Explain how the objectives could enable exploration activities, produce knowledge, or provide benefits to space and other applications;

Identify terrestrial, airborne, and space-based platforms and facilities that could most effectively achieve the objectives;

Identify potential research synergies between NASA and other US government agencies, as well as with commercial entities and international partners;

Identify potential research objectives beyond 2020.

Decadal Study Panels

Steering Committee

Life Sciences

- Animal & Human Biology
- Plant & Microbial Biology
- Human & Behavioral Health

Translation

- Integrative & Translational Research for the Human System
- Translation to Space Exploration Systems

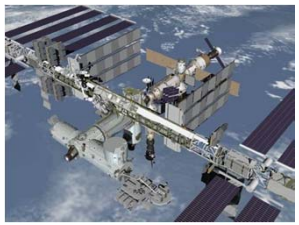
Physical Sciences

- Fundamental Physical Sciences
- Applied Physical Sciences

http://www7.nationalacademies.org/ssb/microgravdecadal.html

Translational Research

- The flow of information between basic science and complex applications has been difficult.
- We focus on the National Institutes of Health approach:
  - Develop broad processes for *translational research* to try and remove these obstacles
    - Facilitate and expedite the practical application of scientific discoveries
  - Translating knowledge from laboratory discoveries to operational conditions is challenging:
    - Horizontal integration requires multi- and trans-disciplinary approaches to complex problems;
    - Vertical translation requires meaningful interactions among basic, preclinical, and/or applied scientists to translate fundamental discoveries into improvements in the health of crew members or the functioning of complex systems in space
  - Strong emphasis placed on the need for effective coupling of biological, physical and engineering problem-solving strategies.



Research Infrastructure

- Research Infrastructure
  - ISS is vital to answering many of the most important research questions detailed in the decadal survey.
    - But ISS is only one component of a robust program. Other platforms and elements of research infrastructure will be important, including those that are ground based.
  - Flight research part of a continuum of efforts:
    - Laboratories and analog environments on the ground,
    - Through other low-gravity platforms such as drop towers and aircraft
    - Through free-flyers and unattended platforms as needed and available
    - Eventually into extended-duration flight
  - Like any process of scientific discovery this effort is iterative, and further cycles of integrated ground-based and flight research are likely to be warranted as understanding of the system under study evolves.

Critical Needs for the Successful Renewal of Life & Physical Sciences Research

Elevate the priority of life & physical sciences in space exploration

Establish a stable &sufficient funding base

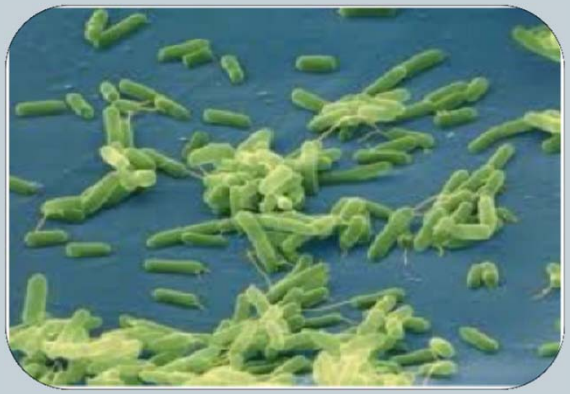
Improve the process for solicitation & review of high quality research

Rejuvenate the educational pipeline

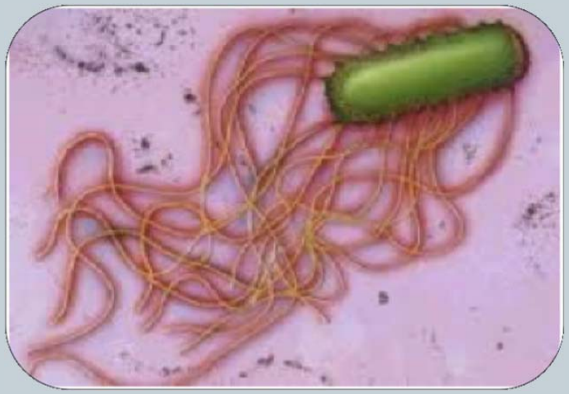
Link science to mission through multidisciplinary translational programs

Develop commercial sector interactions to enhance science

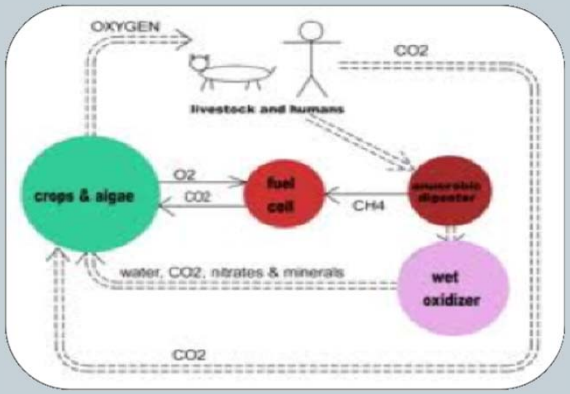
Plant & Microbial Biology



Establish a “microbial observatory” program on the ISS

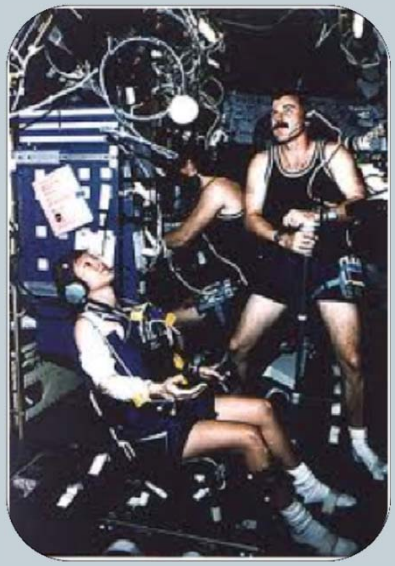


Establish a program to analyze plant and microbial growth and physiological responses to the spaceflight environments



Demonstrate the roles of microbial-plant systems in long-term life support systems

Behavior & Mental Health



Develop measures of mission-relevant performance for both astronauts and ground crew

In simulated long duration missions, study the interrelationship between individual functioning, cognitive performance, sleep and group dynamics

Determine the genetic, physiological and psychological underpinnings of individual differences in resilience to stressors

Research on performance, and effectiveness of multinational crews

Animal & Human Biology

Bone

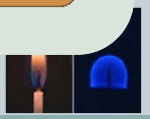
- Test the efficacy of bisphosphonates on the ISS during a 6- month mission
- The preservation/reversibility of bone structure/strength should be evaluated when assessing countermeasures.
- Bone loss studies of genetically altered mice exposed to weightlessness
- Test new osteoporosis drugs in animal models of weightlessness.
- Studies on underlying mechanisms regulating net skeletal muscle protein balance and turnover.

Muscle

- Determine the daily levels and pattern of recruitment of flexor and extensor muscles of the neck, trunk, arms and legs at 1 g and after being in a novel gravitational environment for up to 6 months.
- Studies should be done to develop and test new prototype exercise devises, and to optimize physical activity paradigms/prescriptions targeting multi-system countermeasures.

Vascular

- Determine the integrative mechanisms of orthostatic intolerance after restoration of gravitational gradients (both 1 g and 3/8 g).
- Collaborative studies among flight medicine and cardiovascular epidemiologists to determine strategies to avoid flying astronauts with subclinical coronary heart disease that could have impact during a 3 year mission
- Determine the basic mechanisms, adaptations, and clinical significance of changes in regional vascular/interstitial pressures (Starling forces) during long duration space missions.



Animal & Human Biology

Immune System

Multiple parameters of T cell activation in cells should be obtained from astronauts before and after re-entry to establish which parameters are altered during flight.

To both address the mechanism(s) of the changes in the immune system and to develop measures to limit the changes, data from multiple "organ/system-based" studies need to be integrated.

Perform mouse studies, on the ISS to establish the biological relevance of the changes observed in the immune system. Parameters need to be aligned with those influenced by flight in humans.

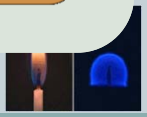
Animal Models

Studies should be conducted on transmission across generations of structural and functional changes induced by exposure to space during development. Ground-based studies should be conducted to develop specialized habitats to support reproducing and developing rodents in space.

Other

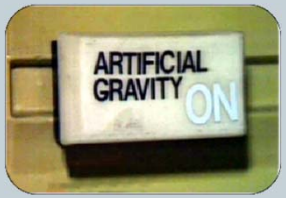
Investigate the effect of prolonged periods of microgravity and partial (3/8 or 1/6 G) gravity on the determinants of task specific, enabling levels of work capacity.

Determine the amount and site of the deposition of aerosols of different sizes in the lungs of humans and animals in microgravity.

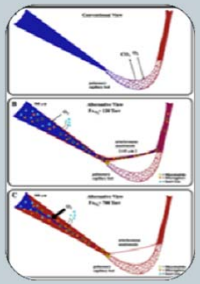


Cross-Cutting Issues for Humans in the Space Environment

Quantify post-landing vertigo and orthostatic intolerance.



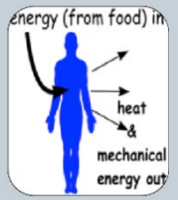
Determine whether artificial gravity is needed as a multi-system countermeasure.



Studies on whether there is an effect of gravity on micronucleation and/or intrapulmonary shunting.

Optimizing dietary strategies for crews and food preservation strategies.

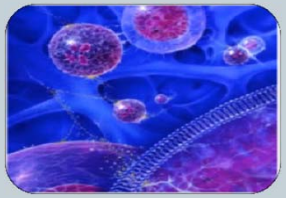
Initiate a robust food science program focused on preserving nutrient stability for three or more years.



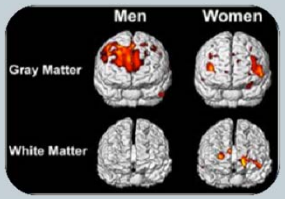
Include food and energy intake as an outcome variable in intervention in studies in humans.

Studies of astronauts for cataract incidence exposures.

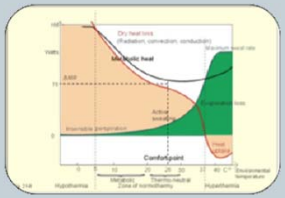
Animal studies to assess radiation risks from cancer, cataracts, cardiovascular disease, and others.



Cellular ground-based studies to develop endpoints and markers that can be used to define acute and late radiation toxicities.

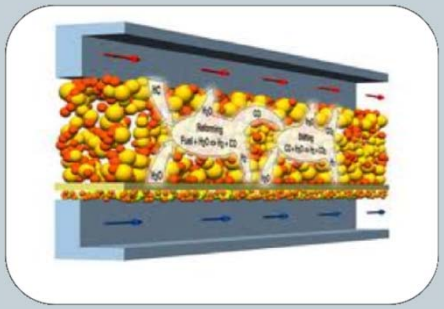


Expand our understanding of gender differences in adaptation to the spaceflight environment.

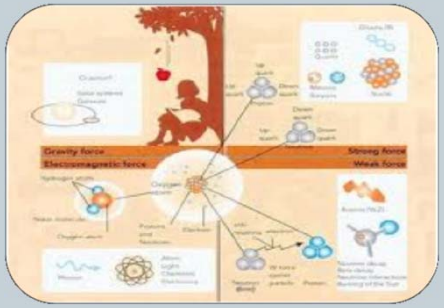


Investigate the biophysical principles of thermal balance.

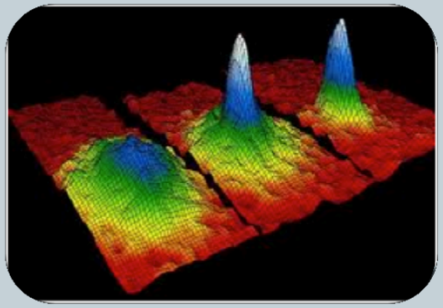
Fundamental Physical Sciences



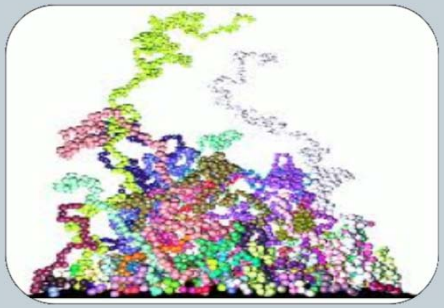
Research on complex fluids and soft matter.



Understanding of the fundamental forces and symmetries of Nature.

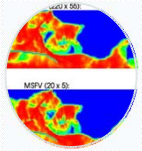


Research related to the physics and applications of quantum gases.



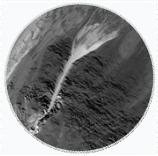
Investigations of matter near a critical phase transition.

Applied Physical Sciences in Space



Reduced-gravity multiphase flows

Interfacial flows and phenomena.



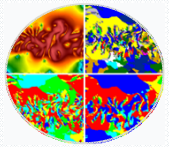
Dynamic granular material behavior.

Fundamentals-based strategies for dust mitigation.

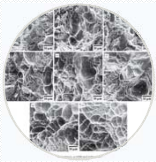
Complex fluid physics in a zero-gravity environment

Fire safety research.

Combustion processes research.



Numerical simulation of combustion research.

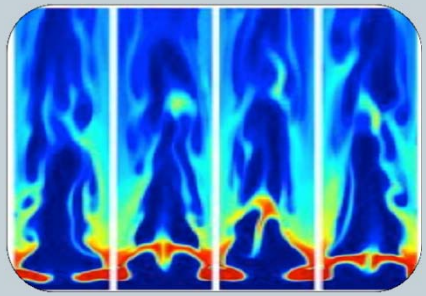


Materials synthesis and processing and control of microstructure

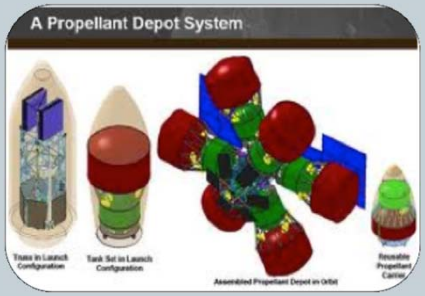
Develop advanced materials with new property requirements.

Technologies for extraction, and processing of minerals, metals, and other materials.

Translation to Space Exploration Systems



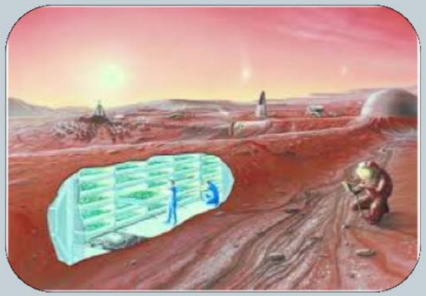
Research to address active two-phase flow questions for to thermal management.



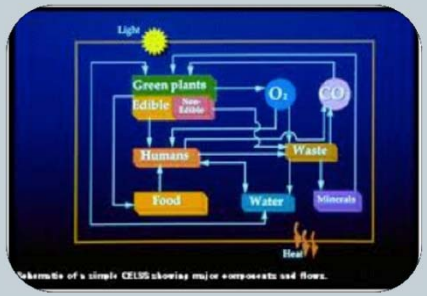
Research in support of zero-boiloff propellant storage and cryogenic fluid management.

Research to enhance surface mobility.

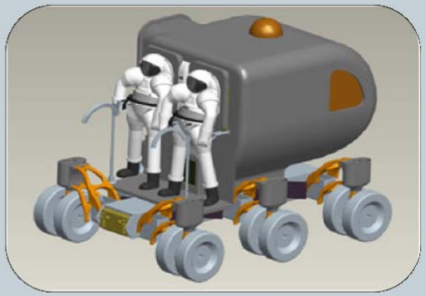
Develop and demonstrate technologies to mitigate the effects of dust on EVA systems and suits, life support systems, and surface construction systems.



Define requirements for thermal control, micrometeoroid and orbital debris impact and protection, and radiation protection for all systems & shelters.

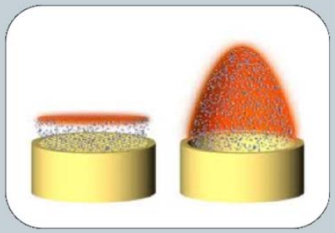


Conduct research for the development and demonstration of closed-loop life support systems and supporting technologies.



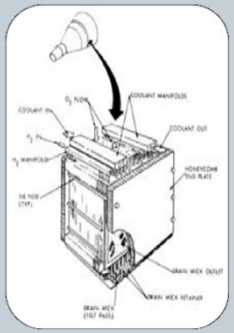
Develop and demonstrate technologies to support thermoregulation of habitats, rovers, and spacesuits on the lunar surface.

Translation to Space Exploration Systems

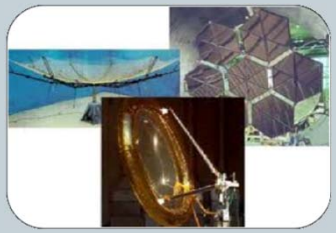


Fire safety research to develop new standards.

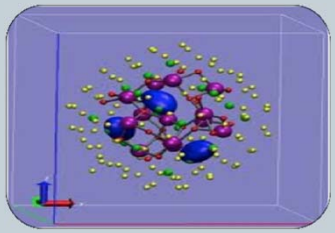
Understand fire suppression and post-fire recovery strategies.



Demonstrate regenerative fuel-cell technologies in reduced gravity



New energy conversion technologies.



High-temperature, low-weight materials to enable fission surface power systems.

Ascent and descent system technologies.

Develop and demonstrate of space nuclear propulsion systems.

Excavation, extraction, preparation, handling, and processing techniques for a lunar water/oxygen extraction system.

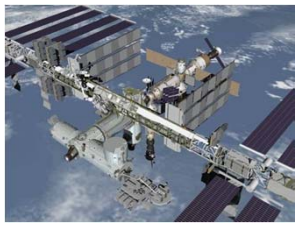
Establish plans for ISRU capability development and surface habitats.

The Role of the ISS

The platforms and facilities required for each research area are varied

For the majority of investigations, ISS will provide the most advantageous research platform once the investigations transition to flight. In many cases, ISS will be the *only* platform capable of meeting the requirements of the investigation and ISS is the only platform that can provide very long duration of microgravity.

- Life Sciences
  - Comprehensive program dedicated to analyzing microbial populations and responses to spaceflight
  - Understand how and why human physiology is altered in space
  - Carry out both the fundamental and translational research on organ and systemic function in the absence of the gravity variable
  - Probing of fundamental questions about animal biology not directly related to human health, such as the role of gravity in developmental biology
  - Use as a test bed to facilitate studies on plant and microbial components of a biogenerative life support system
- Physical Sciences
  - Fundamental physics studies with long durations of low gravity:
    - Understanding soft matter and complex fluids
    - Precision measurements of fundamental forces and symmetries
  - Multi-phase flows & pool boiling experiments
  - Performance studies of power generation and energy storage systems
  - Combustion processes



ISS as Translational Platform

Human Systems

- Multi-system countermeasures
- Dietary strategies
- Radiation risks
- Thermal balance

Exploration Systems

- Active two-phase flow
- Closed-loop life support
- Fire safety
- Regenerative fuel cells
- Thermal regulation

What is Happening?

- ISS National Lab management contract
  - CASIS will develop and manage a diversified research and development portfolio based on U.S. national needs for basic and applied research
- NASA Office of the Chief Technologist roadmaps
  - http://www.nasa.gov/pdf/501627main_TASR-TABS_Foldouts-A.pdf
- Human Exploration and Operations Directorate
  - Space Life & Physical Sciences Research & Applications
    - HRP, CHS, Fundamental Space Biology, Physical Sciences, ISS National Lab Management
  - Reports to the NASA Chief Scientist in a “dotted line” sense

Thoughts for the International Community

Broader data sharing needed to make translation to missions more effective

Common roadmaps to optimize R&D expenditures

Joint discussions on speeding basic research results to mission applications with collaborations in the use of R&D infrastructure

Thank You