LIFE & PHYSICAL SCIENCES IN MICROGRAVITY & PARTIAL GRAVITY ENVIRONMENTS

DISCUSSION FOR THE AUGUSTINE COMMITTEE

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THE DECADAL STUDY FOR LIFE & PHYSICAL SCIENCES RESEARCH IN MICROGRAVITY AND PARTIAL GRAVITY ENVIRONMENTS

Per the Explanatory Statement accompanying the FY 2008 Omnibus Appropriations Act (P.L. 110-161) NASA was directed to initiate a decadal survey in life and physical sciences:

- “Achieving the goals of the Exploration Initiative will require a greater understanding of life and physical sciences phenomena in microgravity as well as in the partial gravity environments of the Moon and Mars. Therefore, the Administrator is directed to enter into an arrangement with the National Research Council to conduct a “decadal survey” of life and physical sciences research in microgravity and partial gravity to establish priorities for research for the 2010-2020 decade.”

To that end, 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; and
  - Identify potential research objectives beyond 2020.
Panels for this Decadal Study

Life Sciences
- Animal & Human Biology
- Plant & Microbial Biology
- Human Behavior & Mental Health

Translation
- Integrative & Translational Research on the Human System
- Translation Science for Exploration Systems

Physical Sciences
- Fundamental Physical Sciences
- Applied Physical Sciences
SCIENCE ENABLED BY SPACE EXPLORATION ENVIRONMENTS

Cellular, molecular and developmental biology

- Understanding how life at molecular and cellular levels responds to physical forces – e.g. cellular mechanotransduction
- Fundamental studies of organisms with gravitationally effected behaviors – e.g. gravitropism, morphological behaviors - throughout their lives
- Interactions between organisms in unique environments
- Life across generations, especially as it relates to space exploration

Fundamental physics, complex physical interactions

- Tests of general relativity
- Ultra-precise measurement of fundamental constants
- Investigation of fluid science such as phase transitions broadened by gravity when performed on Earth
- Studies of soft matter
- Reactive chemistry in systems where convection dominates or masks underlying dynamics
EXPLORATIONS NEEDS, REQUIREMENTS & PHENOMENA THAT CAN MOTIVATE RESEARCH

The Human System

- Risk Reduction Needs
  - Space Radiation
  - Human Health Countermeasures
  - Exploration Medical Capability
  - Space Human Factors & Habitability
  - Behavioral Health & Performance

- Human Requirements
  - Crews must live & work safely
  - Medical standards
  - Validated countermeasures
  - Health management
  - Human factors
  - Environmental health
  - Food technology
  - Tools and strategies that mitigate behavioral & performance risks

Exploration Systems

- System Function Needs
  - Power Generation & Storage
  - Space Propulsion
  - Life Support
  - Hazard Control
  - Material Production & Storage
  - Construction & Maintenance

- Gravity-Dependent Phenomena
  - Interfacial phenomena
  - Multiphase Flow
  - Heat transfer
  - Solidification
  - Chemical Transformation
  - Behavior of Granular Materials
EXPLORATION CHALLENGES THAT SCIENCE CAN ADDRESS

- Cryogenic Fluid & Thermal Management
  - Mixing of Cryogenic Fluids
  - Partial Gravity
  - Multiphase Flows
  - Heat Transfer
  - Materials Development

- Surface Mobility & Extravehicular Activity
  - Anthropometry & Ergonomics
  - Radiation Monitoring & Protection
  - Toxicity of Atmospheric Contaminants
  - Biological Life Support
  - High Performance Materials
  - Materials Processing & Recycling
  - Spacecraft Fire Safety

- Life Support & Habitation
  - Behavioural Health
  - Anthropometry & Ergonomics
  - Radiation Protection
  - Toxicity of Atmospheric Contaminants
  - Biological Life Support
  - High Performance Materials
  - Materials Processing & Recycling
  - Multiphase Flows
  - Spacecraft Fire Safety

- In-Situ Resource Utilization
  - Sharp-edged granular media
  - Multiphase Flows
  - Mixing of Cryogenic Fluids
  - Heat Transfer
  - Chemical Reduction Processes
  - Processing Materials in Low & Partial Gravity

- Maintaining Human Health
  - Human Physiology
  - Medical Capability
  - Microbiology
  - Radiation
  - Behavior & Performance
  - Habitation & Environment
  - Lunar Dust

- Enabling Scientific Discovery
  - Chemical Processes
  - Fluid Flow
  - Granular Media
  - Heat Transfer
  - High Performance Materials
  - Preserving Biological Samples
  - Survival of Microbes in extreme Environments
  - Human Factors
## LINKS WITH TERRESTRIAL CHALLENGES

<table>
<thead>
<tr>
<th>Exploration Challenge</th>
<th>Terrestrial Need</th>
<th>Common Scientific Element(s)</th>
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<tbody>
<tr>
<td>Mass reduction for aerospace power systems</td>
<td>Efficient and renewable energy systems</td>
<td>Multiband gap photonics, materials for energy storage, thermal management for micro-devices</td>
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<tr>
<td>Radiation protection</td>
<td>Effects of medical proton therapies</td>
<td>Studies of proton exposures, models developed from these studies to understand exposure effects</td>
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<tr>
<td>Recycling and disinfection of water to reduce weight, maintain human health</td>
<td>Recycling, reuse and disinfection of water to optimize cost and availability of increasingly scarce resource</td>
<td>Materials development for low cost, low power, low maintenance water processing technologies</td>
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<tr>
<td>Spacecraft fire safety</td>
<td>Building fire safety</td>
<td>New materials, sensing modalities and models to detect, prevent and mitigate fires</td>
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<td>Muscle de-conditioning</td>
<td>Diseases and conditions in which musculoskeletal disabilities such as extremity dysfunction or other forms of immobility are present</td>
<td>Studies aimed at elucidating the plasticity of the musculoskeletal system and how it maintains homeostasis</td>
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THE VALUE OF ACCESS TO SPACE PLATFORMS

- Microgravity and partial gravity research utilizes a wide range of laboratory capabilities. For many types of studies, timely, repeatable access to these environments for time scales relevant to those of human exploration missions is essential.

<table>
<thead>
<tr>
<th>Platform</th>
<th>Low or Micro G Time</th>
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<tbody>
<tr>
<td>Ground Facilities</td>
<td>10-30 sec</td>
</tr>
<tr>
<td>Sounding Rockets</td>
<td>5-7 min</td>
</tr>
<tr>
<td>Space Shuttle</td>
<td>10-20 days</td>
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<tr>
<td>Free Flyers</td>
<td>weeks-months</td>
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<tr>
<td>ISS</td>
<td>continuous</td>
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<tr>
<td>Planetary Laboratories</td>
<td>continuous</td>
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Science and Human Exploration

Science objectives that will enable NASA’s Human Space Flight program?
- Greater understanding of life and physical sciences phenomena in microgravity as well as in the partial gravity environments of the Moon and Mars
  - Risk reduction for the human system
  - Function enhancement (or creation) for exploration systems

Science enabled by NASA’s Human Space Flight program?
- Cellular, molecular and developmental biology
- Fundamental physics, complex physical interactions

How, and in what areas, can science enable exploration?
- Life support & habitation
- Cryogenic fluid & thermal management
- Surface mobility & extravehicular activity
- Maintenance of human health
- In-situ resource utilization
- Tools for discovery science in exploration environments
BACKUP

Key National Academy studies for reference

- Microgravity Research in Support of Technologies for the Human Exploration and Development of Space and Planetary Bodies, 2000
- Safe Passage: Astronaut Care for Exploration Missions, 2001
- Managing Radiation Risk in the New Era of Space Exploration, 2008