Biological Technologies for Life Beyond Low Earth Orbit (BT4LBLEO)

Study Introduction and Synops

ASGSB 2011

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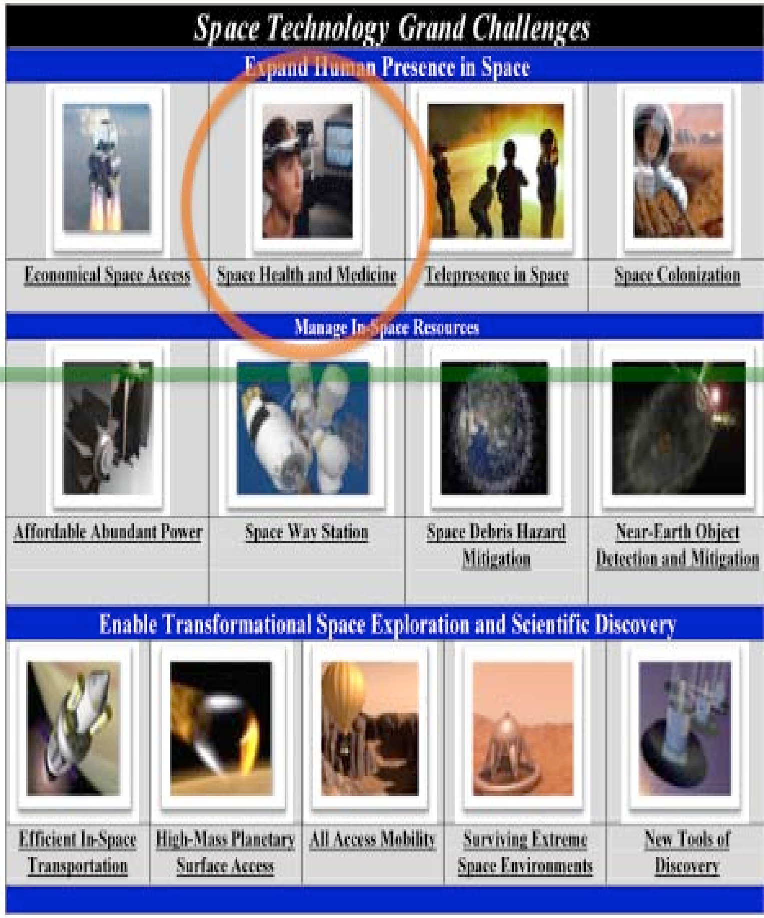
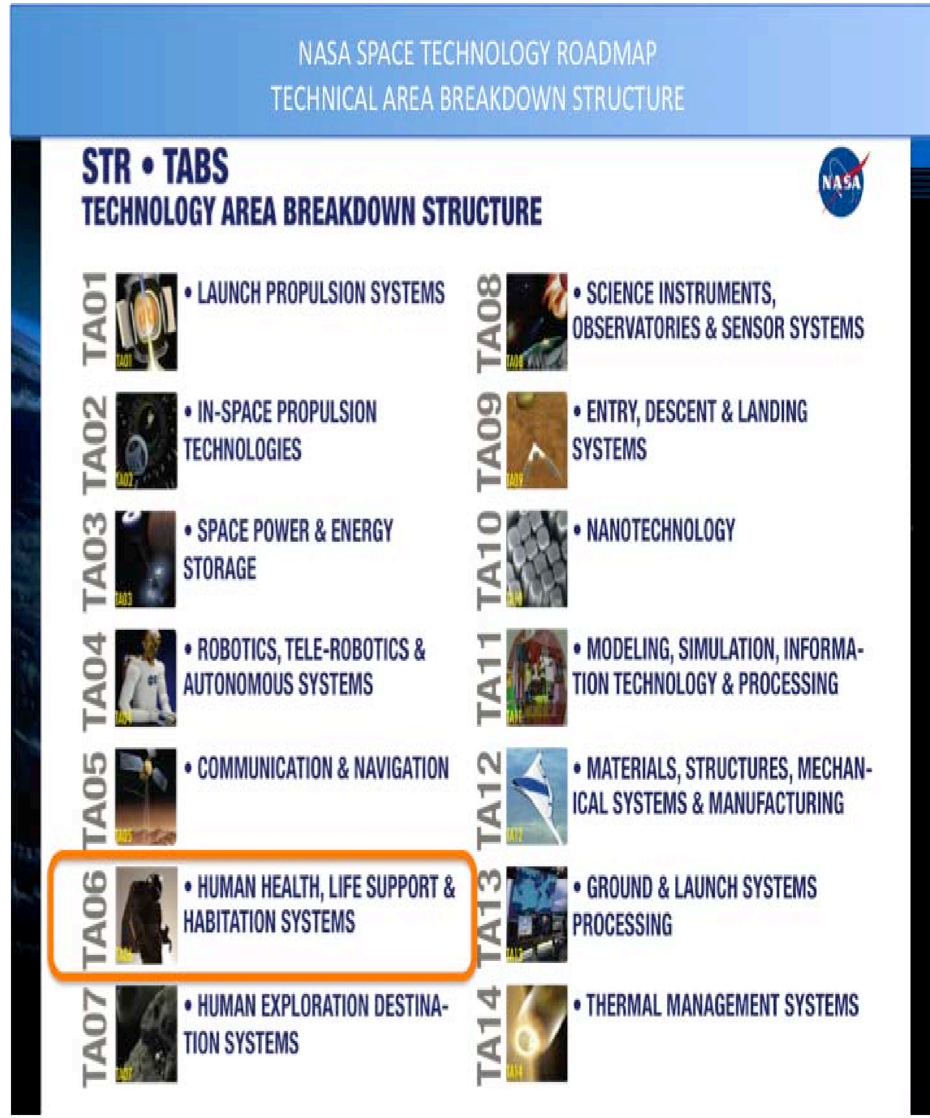
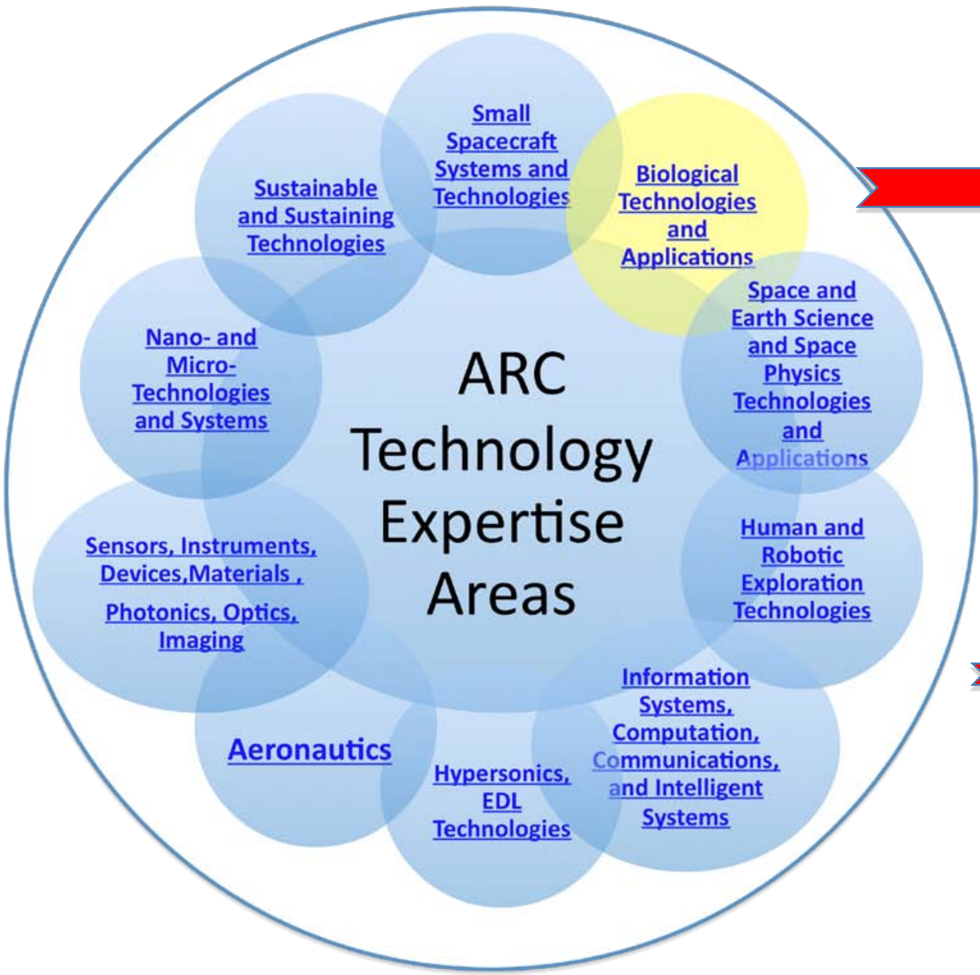
NASA’s Space Technology Program





NASA-Ames Technology Elements

Definition – Development -- Infusion



ARC Strategic Technology Initiatives

Selected Studies

1. Biological Technologies for Life Beyond Low Earth Orbit (BT4LBLEO)
2. Next Generation Spacecraft Systems
3. Emerging Aeronautics Systems and Technologies (EAST)
4. Cyber-Physical Systems Modeling and Analysis (CPSMA)
5. Designing High-Confidence Software and Systems (DHCSS) *
6. Quantum Computing (QuC)
7. Beamed Energy Propulsion (Microwave Thermal Rocket)
8. Active Debris Removal

Studies in Transition

- Synthetic Biology (SynBio)
- PhoneSat

Other Suggested Initiatives

- Low Cost, Off-the-Shelf Space Technologies (LCOSST)
- GREEN Technologies (Technologies for Sustainability)
- Technologies for Earth and Space Science Applications (TESSA)
- Disaster/Homeland Security Monitoring, Mitigation, Training (DHSMMT)

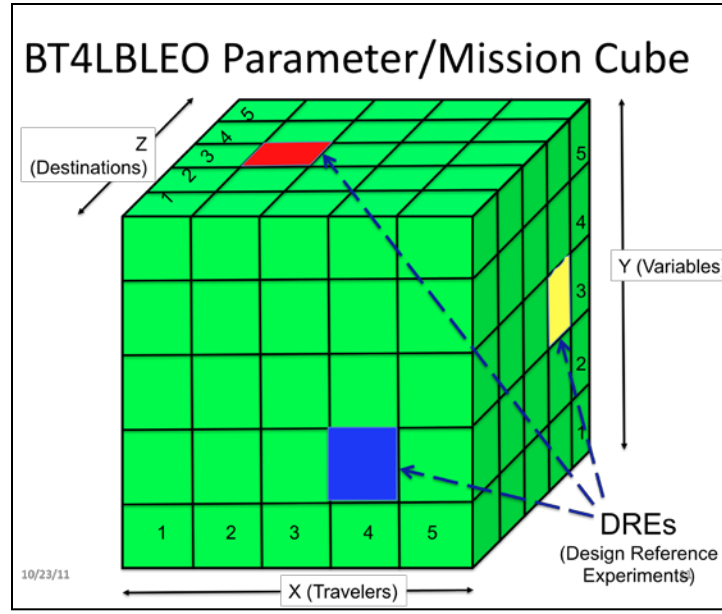
BT4LBLEO Study Objectives

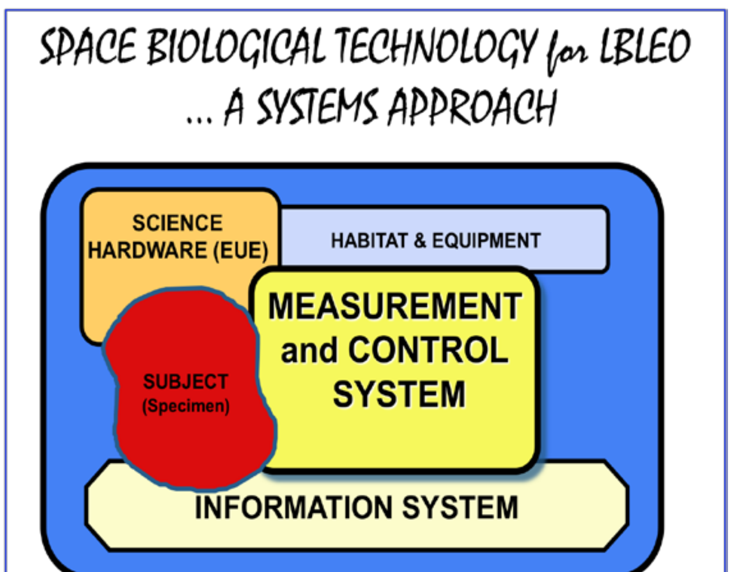
The Biological Technologies to enable Life Beyond Low Earth Orbit (BT4LBLEO) Study will:

1. *Define a set of Design Reference Experiments (DREs)* which address pertinent space biological science and exploration science questions using model and small organisms;

2. *Identify, specify, and recommend the necessary technologies*, techniques and systems to accomplish those DREs; and

3. *Develop and recommend a strategic technology development and insertion roadmap* to provide those technologies for utilization in the BLEO, Moon, Mars and deep space environments in support of Space Biological Research and Human Exploration.





Possible Roadmap Format

DREs	2011	2013	2015	2020	2025	2030	2035
OCT							
HEOMD							
SMD							
GOV							
ACAD							
INDUSTRY							
INTERNAT'L							
BTAB							
1. BTAB 1							
1. N							
2. N							
3. N							
4. N							
5. N							
2. BTAB 2							
3. BTAB 3							
1. N							
2. N							
3. N							
4. BTAB 4							
1. N							
2. N							
3. N							
5. BTAB 5							
1. N							
2. N							
3. N							

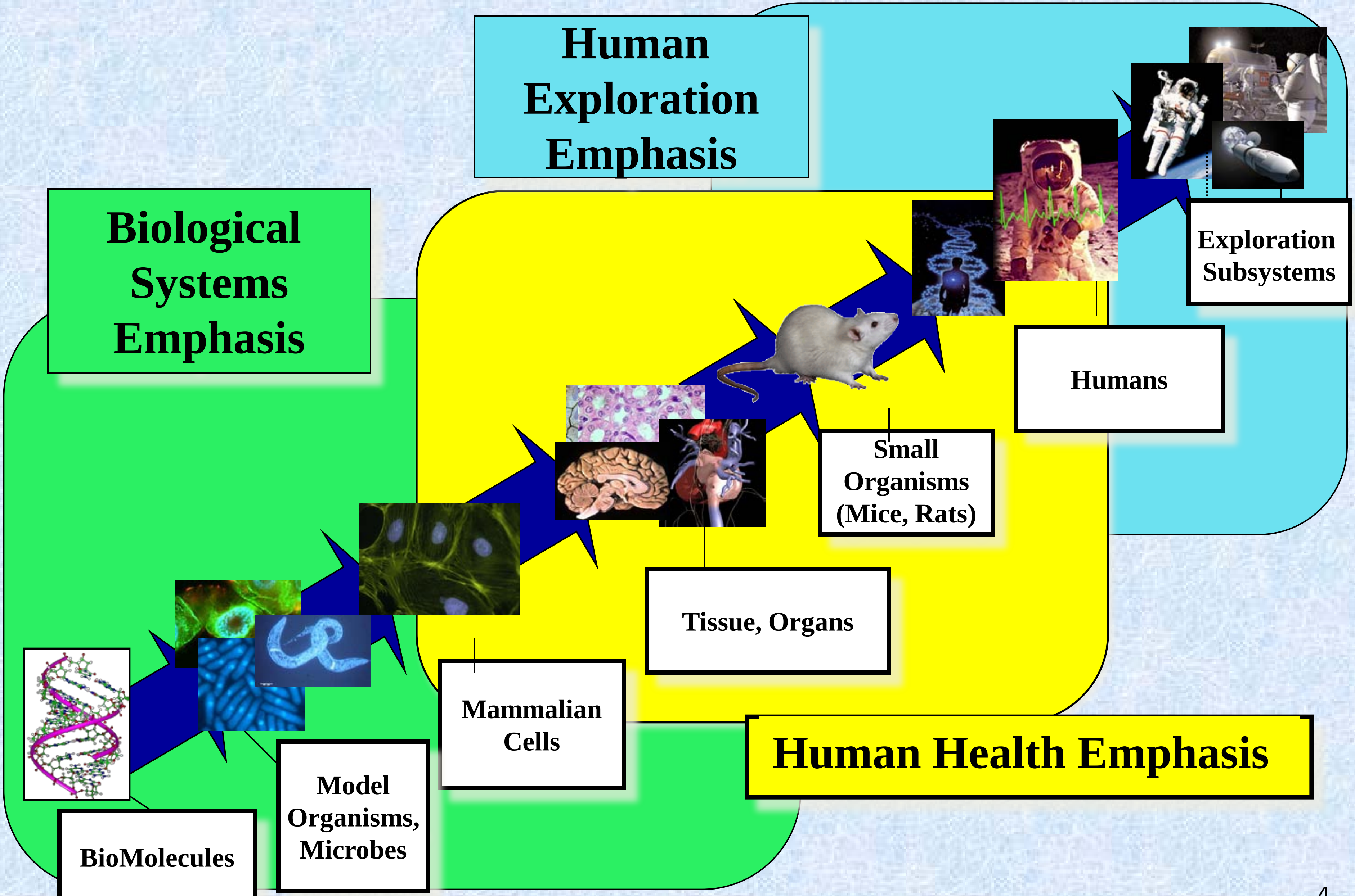
Rationale

- A major element in NASA's new vision of technology innovation and exploration is to prepare for eventual human travel and presence beyond low earth orbit (BLEO), on near-earth-objects, and on the surface of, or in orbit around, the Moon, Mars, and beyond. To accomplish these bold objectives, we must collectively understand how life in general, and specific biological systems in particular, adapt, respond and thrive in these extraterrestrial environments.
- The study will address the following mission concerns:
  - Extended human presence in the environments of deep space as well as the Moon and Mars will require a solid biological understanding of the integrated effects of diminished gravity, enhanced radiation, and transit- and destination-specific variables from the sub-cellular to the whole organism level
  - Biological and associated technologies for biological and robotic precursor missions to realize future objectives for space colonization
  - Surfaces, gravity levels, radiation environments, and atmospheres of these nearest neighbors are radically different in chemical and geological make-up from those on

Relevant and Supporting Science Disciplines:

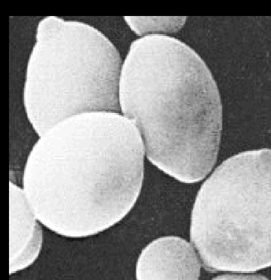
Space Biology, Astrobiology, Lunar Science, Synthetic Biology, Human Research Program, Crew Health Systems, Human Health and Performance, Exploration Life Support, Planetary Protection

NASA Applications of BioScience/BioTechnology



BioScience Targets & Applications (example)

- Goal: Provide the capability to support biological/biotechnology payloads for model organisms, mammalian cells, and other relevant specimens
- Measurement Targets (examples):
  - Gene expression; protein expression; metabolites, signalers, excretates; growth, kill curves; behavior
- Possible Applications (representative subset):
  - Combined radiation/reduced gravity consequences: mammalian cells, human gene carriers (*e.g.* yeast), model organisms.
    - **DNA damage:** *wound healing, **cancer***
    - **Cell membrane damage:** *central nervous system*
    - **Oxidation:** *compromised defense to hazards & pathogens*
    - **Protein damage:** *impaired bone & muscle function*
  - Space effects on microbes/pathogens
    - **Virulence increase/decrease**
    - Changes in pharmacological efficacy (PharmaSat-1)
- Push the envelope of miniaturization, automation: also benefits human-tended payloads, related terrestrial applications– e.g. *"canary-on-a-chip"* .



BT4LBLEO Technology Needs

An important element, which was not specifically defined in the OCT Space Technology Roadmaps (STR), is the area of technologies required to conduct biological research and human exploration precursor missions beyond low earth orbit. Emphasis for this study will be from the biological perspective to define a crosscutting biological technology evolution and insertion strategy, which augments and enhances the present STRs. Particular technology needs include:

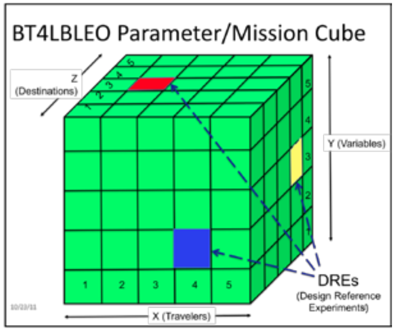
Functional Categories

Transportation	**Sample Return**
Measurement	**Control**
Computation	**Analysis**
Life support	**Habitation**
Sample handling and management	**Biotechnology**
Automated and in-situ bioanalytical instruments	**Fundamental and applied biological R&D**
Biologically based manufacturing and production technologies	

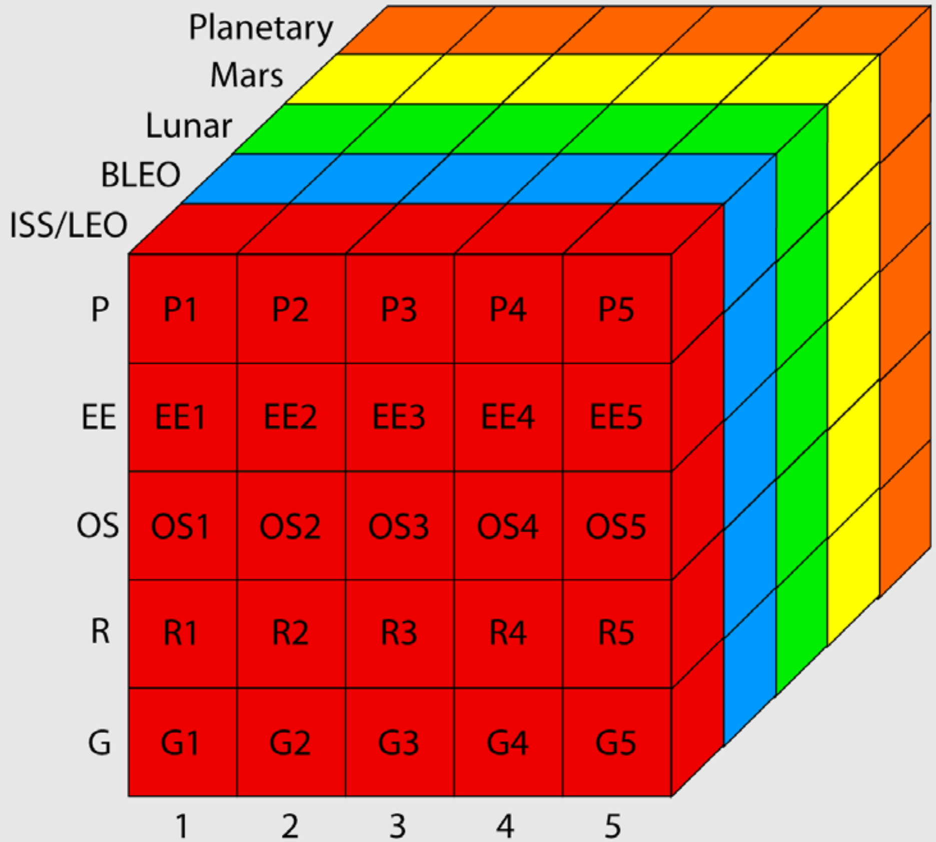
Wish List Specific Examples

- ***Miniature, in-situ Biological Sensors, Arrays, and Signal Processors***
- ***Species-specific Biological Sample Management and Handling Systems***
- ***Programmable, in-situ Biofluidics Modules and Processors***
- ***Advanced, and Multi-Mode Microscopy, Biophotonics, and Imaging Systems***
- ***Long-duration Biospecimen Life Support and Culture Systems***
- ***Technologies for in-situ Molecular Biology (Genomics and Proteomics) Research***
- ***Miniaturized, Fluorescent Activated Cell Sorters / Cytometers***
- ***High-sensitivity, Target-specific BioMolecular Probes, Tags, and Indicators***
- ***Autonomous, Robotic, Biospecimen Preservation and Freezer Modules (Fast, Snap, and Cryogenic)***
- ***Advanced Information Technology Tools for Data Interpretation and Control***
- ***Modular, Adaptable, Multi-Platform Biological Payloads and Subsystems***

- **DREs** *tbd by study team*
- **BT4LBLEO Elements** *(some ideas)*
  - Travelers (Cube X-axis)
    - Molecules/organics
    - Model Organisms
      - MicroOrganisms
      - Nematodes
      - Plants
      - Flies
    - Mammalian Cells, Tissue, Organs
    - Small Animals
    - Integrated Ecologies
  - Variables (Cube Y-axis)
    - MicroGravity
    - Radiation
    - Damage (Cell, DNA, Protein, etc)
    - Pharmacological Efficacy
    - Pathogenicity
    - Oxidative Stress
    - Environmental Exposure
    - Physical (Vibration, Shock,et)
    - Duration
    - other ?
    - ???
  - Destinations/Mission Targets (Cube Z-Axis)
    - ISS/LEO
    - BLEO
      - HEO
      - NEO
      - GEO
      - Libration Points
    - Lunar
    - Mars
    - Planetary Transport/Surface
  - Tech Area Breakdown Structure (B-TABS)
    - Sample Management, Preservation, and Handling
    - Biological Habitats, Specimen Control, and Experiment HW
    - Biological Sensors, Instruments, Measurement and Control Systems
    - In-Situ Bioanalytical Technologies
    - Spaceflight Payloads, Hardware, and Spacecraft Interfaces
    - Space Manufacturing/Production Technologies and Systems
      - Synthetic Biology
      - ISRU
      - Food, Drug, Waste processing
- **End USER** *customers*



Parameter Cube



X Axis
Model Organisms = 1
Molecules / Organics = 2
Cells = 3
Small Animals = 4
Integrated Ecologies = 5

Y Axis
Gravity = G
Radiation = R
Oxidative Stress = OS
Environmental Exposure = EE
Physical = P

Z Axis
ISS/LEO = Red
BLEO = Blue
Lunar = Green
Mars = Violet
Planetary = Orange

BT4LBLEO Design Reference Experiments

[Notional Construct]

<table>
<tr><th>Mission Increments (years)</th><th>Mission Timeline (years)</th><th>Destination Missions/Location</th><th>Complexity</th><th>Organism Type Mission</th><th>Science to be Addressed</th><th>Technologies Required to Address the Science</th></tr>
<tr><td>2</td><td>0 - 2</td><td>Near/ISS</td><td>Low</td><td rowspan="9">Model Organisms, Microbes, Cell Cultures</td><td>Resolve basis of cell cultures, microbial, model organisms, integrated ecologies, and rodents (small animals) response to microgravity and other space environment variables. In addition to questions relevant to: Space Biology, Human Exploration, Astrobiology, and Earth applications.</td><td>1). In-Situ Bioanalytical Technologies
2). Sample Preservation, Management and Handling Technologies
3). Biological Sensors and Instruments</td></tr>
<tr><td>2</td><td>2 - 4</td><td>Near / (GEO/HEO)</td><td>Medium</td><td rowspan="8">Resolve basis of cell cultures, microbial, model organisms and integrated ecologies response to microgravity, radiation, and other space environment variables. In addition to questions relevant to: Space Biology, Human Exploration, Astrobiology, and Earth applications.</td><td rowspan="8">1). In-situ Bioanalytical Technologies
2). Sample Preservation, Management and Handling Technologies
3). Biological Sensors and Instruments
4). Biological Habitats and Experiment Hardware
5). Spaceflight Payload Hardware and Systems</td></tr>
<tr><td>2</td><td>4 - 6</td><td>Near / (GEO/HEO)</td><td>High</td></tr>
<tr><td>2</td><td>6 - 8</td><td>Mid / (Lunar Flyby/Orbit)</td><td>Low</td></tr>
<tr><td>2</td><td>8 - 10</td><td>Mid / (Lunar Flyby/Orbit)</td><td>Medium</td></tr>
<tr><td>2</td><td>10 - 12</td><td>Mid / Lunar Surface Mission</td><td>High</td></tr>
<tr><td>3</td><td>10 - 20</td><td>Long / NEA</td><td>Low</td></tr>
<tr><td>3</td><td>10 - 20</td><td>Long / (Phobos/Deimos)</td><td>Medium</td></tr>
<tr><td>3</td><td>10 - 20</td><td>Long / Mars</td><td>High</td></tr>
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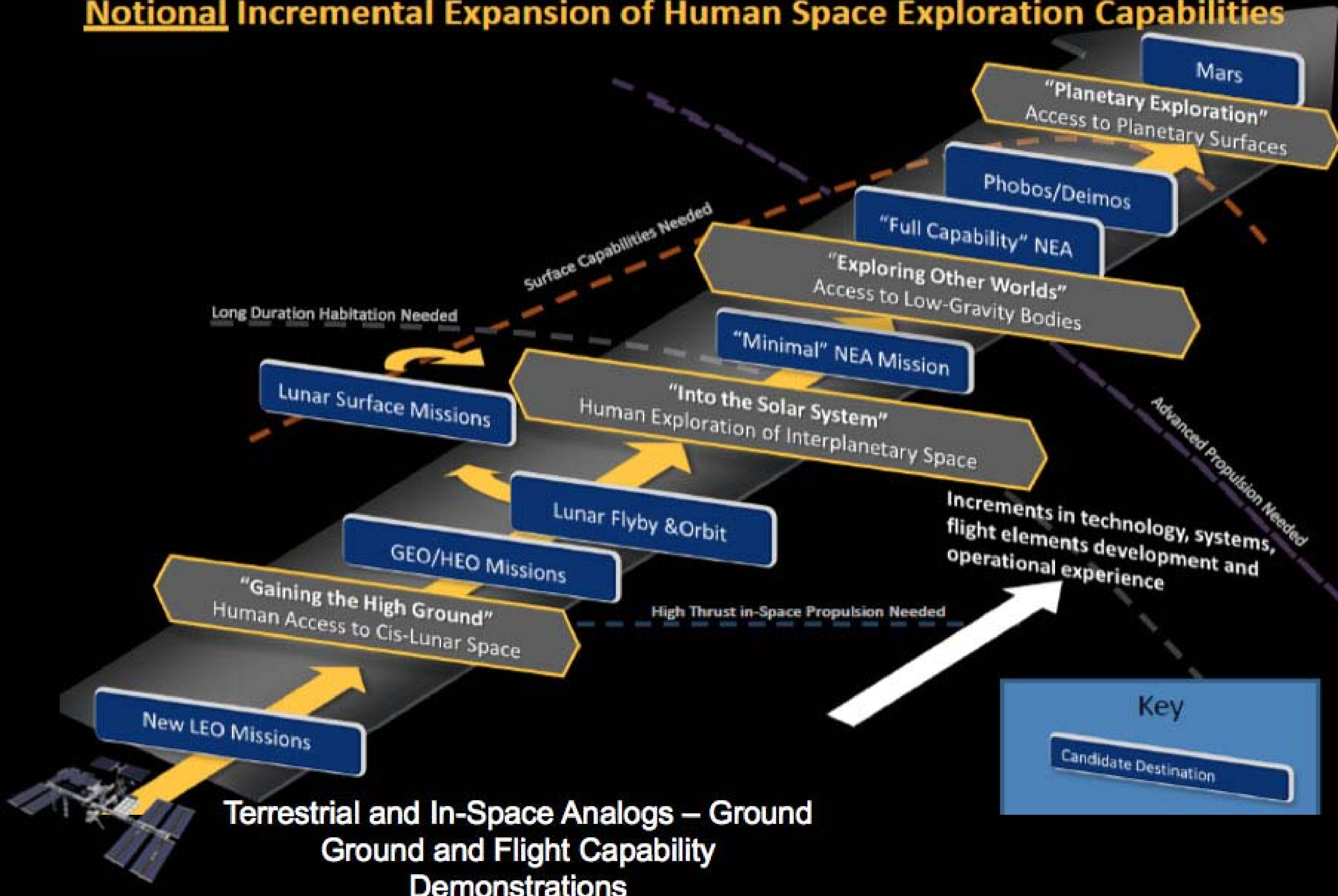
Capability Driven Exploration

Notional Incremental Expansion of Human Space Exploration Capabilities



BT4LBLEO Study Deliverables

DELIVERABLE	TIMEFRAME
Study Team/SME recommendation/approval	ATP+ 30 days *
Roadmap and Implementation Plan	30 days (ATP+60 days)
White Paper	30 days (ATP+90 days)
Workshop#1	60 days (ATP+150 days)
Interim Report	30 days (ATP+180 days)
Workshop #2	30 days (ATP+210 days)
Final Report	60 days (ATP+270 days)

* ATP= Authority to Proceed

Study Synergies

The BT4LBLEO Study complements and supports other agency studies and initiatives as well as the STR activity sponsored by the OCT. In particular, synergistic objectives exist between the Synthetic Biology Initiative and the BT4LBLEO Study. Whereas the Synthetic Biology Initiative concentrates specifically on the fundamental nature and design constructs for engineering organisms for use in space, the BT4LBLEO Study addresses a broader study of the necessary technologies, techniques and systems to support mission and science requirements for multiple mission scenarios, including those missions targeted for testing and utilization of Synthetic Biology products.

Other synergies are noted between the BT4LBLEO Study and STR TA-06 Human Health, Life Support and Habitation Systems (HLHS). While TA-06 focuses on technologies required to achieve national and agency goals in human space exploration, the BT4LBLEO Study concentrates on technologies for use on precursor robotic missions that will enable human exploration.

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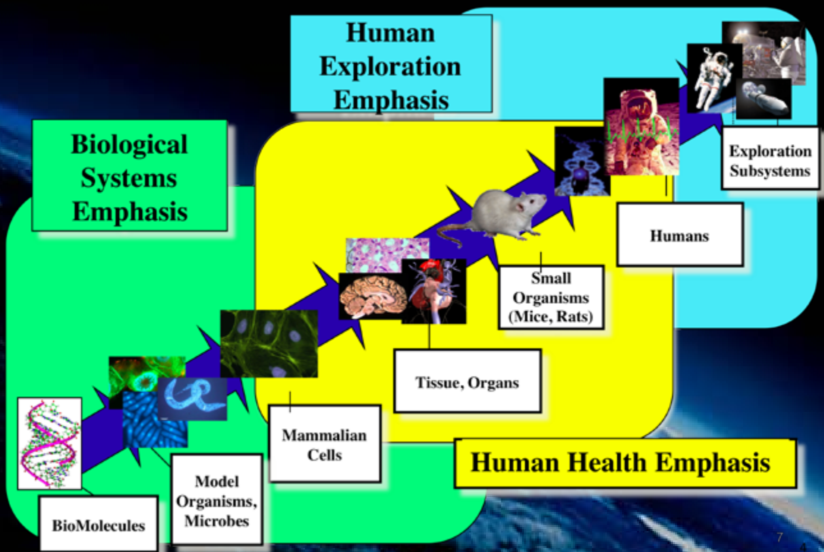
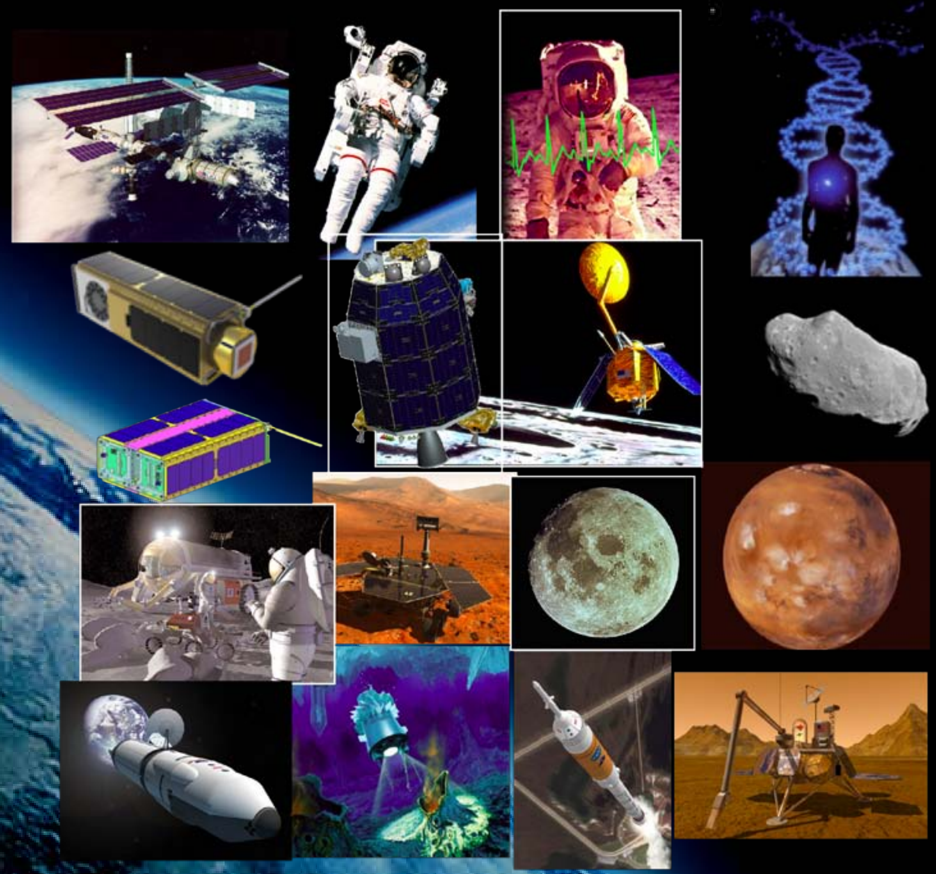
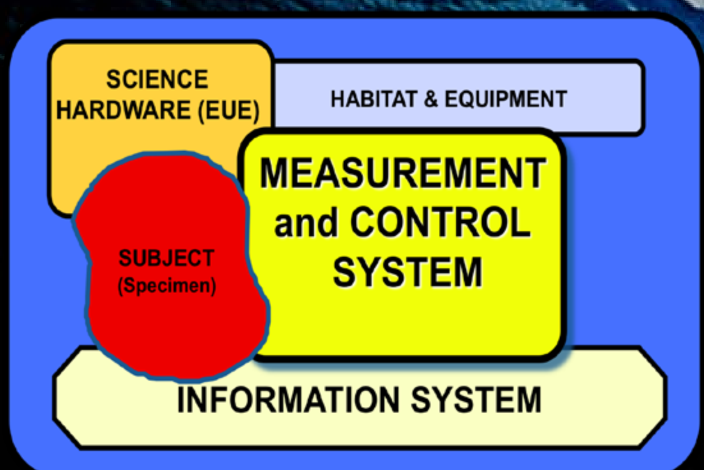


A Systems Study Approach for Biological Technology Definition, Development, and Insertion





http://bt4lbleo.arc.nasa.gov