# BIOASTRONAUTICS TECHNOLOGY NEEDS

## INTRODUCTION

NASA requires a significant number of Bioastronautics technologies to meet its strategic goals, but must balance these needs against the limited resources available to develop them. Like a portfolio, technology needs can be assessed collectively and then selected according to current decision drivers.

To demonstrate one method for identifying Bioastronautics technology needs, the Advanced Technology Integration Group provides this short description of our approach and the resulting portfolio. This is intended for those working with Bioastronautics technologies as a user or developer and particularly for potential collaborators who seek further understanding of priorities in this area.

## APPROACH

Bioastronautics experts completed a detailed technology needs survey (see Figure 1). The survey defines three likely mission scenarios and asks the same questions about each need for each scenario. It asks experts to assess like needs only within their area of expertise, to avoid biasing the portfolio towards one technology area.

Over 300 technology needs are included in the survey, covering adaptation and countermeasures, biological systems and biotechnology, and habitability and environmental factors. Two areas are not covered, but could be at a later date: space medicine and advanced life support.

| Area | Technology Need | ISS Critical | | Moon / L1 | | Mars | | R&D[3] | NASA $ | Benefit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | By 2006 Y / N / M | Priority L / M / H | By 2006 Y / N / M | Priority L / M / H | By 2012 Y / N / M | Priority L / M / H | 1 - 5 | Y / N / U | Y / N |
| Radiation Effects | Biophysical computer models for probabilistic health risk assessment from radiation exposure | | | | | | | | | |

*Figure 1. Sample of Bioastronautics Technology Needs Survey*

To best understand experts' inputs, we developed a decision tool that combines their inputs with weights representing current decision drivers, such as relative cost or priority. This approach allows the same inputs to be re-analyzed readily, should drivers change.

The result is a portfolio of approximately 100 technology needs that reflects current priorities for Bioastronautics. Using this decision tool, we included only those technologies judged by experts to:

1 **have a high priority for the specified mission:**
   - **ISS-critical**: short- to mid-range missions for ISS assembly, maintenance, and research, covering ONLY critical needs not currently met (180 d or more)
   - **Moon/L1**: mid-range missions beyond Earth's orbit for Earth/space science observation or as gateway to other locations; includes Moon (20-60 d), Earth-Moon L1 (40-60 d), and Earth-Sun L2 (90-120 d)
   - **Mars**: long-range missions to Mars or other planets for exploration and research (1000 d or more)

2 **likely be developed to technology readiness level (TRL) 6 within 4 years (ISS/Moon) and 8 years (Mars) with less than $2M**: where TRL 6 is defined as system/subsystem model or prototype demonstrated in the relevant ground or space environment; excludes flight development costs

3 **generally have a medium to high likelihood of success**: >80% chance of reaching TRL 6

This portfolio of needs is organized by Bioastronautics area and aligned with Critical Path Roadmap disciplines where possible (http://bcpr.jsc.nasa.gov).

**The needs are listed alphabetically, NOT in rank order.**

| AREA | TECHNOLOGY NEED | SCENARIO | | |
|---|---|---|---|---|
| | | ISS | Moon | Mars |
| **Behavior and Performance** | Improved workload analysis models and methods for use in real-time daily planning and scheduling of activities | | | ● |
| | Instrumentation to determine cognitive changes during long-duration missions, individual and environmental characteristics of such changes, and the effectiveness of preflight training | | | ● |
| | Methods to adjust crew-system task allocation and schedules in real-time to optimize system performance | | ● | ● |
| | Technology tools and models for determining acceptable performance ranges for different types of tasks | | | ● |
| **Biotechnology and Biological Systems** | Automated miniature cell imaging systems (such as fluorescent microscopy or spectroscopy systems) that allow real-time imaging and optical characterization of cells | ● | ● | ● |
| | Biosentinels for environmental monitoring/threat detection | ● | ● | ● |
| | Freeze drying cells and medium | ● | ● | ● |
| | Low temperature (-80, -180ºC) sample storage for biological sample preservation | ● | ● | ● |
| | Methods and apparatus that allow testing of drugs or biocompatible polymers on live tissues | | ● | ● |
| | Methods to measure changes in cell metabolism, gene expression, cellular immune functions, DNA, RNA, oglionucleotides, intracellular proteins, secretory products, and cytokine or other cell surface receptors | ● | ● | ● |
| | Micro-encapsulation of drugs, radiocontrast agents, and crystals | | ● | ● |
| | Model for predicting human muscle performance | | ● | ● |
| | On-orbit, high-throughput technologies that collect gene expression data from cells | | | ● |
| | Technologies for automated sampling, processing, and storage for cell culture studies. | ● | ● | ● |
| | Three-dimensional tissue models for space-induced muscle atrophy, bone loss, cardiovascular aberration, immune suppression and radiation effect | ● | ● | ● |
| | Variable gravity instrumentation to detect g-threshold for key cellular function and for embryogenesis in higher organisms | ● | ● | ● |

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| **Bone Loss** | Efficient and reliable methods for obtaining self-report information on nutritional intake of calcium-related products | | ● | ● |
| | Inflight, compact, lightweight dual energy X-ray absorptiometry (DEXA) to perform hip, spine, and heel bone mineral density (BMD) measurements | ● | ● | ● |
| | Means to monitor the effectiveness of nutrition and pharmacological agents, exercise and electro-myostimulation | | | ● |
| | Systems that measure inflight changes in calcium and how it affects the neurosensory, cardiac, muscle, or other systems | | ● | ● |
| | Tools that measure inflight BMD in crew and animals, including diagnostics (biochemical markers, DEXA, ultrasound) to monitor and quantify changes in bone mass and strength | ● | ● | ● |
| **Cardiovascular Alterations** | Anti-arrhythmic pharmaceuticals | ● | ● | ● |
| | Cardiac electrophysiological diagnostic and therapeutic equipment | | | ● |
| | G-suit/compression garment designed to prevent orthostatic intolerance and/or provide cardiac assist | | | ● |
| | Hardware for an integrated countermeasures program to maintain orthostatic tolerance for landing, planetary excursion, emergency, entry, egress, and postflight rehabilitation | ● | ● | ● |
| **Contingencies** | Technologies for crew to repair spacecraft systems without support from Earth | | | ● |
| **Environmental Health and Toxicology** | Systems to measure metabolic rates, especially during extra-vehicular activity (EVA), and to relate them to fatigue and risk of decompression illness (DCI) | | ● | ● |
| **Food and Nutrition** | Efficient and reliable methods for obtaining self report information on nutritional intake | | | ● |
| | Enhancements in food acceptability, palatability, and variety | ● | | ● |
| | Equipment to process crops on planetary surface such as wheat, soybeans, potatoes, sweet potatoes, peanuts, dried beans, rice, and tomatoes | | | ● |
| | Improved packaging and other methods to ensure stability of food nutritive value for extended missions | | | ● |
| | Means to minimize waste from packaged food (e.g., biodegradable packaging that can withstand the retort process or other readily recycled material) | | | ● |
| | Means to monitor the effectiveness of nutritional supplements and nutraceuticals in maintaining crew health, safety and performance | | | ● |
| | Means to monitor the quality, safety, and shelf stability of processed food ingredients, including identification and control of microorganisms and development of countermeasures | ● | ● | ● |

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| **Food and Nutrition** *(continued)* | Nutritional supplements that complement a shelf-stable food system and provide phytochemicals and micronutrients that it cannot | | | ● |
| | Preservation technologies (irradiation, sonication, electromagnetism, pressurization, chemical additives, etc.) to store a complete and acceptable diet for 3 - 5 years for use in high-performance environment | | | ● |
| | Technology for sanitizing salad crops through a highly automated process | | | ● |
| | Tools to measure food preferences of individual crewmembers | ● | | ● |
| **Habitability and Human Factors** | Automated analysis of computer-user interfaces for complex display systems, to conduct objective review of displays and controls and to determine compliance with standards | | | ● |
| | Cleaning tools and equipment that require less crew time and use less consumables | | ● | ● |
| | Expert decision-making systems built on a robust electronic knowledge base that enhance teamwork, productivity, and communication | | ● | ● |
| | Means to monitor habitability factors and determine effect of physical and psychosocial environment on cognitive, psychological, and affective measures of behavior and performance | | | ● |
| | New materials, designs, and construction methods to provide a habitat adaptable to crew needs during all mission phases | | ● | ● |
| | On-board information systems that adapt to the needs of autonomous crews | | | ● |
| | Space suit design with protection for joint/soft tissue | | | ● |
| | System health monitoring and maintenance techniques that incorporate humans in the loop | | ● | ● |
| | Technologies for 0 g washing and drying of clothes in habitats and long-duration shelters | | | ● |
| | Trash disposal methods, such as freeze-drying, incineration, bio-oxidation, and potential methods for recycling other solids, that reclaim materials while minimizing disposal volume | | | ● |
| **Immunology, Infection and Hematology** | Inflight cytometer | | | ● |
| | Inflight enzyme-linked immunosorbent assay (ELISA) system | | | ● |
| | Laboratory diagnostics, procedures and standards relevant to immune system function, for use in 0 g and partial g | | ● | ● |
| | Relation of the immune system dysfunction to the incidence of infection, cancer induction, allergy, and autoimmune disease manifestations | ● | ● | ● |
| **Multipurpose** | Means to assess countermeasures and their interaction with other countermeasures or systems | ● | ● | ● |

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| **Medical Systems** | Pharmacological or nutritional agents to counter the deleterious effects of space flight and partial gravity | | ● | ● |
| **Muscle Alterations and Atrophy** | Automated recording devices for logging exercise, body mass, dietary intake, urine void volumes | ● | ● | ● |
| | Exercise countermeasures that allow crewmembers to perform surface tasks and return to Earth | ● | ● | ● |
| | Heavy resistive exercise, including a treadmill (continuous and interval running) | ● | ● | ● |
| | Improved exercise regimes and equipment for use Inflight and rehabilitation postflight | ● | ● | ● |
| | Instrumentation for inflight monitoring and analysis of muscle function and health | ● | ● | ● |
| | Instrumented cycle and rower ergometers that use higher technology equipment and require more intense exercise and greater exercise duration in time and days | | ● | ● |
| | Pharmacological countermeasures for preventing loss of skeletal muscle mass and/or muscle endurance | | | ● |
| **Neuro-vestibular Adaptation** | Gait adaptability trainer that counters postflight musculoskeletal and locomotor dysfunction | | ● | ● |
| | Technologies for determining real-time impact of sensorimotor adaptation on operational performance | ● | ● | ● |
| | Technologies for determining sensorimotor and cognitive consequences of central nervous system (CNS) reorganizations | | ● | ● |
| | Technologies for determining sensorimotor and cognitive consequences of CNS reorganizations | | | ● |
| | Technologies for determining the role of proprioceptive and somatosensory information in sensorimotor functions | | | ● |
| | Vibrotactile orientation system/device for inflight maintenance of spatial orientation, specifically during EVAs | | | ● |
| **Pharmacology** | New drug delivery systems for inhalation and intranasal administration | ● | ● | ● |
| **Radiation Effects** | Animal/ cellular models of human carcinogenesis including tumor induction data | | ● | ● |
| | Animal/cellular models of late deterministic effects, such as cataracts, accelerated aging, etc. | ● | ● | ● |
| | Biophysical computer models for probabilistic health risk assessment from radiation exposure | ● | ● | ● |
| | Determination of radiobiological effectiveness (RBEs) for neoplastic transformation of human cells including lung, mammary, and other cancers | ● | ● | ● |

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| **Radiation Effects** *(continued)* | Early warning system with space weather simulation/prediction/ visualization for predicting solar particle events (SPEs) and their magnitude, based on solar magnetic field characterization, electromagnetic radiation emissions, multi-spectral solar imaging, and interplanetary magnetic field conditions. | | ● | |
| | Improved galactic cosmic ray (GCR) measurement and dosimetry | ● | | ● |
| | Improved radiation transport and shielding codes | ● | ● | ● |
| | Methods for calculating probabilities of cancer induction at the organ level | | | ● |
| | Model(s) of the geomagnetic cutoff, including diurnal, seasonal, and solar cycle activity dependence | ● | | |
| | Model(s) to describe the dynamic behavior of the trapped radiation belts | ● | | |
| | New shielding materials and methods, including evaluation of new materials, composites, and planetary regoliths as shielding media | | ● | ● |
| | Small active dosimeter that measures both the number and linear energy transfer (LET) of particles in the spacecraft environment | | | ● |
| | Small, portable electronic radiation dosimeter, which can be used in EVA suits and habitable volumes to provide dose and dose-equivalent rates and integrated values | | | ● |
| | Space-based active neutron spectrometer/dosimeter, which can measure neutron energies in the presence of high levels of protons | ● | | |
| | Technologies for determining the genetic effects of high LET radiation on humans and plants | ● | ● | ● |
| **Training and Evaluation** | Advanced protocols to evaluate optimum levels of training for critical tasks, emergency responses, planned operations, etc. | | ● | ● |
| | Authoring languages for virtual reality (VR) training systems that incorporate error feedback to the user, prompting, and tools for data collection and performance assessment | | | ● |
| | Inflight training and simulation for skill development, retention, and acquiring new knowledge/information | | ● | ● |
| | Tools to build just-in-time training/decision-support systems to aid human users conducting routine and emergency operations and activities | | | ● |