John Glenn Biomedical Engineering Consortium

Conference – Workshop on
Strategic Research to enable NASA’s
Exploration Missions

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JOHN GLENN BIOMEDICAL ENGINEERING CONSORTIUM

Inter-institutional research and technology development, beginning with ten projects in FY02 that are aimed at applying GRC expertise in fluid physics and sensor development with local biomedical expertise to mitigate the risks of space flight on the health, safety, and performance of astronauts.

It is anticipated that several new technologies will be developed that are applicable to both medical needs in space and on earth.
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Biomedical Engineering Consortium

Members: Case Western Reserve University (CWRU)
        Cleveland Clinic Foundation (CCF)
        University Hospitals of Cleveland (UHC)
        National Center for Microgravity Research (NCMR)
        NASA Glenn Research Center (GRC)

Focus: Interdisciplinary research leveraging GRC expertise in fluid physics and sensor technology to mitigate critical risks to crew health, safety, and performance identified in the Bioastronautics Critical Path Roadmap

Sponsor: Office of Biological and Physical Research (OBPR)

Resources: OBPR Funding - $7.5 M over three years
           Member personnel, facilities, capabilities, leveraging and in-kind contributions

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JGBEC Anticipated Products

Successful conclusion of the projects currently funded by the consortium will result in the following sensor technologies and countermeasures that are compatible with space flight:

- Countermeasure for prevention of bone loss in microgravity
- Prototype portable device to measure human metabolic activity
- Instrument for in-vivo bioluminescent molecular imaging
- Apparatus that will provide several non-invasive optical technologies
- Prototype, wearable sensors’ interface which will wirelessly transmit data
- Revolutionary glucose sensor, self-calibrating requiring no power
- Modified treadmill with incorporated virtual reality capability
- Biochip simulation capability tailored to space applications
- Battery less, potentially implantable unique drug delivery device
- Microscopy capability for assessing countermeasures influence on bone cells

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In Vivo Bioluminescent Molecular Imaging with Application to the Study of Secretory Clusterin, a Potential Biodosimeter During Space Exploration – David Wilson, CWRU

- Introduce luciferase gene from fireflies near a gene of interest in cells
- Luciferase acts as a reporter gene. It expresses luciferase protein whenever the gene of interest is expressed.
- Luciferase protein and its substrate luciferin create light
- Clusterin is secreted by cells in culture and animals following low levels of radiation

**NASA Application:**
Clusterin biodosimeter will measure the biological effect of radiation exposure

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Integrating Non-Invasive Technologies to Enable Effective Countermeasures During Prolonged Space Travel – Rafat Ansari, GRC

Experimental Rack On-board the KC-135 for Ocular Blood Flow Experiment

Ocular Blood Flow Monitoring in “0 g” in a test subject (RRA) On-board the KC-135 airplane

- Ocular and nervous system circulatory physiology
- Monitoring of Blood Glucose
- Monitoring of Oxygen
- Brain physiology

NASA Application:
Head-mounted device using non-invasive optical techniques for monitoring astronaut health and for early detection of disease or abnormality

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Microminiature Monitor for Vital Electrolyte and Metabolite Levels in Astronauts – Miklos Gratzl, CWRU

- Painless and easy to insert, wear, and remove
- Free of track infection
- Continuous
- No driving power required
- No calibrations required
- Fully compatible with telemetry
- Simultaneous monitoring of interstitial glucose, pH, and K+
- Self-test and three-day error-free operation or longer

NASA Application:
Microminiature sensor placed under the skin using non-invasive optical techniques for continuous in vivo monitoring of astronaut electrolytes and metabolite levels

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Acoustically Induced Microdamage to prevent Bone Loss –
Ulf Knothe, CCF

- Identify the bandwidth and application regime necessary to:
  - enhance fluid flow and mass transport through bone matrix
  - produce low-level, diffuse microdamage similar to that ensuing from normal physiological activity on Earth

- Design an experimental device and to test its efficacy in the hind limb suspension model of the rat

**NASA Application:**

Through process of ultrasound therapy, which induces bone microdamage and natural rebuilding, develop a countermeasure device to maintain astronaut bone mass for space application.

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Remote and On-Board Detection, Diagnoses, and Treatment of Serious Cardiac Dysrhythmias (Project “Rescue”) – David York, GRC

- Development of ground based prototype system to test the hypothesis that a system can be provided to detect and diagnose astronaut dysrhythmias both locally on-board a spacecraft and remotely (i.e. from earth) and treated.

- Test the hypothesis that local or remote users of the system can provide commands to, and receive data from the system using only a Web browser.

**NASA Application:**
Non-invasive monitor to detect and diagnose astronaut cardiac dysrhythmias utilizing a wireless communication, low power consumption and high bandwidth data transmission system

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Development of a Portable Unit for Metabolic Analysis (PUMA) – Daniel Dietrich, GRC

- Design and build a prototype device to measure five key respiratory parameters:
  - temperature
  - pressure
  - volumetric flow rate
  - mole fraction of carbon dioxide & oxygen

NASA Application:
Utilize portable device to non-invasively monitor astronaut metabolism during various activities such as exercise to determine overall fitness and effectiveness of exercise programs

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Controlled-Release Microsystems for Pharmacological Agent Delivery - Shuvo Roy, CCF

- **Ultimate Goal (Long-term)**
  - To develop engineered systems for the delivery of natural and/or synthetic compounds that can counteract adverse effects of microgravity on astronaut health

- **Project Goal (Short-term)**
  - To develop MEMS-based drug delivery systems that will enable space biology/medicine researchers to dispense pharmacological agents locally over a sustained period
  - Miniature, Implantable, controlled-release

**NASA Application:**
Controlled continuous drug delivery system for administering pharmacological agents as countermeasures to adverse effects of microgravity on astronaut health

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Rapid Design and Simulation Tools for Space-Based BioChip Devices -
Arnon Chait, GRC

- Develop sustained, in-house, biochip design and simulation capabilities to assist/design/optimize space-bound biochips for medical/diagnostics applications.
- Elucidate fundamental space-specific physical phenomena that are common to all biochip devices intended to operate in space.
- Collaborate with and assist program researchers and leading biochip companies with analysis and design of space-capable biochip devices.

NASA Application:
Development of biochip design and simulation capabilities to optimize space-bound biochips for medical/environmental diagnostics applications:

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To design and develop an exercise countermeasure
- Challenge the postural control system
- Exercise balance and locomotor reflexes
- Alleviate adverse adaptations to neurovestibular system

Address multiple physiological systems
- Neurovestibular
- Musculoskeletal
- Cardiovascular

**NASA Application:**
Provide exercise to address physiological processes of growth and development in muscle, bone, and cardiovascular systems while helping to maintain a sense of physical orientation by stimulating the neurovestibular system

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Confocal and Two-Photon Microscopy for the Assessment of Countermeasures in Bone Loss and Immunology – Greg Zimmerli, GRC

- Develop fluorescence microscopy techniques to assess, at a cellular level, the effectiveness of countermeasures to effects of long duration space flight
- Fluorescence microscopy techniques:
  - Two-photon
  - Fluorescence Correlation Spectroscopy
  - Fluorescence Resonance Energy Transfer
  - Fluorescence Lifetime Imaging Microscopy
- Quantifying cellular response:
  - Cell proliferation
  - Structure
  - Protein associations

NASA Application:

New microscopy techniques will be used to identify and assess potential countermeasures to bone loss in microgravity through investigation of cellular response to other solutions beyond exercise.

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Biomedical Engineering Consortium Projects

- Acoustically Induced Micro-damage to Prevent Bone Loss.
- Glucose levels:
  - 0 mg/dl in PBS
  - 39 mg/dl in PBS
  - 95 mg/dl in PBS
  - 667 mg/dl in PBS
- Microminiature Glucose Sensor
- Nanoporous Membrane
- Micromachined Reservoir
- Pharmacologic Agent Molecule
- Controlled-Release Microsystems for Pharmacological Agent Delivery
- Rapid Design and Simulation Tools of Space-bound Biochips
- Virtual Reality Dual-Action Treadmill for Improved Neurovestibular Adaptation
- Detection and Web-based Reporting of Cardiac Dysrhythmia
- Portable Metabolic Analyzer for Crew
- Bioluminescent imaging for radiation dosimetry
- Microminiature Glucose Sensor
- Non-invasive Eye Measurements to Reveal the Body’s Health
- Acoustically Induced Micro-damage to Prevent Bone Loss.