NASA/CP—2004-213205/VOL1

John Glenn Biomedical Engineering Consortium

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

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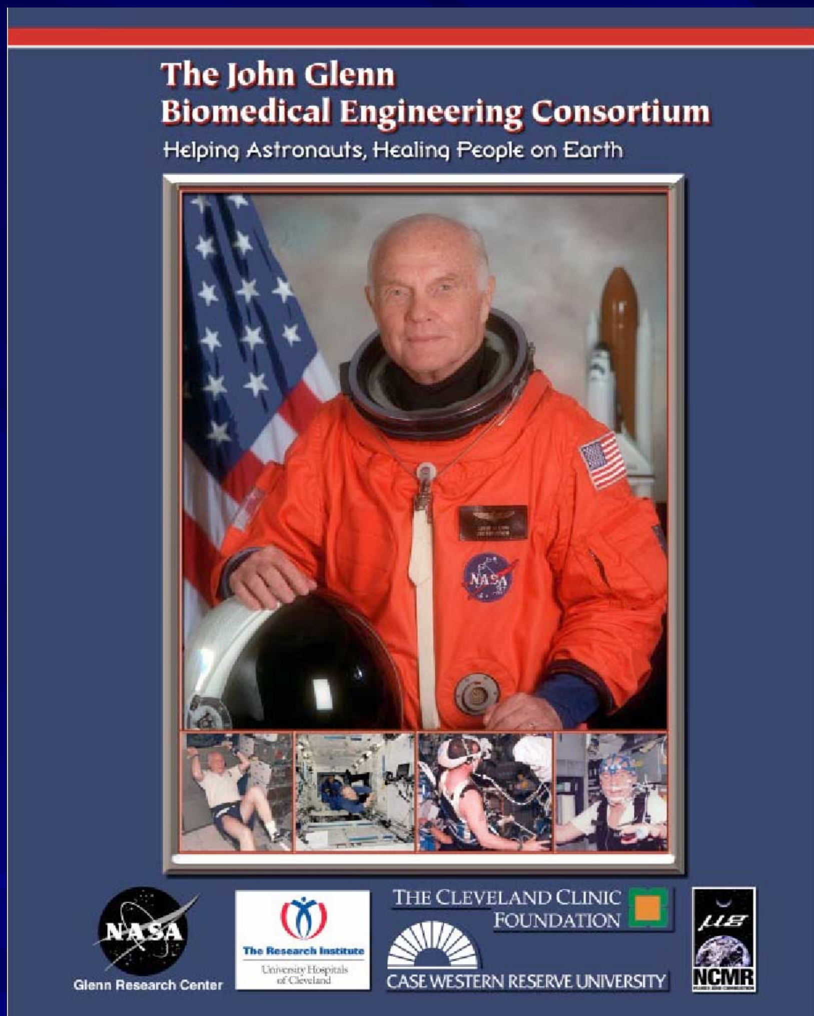

JOHN GLENN BIOMEDICAL ENGINEERING CONSORTIUM

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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John Glenn
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 Projects

Wilson, CWRU Co-I: UH	In-Vivo Bioluminescent Molecular Imaging with Application to the Study of Secretory Clusterin, a Potential Biodosimeter during Space Exploration
Ansari, GRC Co-I: UH	Integrating Non-invasive Technologies to Enable Effective Countermeasures During Prolonged Space Travel
Gratzel, CWRU	Micro-miniature Sensing Platform For Painless, Infection-Free, And Continuous In Vivo Monitoring Of Glucose And Electrolytes Of Astronauts
Knothe, CCF Co-I: CWRU, GRC	Development of a "Decompression Chamber" to Prevent Loss of Bone in Space through Exogenous Application of Acoustic Energy
York, GRC Co-I: CWRU	Remote and On-board Detection, Diagnoses and Treatment of Serious Cardiac Dysrhythmias
Dietrich, GRC Co-I: NCMR, UH	Development of a Portable Metabolic Measurement Device
Roy, CCF Co-I: CWRU, GRC	Controlled-release Microsystems for Pharmacological Agent Delivery
Chait, GRC Co-I: NCMR, CWRU	Rapid Design and Simulation Tools for Space-Bound BioChip Devices
D'Andrea, CCF Co-I: GRC	An Instrumented, Dual-Track, Actuated Treadmill in a Virtual Reality Environment as a Countermeasure for Neurovestibular Adaptations in Microgravity
Zimmerli, GRC Co-I: CCF	Confocal And Two-Photon Microscopy For The Assessment Of Countermeasures In Bone Loss, Hematology, And Immunology

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

In vivo bioluminescence imaging system.

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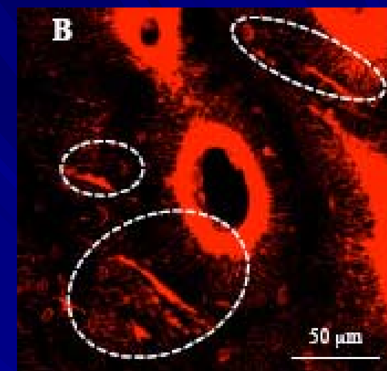
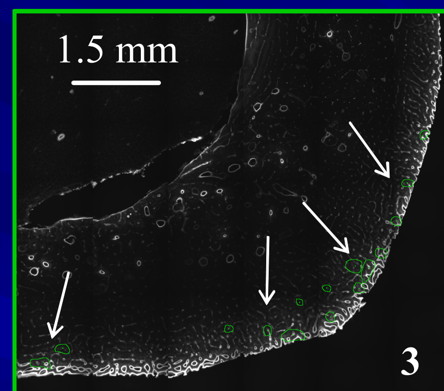
Acoustically Induced Microdamage to prevent Bone Loss – Ulf Knothe, CCF

- 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



Images collected with confocal Microscope at 20x magnification showing overt microdamage



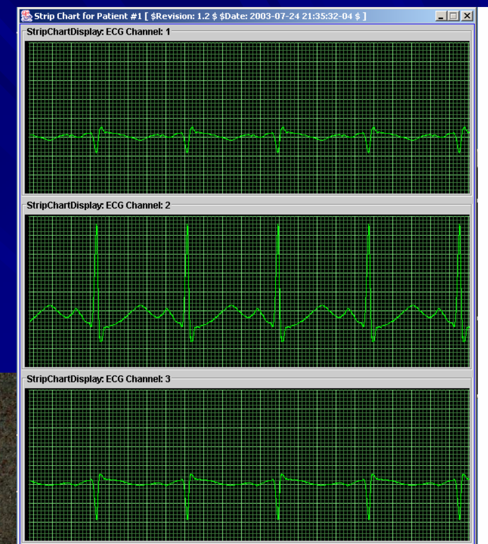
Observed areas of microdamage (arrows)

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.

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.



3-Channel ECG Display on Call Center Data transmitted from Wearable Server to Central Server to Call Center

Wearable server with 8051 single chip processor and Bluetooth cards

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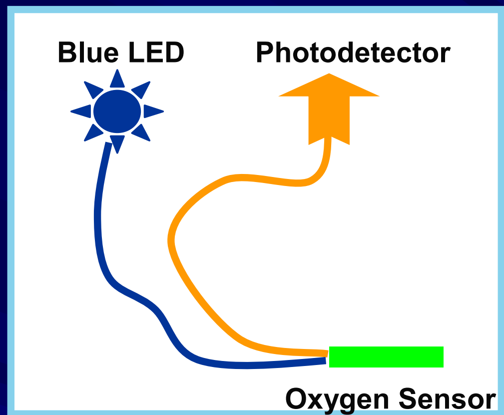
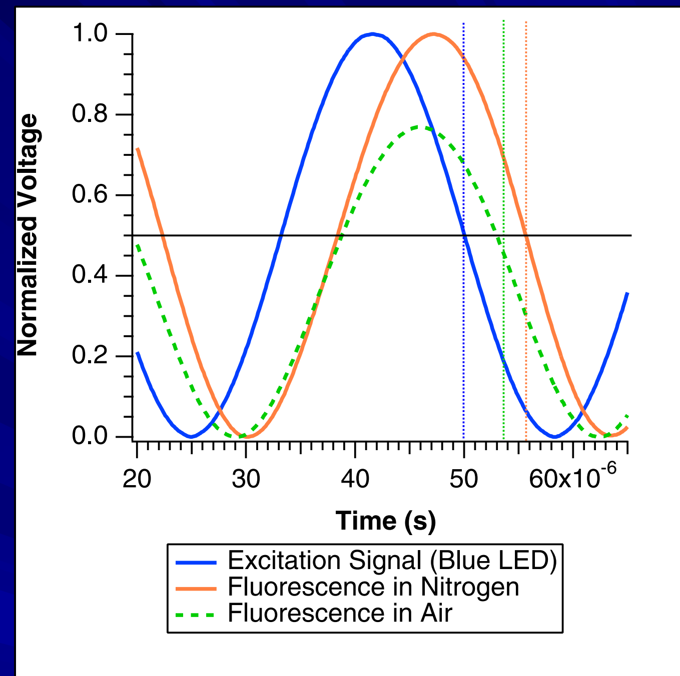
Development of a Portable Unit for Metabolic Analysis (PUMA) – Daniel Dietrich, GRC





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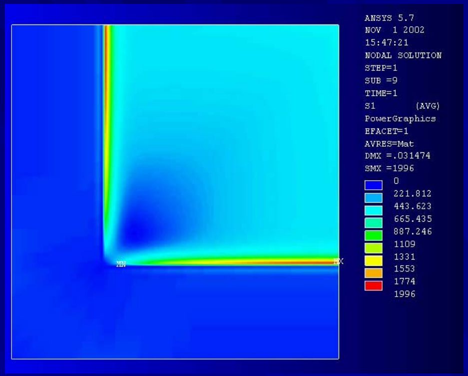
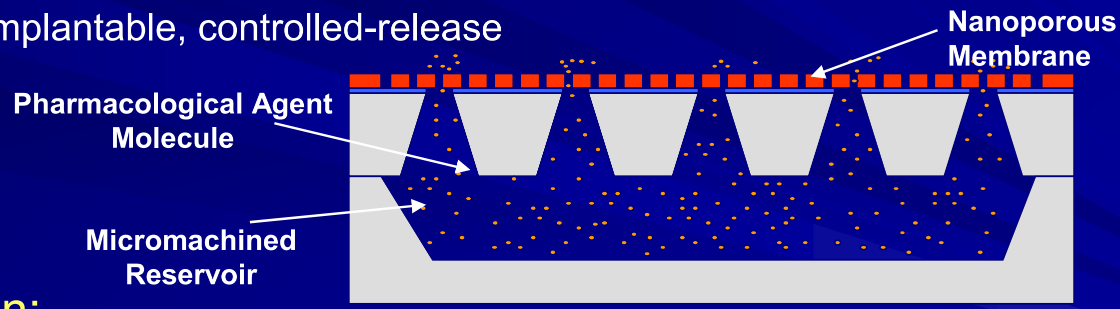
Controlled-Release Microsystems for Pharmacological Agent Delivery - Shuvo Roy, CCF

- 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

FEM Model of Solid Polysilicon Membrane





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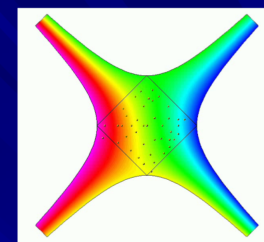
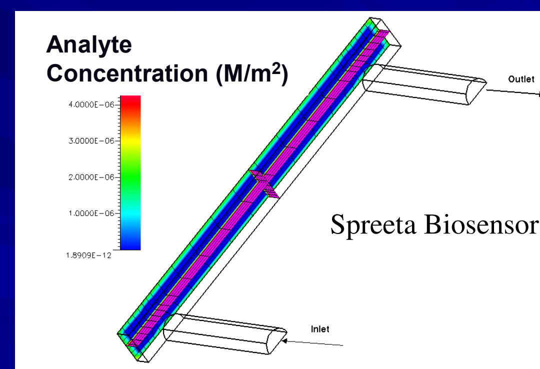
Rapid Design and Simulation Tools for Space-Based BioChip Devices - Arnon Chait, GRC

- 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.



Dielectrophoresis Particle Focusing



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

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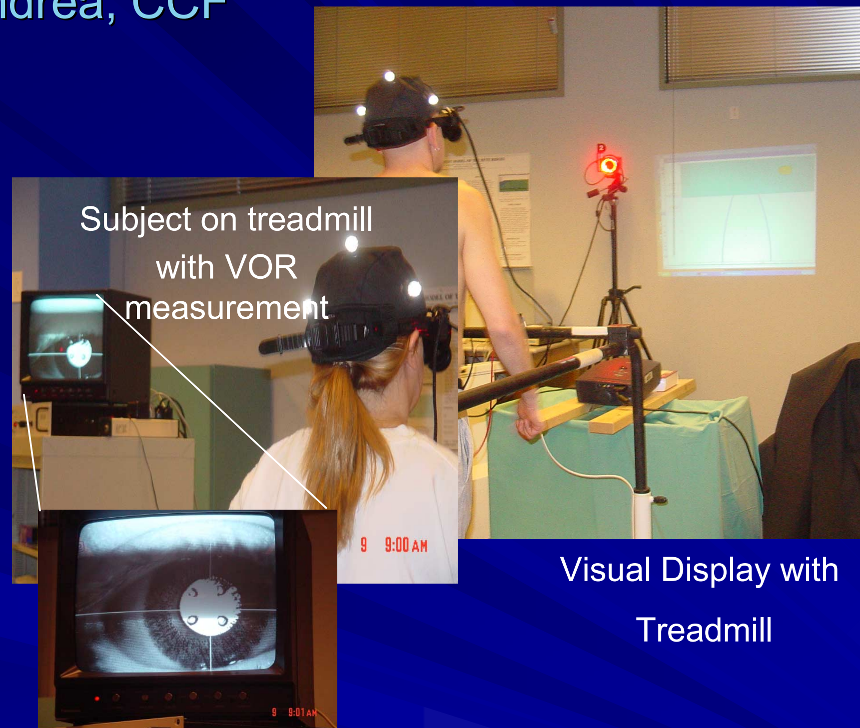
A Dual-Track Actuated Treadmill in a Virtual Reality Environment: A Countermeasure for Neurovestibular Adaptation in Microgravity –Susan D'Andrea, CCF

- 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



Visual Display with Treadmill

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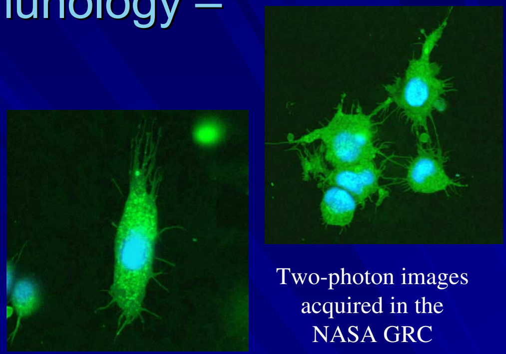
Confocal and Two-Photon Microscopy for the Assessment of Countermeasures in Bone Loss and Immunology – Greg Zimmerli, GRC

- 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



Two-photon images acquired in the NASA GRC Biophotonics lab of the UMR-106 osteosarcoma cells

Two-photon images acquired in the NASA GRC Biophotonics lab of Human femoral head section Sample provided by M.K. Tate CCF

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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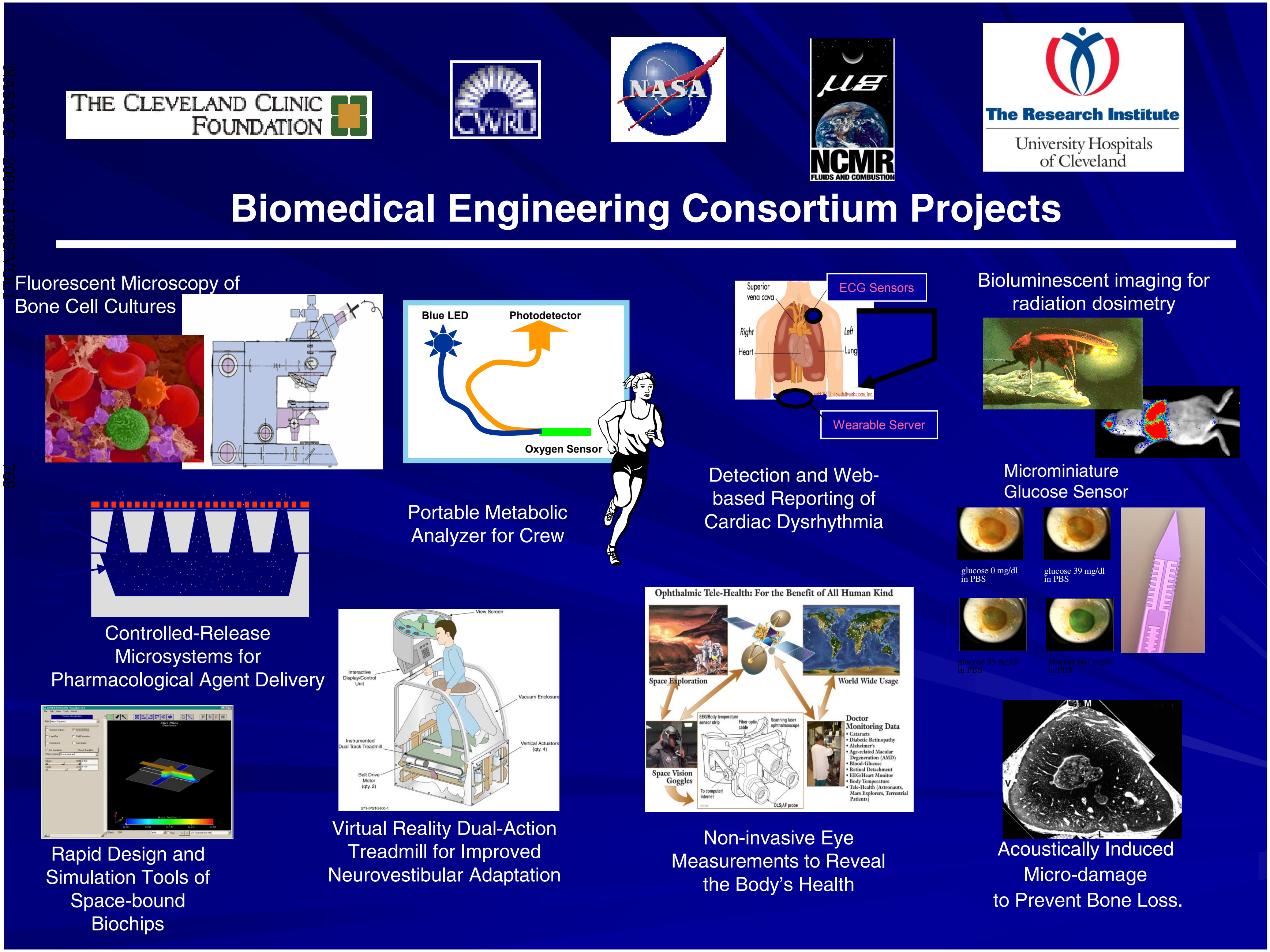
THE CLEVELAND CLINIC FOUNDATION
CWRU
NASA
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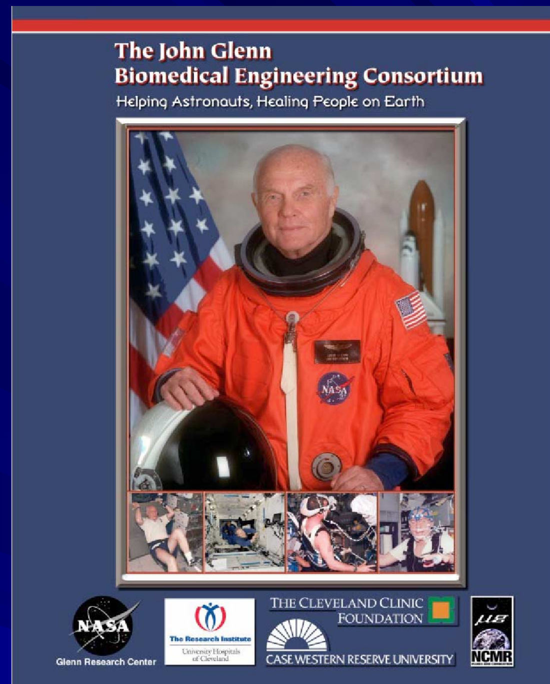
FLUIDS AND COMBUSTION
The Research Institute
University Hospitals of Cleveland
Biomedical Engineering Consortium Projects
Fluorescent Microscopy of Bone Cell Cultures
Blue LED
Photodetector
Oxygen Sensor
Portable Metabolic Analyzer for Crew
Superior vena cava
Right
Heart
Left
Lung
ECG Sensors
Wearable Server
Detection and Web-based Reporting of Cardiac Dysrhythmia
Bioluminescent imaging for radiation dosimetry
Microminiature Glucose Sensor
glucose 0 mg/dl in PBS
glucose 39 mg/dl in PBS
Controlled-Release Microsystems for Pharmacological Agent Delivery
View Screen
Interactive Display/Control Unit
Vacuum Enclosure
Instrumented Dual Track Treadmill
Vertical Actuators (qty. 4)
Belt Drive Motor (qty. 2)
Virtual Reality Dual-Action Treadmill for Improved Neurovestibular Adaptation
Ophthalmic Tele-Health: For the Benefit of All Human Kind
Space Exploration
World Wide Usage
Space Vision Goggles
Doctor Monitoring Data
Non-invasive Eye Measurements to Reveal the Body's Health
Rapid Design and Simulation Tools of Space-bound Biochips
Acoustically Induced Micro-damage to Prevent Bone Loss.



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http://microgravity.grc.nasa.gov/grcbio/bec.html

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