The John Glenn Biomedical Engineering Consortium

Helping Astronauts, Healing People on Earth

Glenn Research Center

The Research Institute
University Hospitals of Cleveland

THE CLEVELAND CLINIC FOUNDATION

CASE WESTERN RESERVE UNIVERSITY

NCMR


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

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Living in space is more complicated than just learning to move in microgravity and capture food as it floats away. For example, more than half of all astronauts become ill with a sickness called space adaptation syndrome during their first few days in space. Their bones and muscles gradually weaken in response to being released from the weight of gravity. After returning to Earth, they often have trouble with balance for several days.

Today, astronauts are spending more time in space than ever before, living and working on the orbiting International Space Station (ISS). They must perform their work and return to Earth without compromising good health. Astronauts who will someday leave the relatively protected atmosphere of low-Earth orbit must be safeguarded from increased cosmic radiation and the usual hazards of space exploration. Such protection will only be possible by integrating biology, physical sciences, engineering, and medical research to develop therapeutics, procedures, techniques, and equipment to address health and safety issues from a distance. To facilitate this interdisciplinary research, NASA's Office of Biological and Physical Research (OBPR) has established the John Glenn Biomedical Engineering Consortium (GBEC) to be managed by the NASA Glenn Research Center. OBPR has directed the consortium to concentrate its research on fluid physics and sensor technology that addresses the risks to crew health, safety, and performance identified in a NASA document known as the Critical Path Roadmap (CPR). The CPR serves as a guide for an evolving program of research to prevent or reduce the most critical space flight risks that astronauts face.

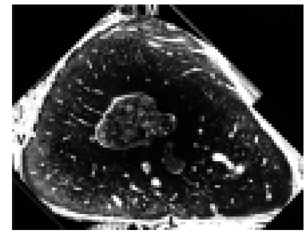
Let's Get Together: The Consortium

Members of the consortium are the **NASA Glenn Research Center (GRC)**, **Case Western Reserve University (CWRU)**, the **Cleveland Clinic Foundation (CCF)**, **University Hospitals of Cleveland (UHC)**, and the **National Center for Microgravity Research (NCMR)**. The consortium will also be working closely with NASA Johnson Space Center, which is responsible for the CPR and assures that new knowledge and technology find their way into use in space.

Scientists and engineers from the NCMR, a Cleveland-area alliance, have already assisted NASA in solving fluids-related problems in space applications and in various biomedical and biotechnology areas. Through participation in this consortium, the NCMR is expanding its role through involvement with several consortium research projects. CWRU's biomedical engineering department is one of the five best in the Nation. UHC and its Research Institute (UHRI) are ranked first in the State of Ohio in terms of research support from the National Institutes of Health. Overall, UHRI investigators attract over $100 million in extramural research funds from Federal, non-Federal, and industry sources. UHC's recognized strengths are in the areas of pediatric research, cancer, orthopedics, infectious diseases, dermatology, radiology, radiation oncology, and genetics. The CCF also maintains about $100 million in sponsored medical research and employs over 400 research scientists, associates, and fellows. It is ranked first in the Nation in cardiac expertise. NASA GRC's previous partnerships with the CCF, CWRU, and UHC have yielded patented devices like heart valves, heart-assist pumps, and bone stress sensors.

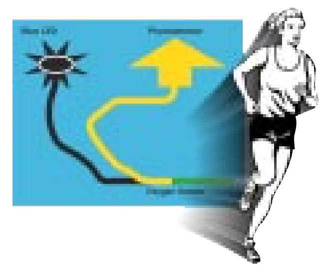
PROJECTS

The work of the consortium begins with ten research projects.



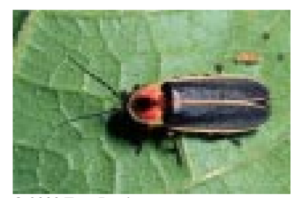
Therapeutic application of ultrasound, a high-frequency acoustic energy, to prevent bone loss in microgravity conditions.

Principal Investigator: Ulf Knothe, M.D., CCF
Co-Investigators: Dwight Davy, Ph.D., CWRU;
Melissa Knothe Tate, Ph.D., CCF, CWRU;
Jerry Myers, Ph.D., GRC; Stevan Streem, M.D., CCF



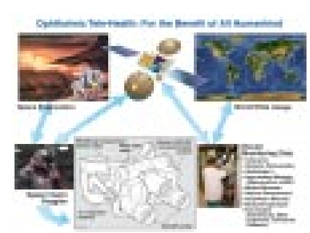
A portable device to measure human metabolic activity at a faster sampling rate than is presently available in space or on Earth.

Principal Investigator: Daniel L. Dietrich, Ph.D., GRC
Co-Investigators: Nancy D. Piltch, Ph.D., GRC;
Marco E. Cabrera, Ph.D., CWRU;
Peter M. Struk and Richard D. Pettegrew, NCMR



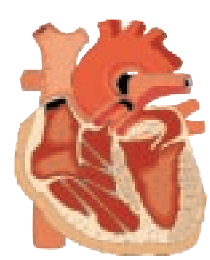
An instrument for in vivo bioluminescent molecular imaging that could be used to create a new biodosimeter for measuring effects from ionizing radiation in space.

Principal Investigator: David L. Wilson, Ph.D., CWRU
Co-Investigators: David A. Boothman, Ph.D., UHC, CWRU;
Andrew Rollins, Ph.D., CWRU



A head-mounted device similar to night-vision goggles that uses noninvasive optical technologies to address problems as disparate as radiation damage that could cause cancer, blood glucose and its links to diabetes, and brain physiology.

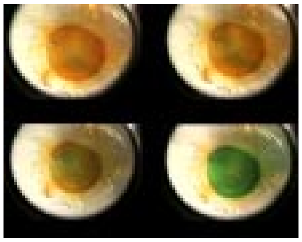
Principal Investigator: Rafat R. Ansari, Ph.D., GRC
Co-Investigator: Marco E. Cabrera, Ph.D., CWRU, UHC



A prototype instrumentation system to detect and report cardiac dysrhythmias remotely using wireless communications and a Web browser.

Principal Investigator: David W. York, GRC
Co-Investigator: David S. Rosenbaum, M.D., CWRU, MetroHealth Systems

PROJECTS

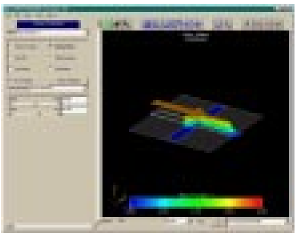


A microminiature monitor for vital electrolyte and metabolite levels with adaptability, self-checking capability, and negligible power requirements.

Principal Investigator: Miklos Gratzl, Ph.D., CWRU
Co-Investigator: Koji Tohda, Ph.D., CWRU

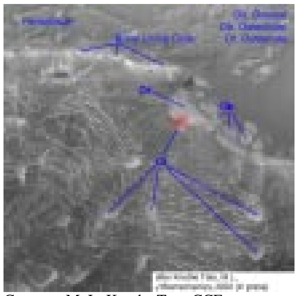
A "virtual-reality" dual-track treadmill for NASA's ongoing development of exercise devices for space crews.

Principal Investigator: Susan E. D'Andrea, Ph.D., CCF
Co-Investigator: Jay G. Horowitz, Ph.D., GRC



Biochip simulation capability that is tailored to space applications, incorporating the latest fluid physics, findings about capillarity, multiphase flow, and surface science.

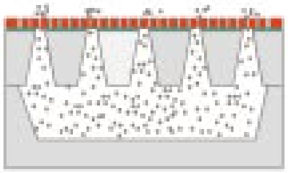
Principal Investigators: Arnon Chait, Ph.D., GRC;
Mohammad Kassemi, Ph.D., NCMR
Co-Investigators: Charles Panzarella, Ph.D., Ohio Aerospace Institute;
David Jacqmin, Ph.D., and Emily Nelson, Ph.D., GRC;
Marianne Zlatkowski, Ph.D., CWRU



Courtesy M. L. Knothe Tate, CCF.

Fluorescent microscopy techniques to assess bone cell cultures and develop countermeasures against bone loss.

Principal Investigator: Gregory Zimmerli, Ph.D., GRC
Co-Investigators: David Fischer, Ph.D., and DeVon Griffin, Ph.D., GRC;
Melissa Knothe Tate, Ph.D., CCF



Miniature implantable microsystems for the controlled release of medicines, which are diffused into the body through tiny silicon nanomembranes. The pore size of the membranes can be designed to achieve different rates of release.

Principal Investigator: Shuvo Roy, Ph.D., CCF
Co-Investigators: Aaron Fleischman, Ph.D., CCF;
David Jacqmin, Ph.D., and Noel Nemeth, Ph.D., GRC;
Christian Zorman, Ph.D., CWRU

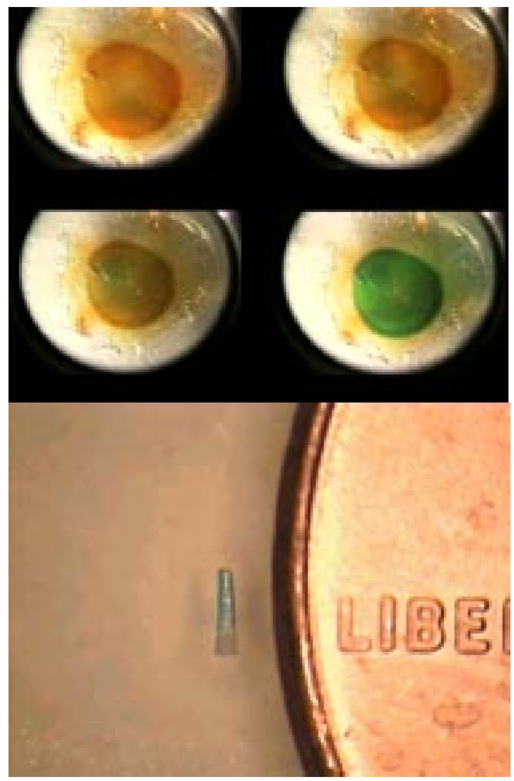
BENEFITS

Anticipated Benefits for People on Earth

All of the proposed consortium projects should produce benefits for people on Earth—some that we anticipate, and some that we will discover in the future.

Revolutionary Diabetic Care

The goal of one GBEC project is continuous drug delivery through a slow infusion, maintaining the right therapeutic concentration of the drug in the patient's body, which eliminates the pain of daily injections and enables better control. Continuous drug delivery to the body through an implantable microsystem is something that will probably benefit all of us some day. At present, patients who take drugs by injection, like diabetics, have to cope with a "burst effect": sudden, and sometimes excessive, drug effects right after administration. For diabetics, a surge of insulin often leads to dangerously low blood sugar levels.



The tiny sensor, much smaller than a penny, changes optical characteristics depending on the amount of glucose that is present.

Research by another GBEC project should produce a new monitor for very accurate, continuous monitoring of critical ions and glucose in the interstitial fluid between cells and tissues under the skin. Continuous monitoring of the interstitial fluid would be much better than taking repeated blood samples for external analyses. The tiny new monitor will penetrate the skin easily and painlessly, so that astronauts or people on Earth can insert it themselves. A watchlike device outside the body, without wires crossing the skin, will transmit the information provided by the monitor.

On Earth, the monitor could help doctors with close monitoring of electrolytes and other blood plasma components of very ill patients. Many diabetics would also greatly benefit from this technology, which would free them from having to take samples from a finger several times a day to monitor blood sugar levels.

Magnetic resonance imaging of vertebrae.

Stronger Bones

Human bone continually "reweaves" itself to stay strong. It is the only tissue in the body that repairs itself without scarring. In space, bone loses some of this natural ability to repair itself. The GBEC-proposed ultrasound therapy would expose the astronauts' bones to stimuli like those they are exposed to naturally on Earth to prevent rapid bone loss. Ultrasound has already been shown to help heal bone fractures.

If therapeutic application of ultrasound proves useful for astronauts in space for maintaining bone mass, it could also be a true lifesaver for people on Earth with fragile bones. Many older people suffer their last illness after breaking a hip. According to the National Osteoporosis Foundation, osteoporosis and low bone mass are major public health threats for approximately 55 percent of the U.S. population aged 50 and older. Ultrasound therapy would be a gentle technique to keep bones strong.

Consortium research using advanced microscopy also aims to learn more about why astronauts lose bone mass while in orbit and why their immune systems are compromised. This research will use confocal and two-photon microscopy to assess, at a cellular level, the effect of various countermeasures (like pharmacological agents and acoustic vibrations) on cell culture systems. Researchers plan to culture bone cells and lymphocytes in a special chamber attached to the microscope stage. Chemicals can be added to the cultures, and the response of the cells will be monitored. Understanding of the cell-level processes at work will help explain what depletes bones and what makes them more dense.

BENEFITS

Pain-Free Probing

A prototype instrument that looks into the eye and gathers data on the subject's health, and then sends it to the laptop computer for analysis.

The body is constantly transmitting clues about its state of health that we are not yet able to read. Having a more sophisticated ability to interpret the body's messages would make our therapeutic approach to disease much more refined.

For every tissue type in the body, there is a corresponding tissue type in the eye. The special helmet and goggles proposed by the consortium for use in space will incorporate several diagnostic procedures simultaneously, using the eye as a "window to the body" to allow noninvasive detection of various disorders. One of the technologies in the proposed device is already being used for the early detection of cataracts in clinical studies jointly sponsored by NASA and the National Institutes of Health. Someday it may enable very early screening for diseases like diabetes and Alzheimer's during a routine eye exam, improving the health of millions of people worldwide.

Another version of the instrument could be integrated into something like night-vision goggles.

Other noninvasive optical diagnostic technologies are being considered for integration into the goggle instrument for a variety of purposes: to monitor blood glucose through optical activity measurements; to monitor blood flow for age-related macular degeneration; to detect cataracts, diabetic retinopathy, age-related macular degeneration, glaucoma, and corneal abnormalities after laser in situ keratomileusis (LASIK) surgery; to detect diabetic retinopathy and the effects of aging; and to evaluate the effects of prolonged weightlessness on ocular and central nervous system circulatory physiology. This device may ultimately prove useful for several medical applications on Earth, especially for telemedicine.

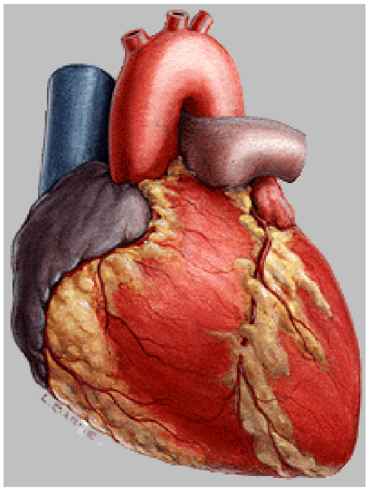
Exercise equipment for astronauts includes treadmills, recumbent bicycles, and resistance devices. A portable metabolic measurement device could be used with any of this equipment.

Data on metabolic activity, especially during exercise, is important to assess human health in space or on Earth. The consortium's proposed portable device to measure metabolic activity will have the fastest sampling rate yet available. Instead of measuring captured samples and waiting for results, exercise physiologists can read measurements taken directly from a subject's inhalations and exhalations to obtain new information on breathing patterns before, during, and after exercise.

Astronaut exposure to cosmic radiation is a risk that must be overcome before interplanetary travel can be undertaken. First, technology must be developed that accurately assesses the radiation exposure. The standard dosimeters on the ISS measure the amount of radiation striking the surfaces of the spacecraft or an astronaut's body, from which the individual's radiological burden and response must be deduced. Safety is assessed on the basis of conventional "limits." The proposed dosimeter will assess internal radiation exposure on the basis of actual physiological responses. If proven feasible, a new biodosimeter could predict radiation sickness and carcinogenesis for an individual and help determine the exposure limit that requires termination of a space flight mission. On Earth, a biodosimeter might be used to map radiation exposures to persons following a terrorist attack with a "dirty bomb" radioactive weapon.

BENEFITS

Beating Heart Attacks Before They Happen



Over 300,000 Americans die every year of “sudden heart attacks.” These deaths are attributable to electrical malfunctions of the heart known as cardiac dysrhythmias or arrhythmias. The GBEC’s proposed prototype system for use with astronauts would also apply to remote monitoring of arrhythmia patients on Earth, potentially saving many lives. This approach benefits the patients by allowing them to resume normal activities outside the hospital while being monitored continuously. The system is planned for use with Glenn’s award-winning Embedded Web Technology which would enable remote monitoring of the cardiac condition of patients in near real time via the Web.

Wait-Less Lab Analysis

A biochip is a collection of miniaturized test sites on a surface area usually smaller than a fingernail. The test sites, or microarrays, can perform many biological tests at the same time. Like a computer chip that can perform millions of mathematical operations in a second, a biochip can quickly perform thousands of biological reactions. As a result, biochips and microarray technologies are rapidly becoming critical for genetic, toxicological, protein, and biochemical research. Biochips could provide miniaturized onboard diagnostics systems and treatment devices for long-duration NASA missions that no other technology can. In this GBEC-funded research, a biochip simulation capability will be developed that will be suitable to both space and ground-based biomedical applications.

Form, Function, Fitness, Fun

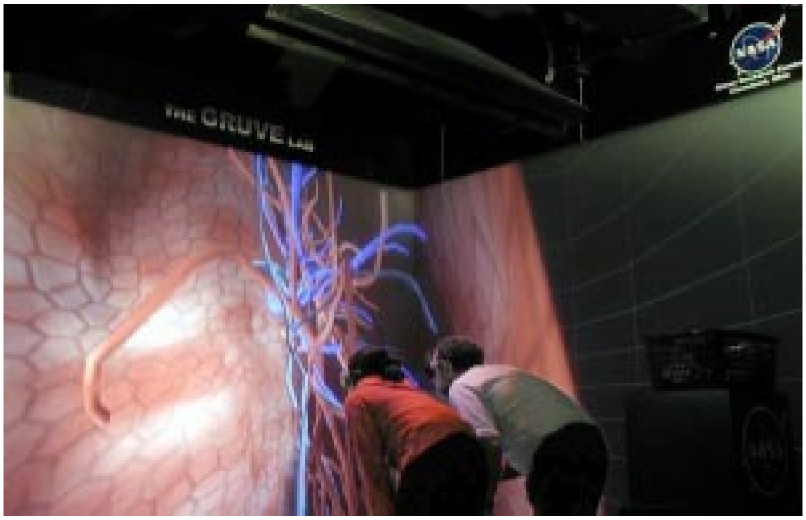
Astronauts try to maintain their fitness level, muscular strength, and bone density by working out on exercise equipment in space. Their daily routines, however, lack the physical

challenges of the gravity environment. Astronauts require exercise machinery and sophisticated training aids that can maintain bones and muscles for their return to Earth.

This dual track measures the force on each foot during exercise.

The GBEC-proposed treadmill with virtual reality technology will encase astronauts in an Earthlike world. They will be able to respond to a virtual reality environment using split, movable tracks. Unlike on conventional treadmills, each foot will be moving independently—forwards, backwards, or up and down—on its own belt. The user will experience the sensation of walking around curves, stepping over obstacles, or climbing hills. In addition to fostering normal physiological processes of growth, development, and movement, the virtual reality feature could help maintain a sense of physical orientation. And the prospect of going for a mountain hike when you've spent several weeks in a small spacecraft has to make exercise sound more appealing.

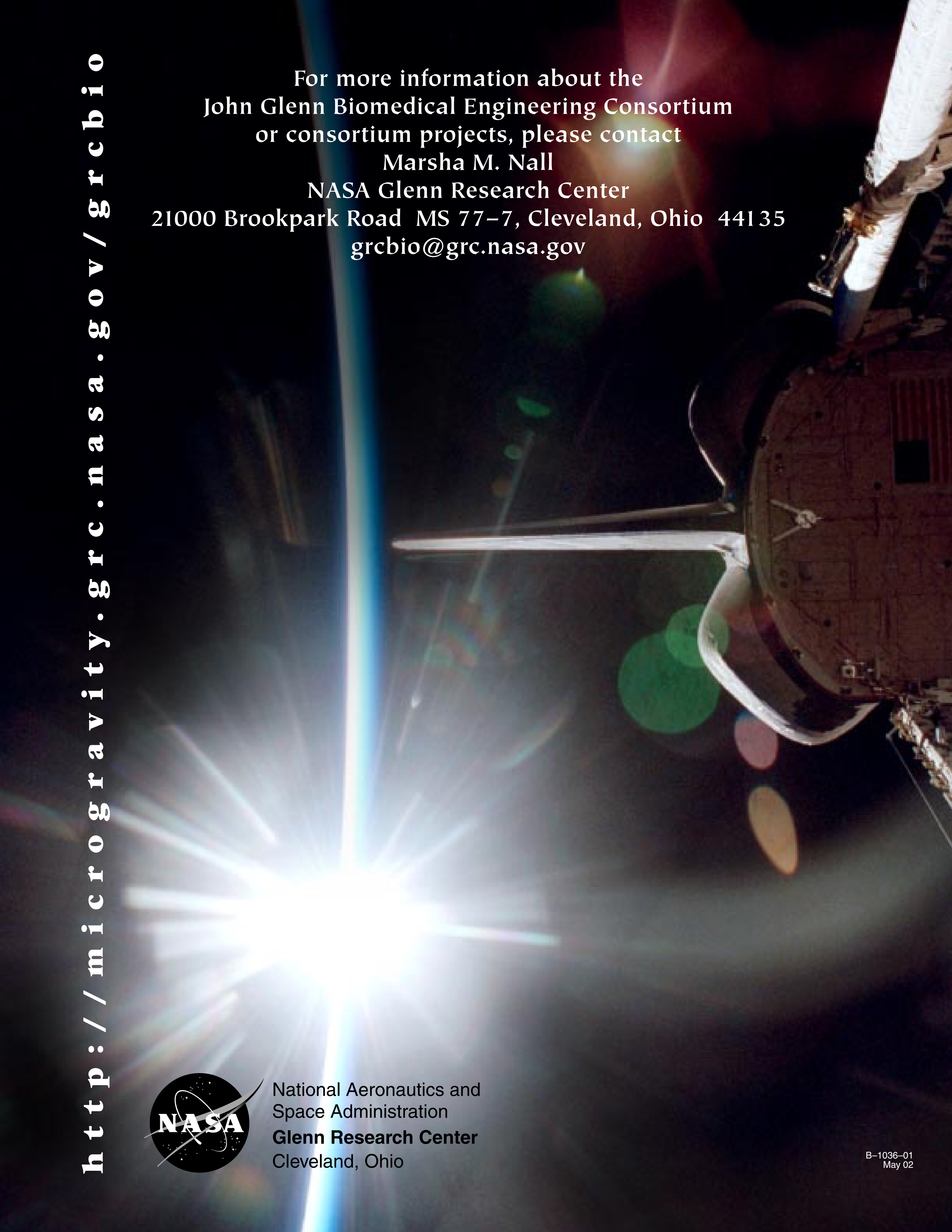
Because of the new information it can gather, this instrumented treadmill could be an ideal tool for the rehabilitation of balance disorder patients on Earth. Other Earth benefits include a better understanding of human neurological response to perturbation during walking or running. And it is easy to imagine countless applications—training, environmental adaptation, recreation—for a virtual reality system that is portable and flexible.



Researchers can use virtual reality to view the human heart.

Summing Up

While working to assure the health of people working at the ISS, the Biomedical Engineering Consortium seeks to improve lives here on Earth, and help a new generation of astronauts who may someday, on our behalf, leave the orbit of our planet.



For more information about the John Glenn Biomedical Engineering Consortium or consortium projects, please contact

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B–1036–01
May 02