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Space Research

Office of Biological and Physical Research

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The People of STS-107

Profile: John Charles

National Aeronautics and Space Administration

Letter From the Associate Administrator

When Space Shuttle *Columbia* lifts off this summer, the work of thousands of scientists, engineers, and administrators will be sent into orbit. Cradled in the payload bay of the space shuttle will be more than a hundred experiments in physical sciences, life sciences, commercial research, and other fields. Sponsored by the Office of Biological and Physical Research (OBPR) and space agencies from other countries, as well as by U.S. universities and commercial entities, these experiments range from examining how the cardiovascular system of an astronaut behaves in microgravity to how soil acts like a liquid during an earthquake. Not since Space Shuttle *Discovery* flew John Glenn and crew for a 10-day scientific mission during the autumn of 1998 has there been such a concentrated effort to advance so many research investigations at once.

The feature article for this issue, "The People of STS-107," looks at just a few of the faces and the inspirations behind one of the most important research missions to fly in recent years. The researchers interviewed for the article, Laura Barger, John Charles, Michael Delp, Buddy Guynes, and Michael Jacox, have played key roles in advancing studies that are meaningful not only to the scientific communities supporting their particular disciplines but also, and more importantly, to the public at large.

These researchers will have the opportunity to use the space shuttle as a space laboratory to take advantage of the microgravity environment of orbit. Why is conducting research in microgravity important? The microgravity of orbit serves as a comparative tool for learning important new knowledge that helps NASA in its undertakings. Space-based research also benefits people here on Earth by improving our health, stimulating the economy, and educating our children.

I am proud of the experiments that the OBPR will sponsor on STS-107. The researchers have had to work harder to get their space-based experiments done than they would have if the research had been performed in terrestrial labs. First, the investigators had to ask new, important scientific questions on topics that other scientists in the same field of research believed to be worthwhile. Then, a peer-review panel agreed that these experiments are worth spending your tax dollars to carry out in the space laboratory. Finally, the investigators and NASA had to work together to make sure that the research logistics could actually be accomplished in the challenging environment of space itself. This is often the most difficult part. One example of the problems that can arise when doing research in space is that the average "day" on the space shuttle is only 90 minutes long — 45 minutes of daylight and 45 minutes of darkness. If astronauts spend time looking out the shuttle windows, this repeating day/night cycle may affect their ability to sleep soundly during their regular eight hours of sleep. You will learn in this issue about how our research is addressing this problem. Solving this problem also has concomitant benefits of perhaps understanding the causes and effects of sleep disorders here on Earth.

STS-107 is the last planned dedicated space shuttle research mission leading into a new era of the International Space Station (ISS). We use the environment of space, particularly microgravity, to add to our knowledge of biology, physics, and life and material sciences, and to continue our preparations to become permanent residents in space. Our ability to use both the ISS and the shuttle for our research is an important NASA achievement. We hope insights gained on this mission will help answer scientific questions and will also provide lessons learned to help us perform research more effectively on the ISS.

We have a very strong OBPR team. They have proven again and again that no challenge is too great. Accomplishing the research of STS-107 is just another example of how the abilities, spirit, and expertise of team members work together toward success. We hope you enjoy learning about some of "The People of STS-107."

Kristen Erickson
Acting Deputy Associate Administrator (Management)
Office of Biological and Physical Research

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On the cover:
On the cover: Principal Investigator Michael Delp is sending on space shuttle flight STS-107 a blood vessel–response experiment that may find solutions to circulation problems for astronauts and Earthbound individuals alike. credit: NASA

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Olsen Nominated Associate Director of OSTP


credit: NASA

President George W. Bush and the entire country soon stand to benefit from the scientific knowledge and experience of one of NASA's own. Kathie Olsen, NASA's former chief scientist and acting associate administrator of the Office of Biological and Physical Research (OBPR), will help provide science advice to the president within the next few months, pending Congressional confirmation.

Bush has nominated Olsen as the associate director of the Office of Science and Technology Policy (OSTP) in the Executive Office of the President. In this capacity, Olsen, a specialist in human brain characteristics, will work closely with OSTP Director John Marburger III to fulfill the responsibilities of the office. These responsibilities are as follows:

- Advise the president on the impacts of science and technology on domestic and international affairs
- Lead interagency efforts to develop and implement sound science and technology policies and budgets
- Work with the private sector to ensure that federal investments in science and technology contribute to economic prosperity, environmental quality, and national security
- Build strong partnerships among federal, state, and local governments; other countries; and scientific communities
- Evaluate the scale, quality, and effectiveness of the federal effort in science and technology

Olsen has served as NASA's chief scientist since May 1999 and as the acting associate administrator of OBPR since May 2000. Acting Deputy Associate Administrator (Management) Kristen Erickson describes the qualities and benefits Olsen has brought to OBPR: "She has embodied the excellence in peer-review research and the positive impact that having scientists at the decision-making table can have for the nation's space program. In the two years that Dr. Olsen has worked as chief scientist, we became an enterprise, our budget more than doubled, and we're requesting two research initiatives on radiation and multiple generations in space [See "Presidential Initiatives," page 5] — unprecedented success for any enterprise at NASA."

Assuming Olsen's former position as chief scientist will be space researcher and NASA astronaut Shannon Lucid. Mary Kicza is the recently appointed OBPR associate administrator (see "OBPR Welcomes Mary Kicza," below).

For more information on the OSTP, visit the office's World Wide Web site at *http://www.ostp.gov/*.

OBPR Welcomes Mary Kicza


credit: NASA

NASA Administrator Sean O'Keefe has named Goddard Space Flight Center's Associate Center Director Mary Kicza as the new associate administrator of the Office of Biological and Physical Research (OBPR). Kicza replaces Acting Associate Administrator and NASA Chief Scientist Kathie Olsen, who has been nominated by President Bush to be the associate director of the Office of Science and Technology Policy.

Kicza has a bachelor's degree in electrical and electronics engineering from California State University, Sacramento, and a master's degree in business administration from the Florida Institute of Technology.

Kicza began her NASA career in 1982 at Kennedy Space Center, where she was the lead systems engineer for the Centaur (a chemical rocket launch vehicle) Engineering Support Group and test coordinator for the computer systems supporting the program's tests and launches. From 1992 to 1994, Kicza served as deputy division director for the Office of Space Science's Solar System Exploration Division and as program manager for the Discovery program, which included the Mars *Pathfinder* mission. In 1994, Kicza became assistant associate administrator for technology for the Office of Space Science at NASA headquarters in Washington, D.C., where she remained until 1996.

When she transferred to Goddard Spaceflight Center in Greenbelt, Maryland, Kicza took the position of associate center director for space science programs, where she was responsible for the management of all of Goddard's space science programs. She also served as the co-chair of the team that performed independent annual reviews of the International Space Station and its research programs.

Before her appointment as OBPR associate administrator, Kicza was the senior manager responsible for coordinating and integrating all of Goddard's space science, Earth science, and enabling technology programs and activities.

Kicza has been honored with NASA's Exceptional Performance Award as well as with the rank of Meritorious Executive in the Senior Executive Service for sustained superior accomplishment in the management of U.S. government programs.

Look for Kicza's inaugural OBPR associate administrator's letter in the next issue of *Space Research*.

Combustion Researchers Elected To National Academy of Engineering

Ronald Hanson, James Keck, Chung (Ed) Law, and William Sirigiano, all current or former NASA microgravity investigators, are among the 74 newly elected members of the National Academy of Engineering (NAE). Election to the NAE is the highest professional honor that can be awarded to an engineer. NAE membership is reserved for engineers who have made important contributions to engineering theory and practice or who have had significant achievements in pioneering new and developing fields of technology.

Hanson, chair of the Department of Engineering at Stanford University, was honored for the development and application of laser diagnostics and sensors in the combustion, chemical kinetics, and power conversion fields. Keck, the Ford Professor of Engineering (emeritus) and senior lecturer at the Massachusetts Institute of Technology, was recognized for developing innovative and widely used new concepts for modeling coupled chemical and physical phenomena in engine combustion and high-temperature flows. Law, the Robert H. Goddard Professor in the Department of Aerospace and Mechanical Engineering at Princeton University, was honored for his contributions to the understanding of the fundamentals of combustion processes and theory and their applications in propulsion systems. Sirigiano, professor of mechanical and aerospace engineering at the University of California, Irvine, was recognized for his contributions to the science and technology of spray combustion systems for propulsion.

Executive Budget Supports New Research Initiatives

credit: NASA

With funding from the president's proposed budget, OBPR scientists plan to further their research of how radiation and microgravity affect astronauts and the materials used to shield them from those effects.

Efforts to find out how terrestrial organisms adapt to the space environment and evolve over generations, and to learn how radiation and microgravity interact with and affect astronauts, will receive a boost with President George W. Bush's proposed budget for fiscal year 2003.

The budget, under review by Congress, includes over $21 million for two new research initiatives proposed by NASA's Office of Biological and Physical Research (OBPR): "Generations" and "Space Radiation." Generations will involve investigating how life responds, adapts, and evolves by studying in space all levels of the biological hierarchy. These studies will add new fundamental understandings of biology to space and ground-based research and will contribute knowledge to support future space missions.

The project will include ground-based research as well as long-duration flight research on the International Space Station and potentially on free-flying missions. Investigators will use integrated, highly autonomous, miniaturized biological laboratories for flight research. Studies will result in contributions to the following areas:

- Understanding of biological mechanisms that control physiological and evolutionary processes in response to long-term exposure to the space environment
- Understanding of possible consequences of such changes to crew health and spacecraft environment and structure
- Miniaturized and autonomous instrumentation for biological and biomedical research

Space Radiation involves research that will help reduce the adverse health effects of radiation on astronauts. These effects threaten NASA's ability to develop long-duration space missions for humans. Currently, large safety margins mean that most astronauts would not qualify for more than one or two 180-day missions. OBPR's goal is to increase knowledge about radiation, more accurately pinpoint its effects, and develop new countermeasures. Ultimately, the aim is to eventually have a safe, permanent presence in space.

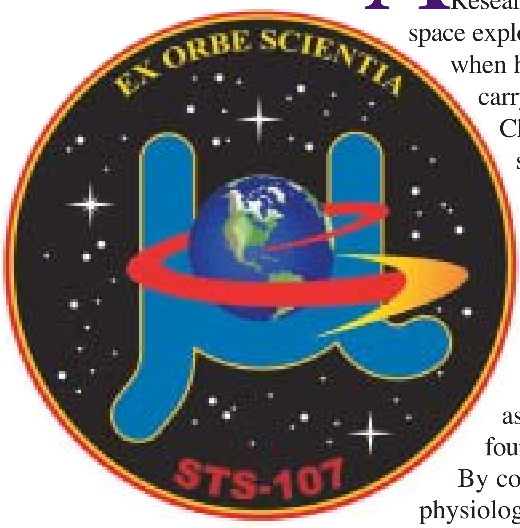
Research for Space Radiation will largely be conducted at a new ground-based irradiation facility. The Booster Applications Facility, being built by NASA at the Department of Energy's Brookhaven National Laboratory, will provide a cost-effective way to simulate space radiation for radiobiologists and materials scientists working with OBPR.

The Space Radiation effort will be integrated across all OBPR disciplines:

- Bioastronautics research investigations based on an understanding of radiobiological mechanisms will be used to develop accurate predictions of radiation risk to humans and to discover, evaluate, and validate biological countermeasures.
- Fundamental space biology studies of molecular, cellular, and tissue radiobiology will lead to accurate characterization of biological radiation effects unique to space.
- Physical sciences research will complete the required physics database detailing the interaction of radiation with materials and will develop design tools and strategies to optimize shielding.
- Space Product Development research includes remote diagnostic equipment to monitor astronaut health or aid in healthcare services on Earth in areas where traditional medical diagnostic equipment and infrastructure are not easily accessible.

The People of STS-107 — Mission Researchers Share Quest for

After years of exacting research and high aspirations, investigators and managers are entrusting astronauts on STS-107 with 30 payloads to improve travel in space and life on Earth.



Mission STS-107 is giving scientists the opportunity to look for answers to numerous questions in physical and life sciences.

Ask John Charles, STS-107 mission scientist in NASA's Office of Biological and Physical Research (OBPR), for an early memory of space exploration, and he recalls his disappointment when he wasn't able to watch the astronaut-carrying Mercury missions on television.

Charles didn't get home from elementary school in time to see them. But he could, he says, pretend to be astronaut (later Senator) John Glenn during recess while lying on his back in the playground dust, looking up at the sky and imagining himself on a rocket roaring into orbit around the Earth.

Charles never did become the astronaut he fancied he might. Instead, he found another way to stay connected to space. By combining his interests in physics and physiology, Charles would pursue a career in biophysics, researching how spaceflight affects the body and helping NASA conduct experiments in space. Now he is the coordinating scientist for the OBPR experiments on the STS-107 space shuttle flight, one of the most science-packed of recent shuttle missions.

"This flight allows scientists to do what scientists do best: ask the kind of questions that we don't yet have complete answers for," Charles says. "This mission is yet another example of the kind of investigations that we as researchers are capable of and that we as a society should expect of NASA. All are important in answering the questions inquisitive people have about the universe and our place in it."

credit: NASA

To prepare for life sciences experiments during the STS-107 mission, astronaut Dr. Laurel Clark draws blood from volunteer and surrogate astronaut John Charles, mission scientist for the OBPR experiments on *Columbia*'s July flight.

And there are a lot of questions to be asked. Thirty payloads with a total of roughly five dozen experiments will fly aboard STS-107 this summer. A superficial glance at the studies planned for the flight first reveals a diverse array of research with seemingly little commonality. Among the investigations scheduled are ones involving solar radiation, gas viscosity, condensed matter and particle physics, and communications technology. Take a closer and more detailed look at this "mixed manifest" mission, though, and the interrelations are more apparent. Because the majority of the experiments slated during the shuttle *Columbia*'s 16-day orbital sojourn planned to begin July 19 are of the applied-science kind, the bulk of the research results gleaned are likely to have significant practical impact for taxpayers on the ground.

Eighteen of STS-107's 30 payloads relate to or involve biology and biotechnology. Several studies, for example, will grow protein crystals, crucial to the creation of enhanced medications with fewer side effects. Others will look at the mechanisms involved in gene transfer and gene expression, while a set of medical experiments (some conducted in flight and others when *Columbia* lands) will study how calcium is added to and removed from bone. Two studies will determine how viruses spread and are shared within closed environments. A rotating bioreactor, the Biotechnology Demonstration System, will suspend and nurture cells for three-dimensional tissue growth under conditions impossible to replicate on Earth. And, to better understand how sleep is disrupted in space, STS-107 astronauts will wear specialized wrist accelerometers to track disturbed sleep-wake patterns that will likely aid in finding means of minimizing sleep disruption on Earth as well as in space.

"Spaceflight factors — weightlessness, radiation, rapid day/night cycles — give us valuable insights into normal biology on Earth and human health in space," Charles says. "They enhance our understanding of physiological processes using space as the newest research venue. On Earth, gravity is always present, even during bed rest or [water] immersion studies. Beyond the surface of the Earth, weightlessness will be an important parameter."

Answers Beyond Earth's Bounds

While it is common to refer to the weightlessness of space, in reality those on a spacecraft orbiting 100 to 300 miles above the planet experience from one-thousandth to one-millionth of Earth's normal gravitational pull as they freefall around the globe. Reduced gravity affects the ways components within complex systems interact, making microgravity an essential parameter for experiments in both the life and physical sciences. Researchers can observe changes to phenomena such as those involved in fluid dynamics and combustion. For instance, in the absence of a strong gravitational field, surface tension becomes more evident while convection-related processes are minimized.

One of *Columbia*'s physical science payloads is a rugged chamber for conducting studies that will examine the physics of combustion, soot production, and (in a commercial payload) fire-quenching processes in order to provide insight into new means of fire suppression. Another investigation involves the compression of granular materials to further understanding of soil behavior in order to improve prediction of earth movements in areas where earthquakes, floods, and landslides are common. STS-107's astronauts will also oversee the formation of zeolite crystals, which can speed the chemical reactions that are the basis for industrial and biomedical processes. In addition, mission specialists will conduct research on the properties of xenon as it goes from a gaseous to a liquid state, a transition during which many thousands of its atoms exhibit behavior known as long-range ordering.

According to Charles, NASA selected the life and physical sciences investigations for the mission with an emphasis on crew health and safety in preparation for extended orbital stays on the International Space Station (ISS). An independent panel of experts evaluated submitted research proposals for scientific excellence. Ultimately, proposals were competitively selected based upon scientific merit as determined by peer review, programmatic need, and funding availability. In the case of STS-107, scientific experiments were chosen from a queue of research that had already passed NASA's rigorous and competitive peer-review process. Commercial research followed a separate selection process, with emphasis on the willingness of business and industry to underwrite the experiment, potential market strength, and investment returns from the development of new products.

"STS-107 is an example of a research mission that represents a very productive use of shuttle resources for experiments that have been peer-reviewed and approved in a large number of areas," Charles says. "All of these investigations have been waiting in line for this opportunity. The space station will be the ultimate venue for these kinds of investigations."

For many members of the STS-107 science team, the mission's manifest represents a milestone in careers that often included or even began with dreams of traveling in space. Imagination can pay off — benefits derived from their research could have far-reaching impacts.

credit: G. Stephen Grindley

The STS-107 mission allows Laura Barger, a research fellow in medicine at Harvard Medical School and Brigham and Women's Hospital in Boston, Massachusetts, to combine her interest in spaceflight with studies of sleep and circadian rhythms.

Perchance to Dream

The STS experiment led by Principal Investigator Charles Czeisler to study astronaut sleep patterns has allowed Laura Barger to realize two aspirations at once. "STS-107 is a good way to combine my interest in sleep and circadian rhythms with spaceflight," says Barger, a research fellow in medicine at Harvard Medical School and Brigham and Women's Hospital in Boston, Massachusetts. After a 10-year stint as an Air Force navigator on a KC-135, a refueling airplane, Barger entered a graduate program and toyed with the idea of becoming an astronaut. But a specific kind of research interest would take priority and, eventually, lead her to space in a less direct route. "I did a lot of traveling across time zones in the Air Force," Barger says. "I experienced jet lag firsthand. That's when I became aware of the importance of circadian rhythm research."

Circadian rhythms are biological patterns that oscillate within a 24-hour period. Most organisms experience a pattern of rest and activity that repeats every day. Disruption to these patterns can have a profound effect on the sleep-wake cycle in earthbound individuals and astronauts alike. Too little slumber can lead to mental and physical impairment, interfering with concentration and potentially affecting immune system functioning.

Research suggests that sleep-deprived individuals can become, and remain, sicker (usually with garden-variety viruses and, perhaps, with more serious diseases, like heart attacks and cancer) than those who sleep normally. Certainly, sleep deprivation and/or disturbance is a chronic issue for shift workers. Those who work alternate shifts have repeatedly complained that sleep, even when obtained, is usually of shorter duration and

credit: NASA

Principal Investigator Michael Delp, an associate professor in Texas A&M University's Department of Health and Kinesiology, has designed a blood vessel–response experiment that may find solutions to circulation problems for astronauts and Earthbound individuals alike

not as restful as that experienced on a regular schedule.

The research team at Harvard Medical School and Brigham and Women's Hospital has designed a "sleep actigraphy" experiment that will examine the degree and extent to which sleep is disturbed or interrupted for the STS-107 mission astronauts. Barger says that astronauts don't sleep all that well before a mission because of excitement, anticipation, shifting of sleep times to accommodate the launch schedule, and the increased pace of preflight operations. Once in orbit, sleep is hard to come by as well; previous studies have shown astronauts sleep one to two hours less per 24-hour period in space than on the ground. Part of that disruption may be due to novel surroundings, spacecraft noise, workload, and high adrenal activity, but a more significant part may also be due to the misalignment of circadian rhythms normally set on Earth by the 24-hour light-dark cycle.

"During shuttle flights, the light-dark cycle is about 90 minutes long," Barger explains. "Seeing a sunset and sunrise every 90 minutes can send potentially disruptive signals to the area of the brain that regulates circadian rhythmicity. Additionally, the lighting onboard the space shuttle might not be sufficiently intense to maintain circadian alignment. Consequently, sleep could be disturbed. If the astronauts sleep one to two hours less per night, over a 16-day mission, that can add up to a 32-hour sleep deficit." Such a deficit may have performance consequences, possibly affecting the monitoring of experiments. Barger also points out that the consequences for long-term space travelers are unknown. "If we're to go any farther, say, on missions to Mars," she adds, "we have to understand how the human body will cope for extended periods."

STS-107 astronauts have volunteered as test subjects for the sleep study. Researchers want to know if light levels inside the shuttle are inappropriate for maintaining normal circadian rhythms, if astronauts have a harder time falling asleep, wake more frequently, and are not as satisfied by the quality of their sleep. Ninety days before launch, astronauts' sleep patterns were monitored to establish a baseline of what "normal" sleep is like for each individual; in orbit, the astronauts' sleep will be compared to their baseline measurements.

Each volunteer astronaut will wear a watch-sized actigraph, essentially a computerized accelerometer that records wrist movement in any direction. Increased wrist activity indicates that an individual is awake; thus, by monitoring wrist activity, sleep-wake patterns can be established. A light-sensitive diode on the device will track and record light levels, so that activity and sleep can be correlated with light exposure. Placing the actigraph directly on a specialized reader downloads its stored data wirelessly to a computer. Researchers will then be able to correlate objective criteria with astronauts' subjective experiences, recorded in a daily sleep log, in order to evaluate the degree of sleep disruption.

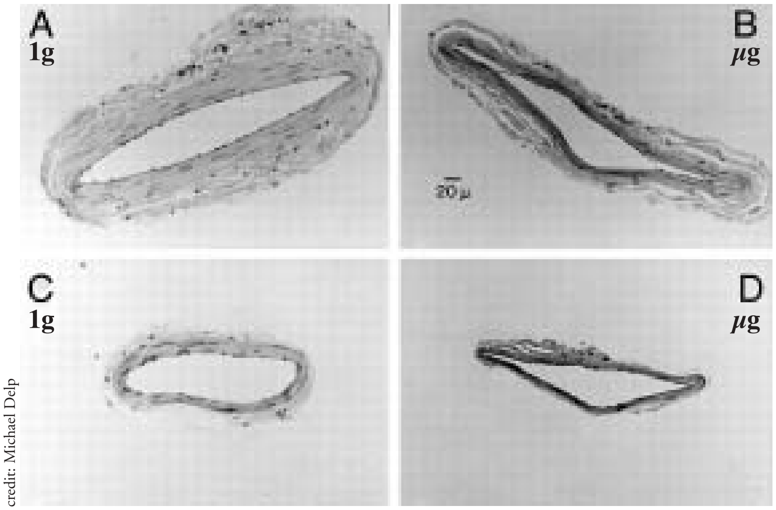
This is the third time this experiment has been conducted, with three more sleep-disturbance studies planned for upcoming shuttle missions. Repeatability is key; having multiple test subjects increases the likelihood of obtaining meaningful data while eliminating the role of chance in outcomes. "It's a relatively simple experiment that we're hoping will generate a lot of valuable information," Barger says. "We hope to be able to recommend countermeasures that will help astronauts sleep soundly." Eventually, anyone whose sleep is disturbed could also benefit.

Vascular Health in Space

Principal Investigator Michael Delp, an associate professor in Texas A&M University's Department of Health and Kinesiology, has also designed an experiment that may bring answers to health problems for astronauts and earthbound individuals alike — as well as an opportunity to participate in the "camping trip" of his dreams. As a child, Delp wanted to be either a park ranger or an astronaut. "It was that sense of adventure," he says. "I always liked camping and being in the outdoors. To me, microgravity is the ultimate outdoor adventure." Delp hopes his research in vascular health will help to make the adventure of space travel safer for those who do take their sleeping bags into orbit and beyond.

As one of the designers of an STS-107 experiment to measure blood vessel response in gravity's near-absence, Delp will directly gauge some of the detrimental effects of spaceflight. Because the human cardiovascular system is well-adapted to the constant gravitational force of the Earth — vessels in the legs, for example, constrict to prevent blood from collecting in the lower extremities — its absence causes physiological dysfunction. Blood vessels are made up of smooth muscle, which atrophies unless challenged by gravity. In reduced gravity, smaller vessels lose the ability to either dilate or constrict. The effect is intensified by duration; the longer the time without sufficient gravity, the weaker the circulatory system becomes.

Microgravity also decreases head-to-foot arterial blood pressure gradient, shifting fluids from the lower to the upper portions of the body. In turn, this triggers adaptations within the cardiovascular system to accommodate the new pressure and fluid gradients. By the time the subject returns to normal gravity, blood vessels have become "deconditioned" for Earth living, losing the ability to push blood to the brain. Without adequate



credit: Michael Delp

Delp is testing the hypothesis that blood vessels in rats will become thinner and weaker in actual microgravity, just as they do in simulated microgravity, shown in images B and D. (Images A and C show control blood vessels in normal gravity.)

blood supply, the brain shuts down, and the individual faints. Upon returning to Earth after missions of more than a few days, most astronauts become dizzy when standing upright. Sixty percent cannot pass a 10-minute stand test without losing consciousness, a condition known formally as orthostatic intolerance. With stays on the ISS lasting for months, and potential interplanetary travel expected to last two years or longer, ways must be found to compensate. (For information on a study examining orthostatic intolerance, see "Research Examines Adaptations of Cardiovascular System to Microgravity," page 12.) First, however, circulatory mechanisms must be precisely understood in order to develop effective countermeasures.

"Gravity pulls blood down to the feet normally. Arteries resist that pull," Delp explains. "In microgravity there's no weight bearing. The body responds to the lack of force by remodeling itself. Look at what happens if a weightlifter stops working out. If a muscle is no longer stressed, it loses mass."

In an effort to understand the mechanisms of these cardiovascular adaptations at the cellular and vascular levels, Delp will intensively analyze the postflight tissue of rats flown on the July shuttle flight. His hypothesis is that, in microgravity, blood vessels in rat hind limbs become thinner and weaker and constrict less in response to pressure changes and to chemical signals essential to vascular health. The physiological alterations should be apparent. Because rats react more quickly than humans to space-induced physical change, *Columbia*'s 16-day mission is the human equivalent of several months in microgravity.

The rats will be housed in special enclosures that have been used successfully on a number of prior shuttle flights. The crew will make daily health checks and will replenish the water supply as needed. Following landing, the small blood vessels in hind limb skeletal muscles that provide blood-pressure resistance will be analyzed for their responses to chemical signals and pressure changes, and for changes in vessel structure and gene expression.

Delp expects the experiment to yield crucial information on the basic physiological responses of individual blood vessels involved in blood flow and pressure regulation. Data derived from the examinations should eventually result in the development of treatments or countermeasures to improve crew health and performance following their return to Earth. The study is also expected to aid the elderly, who can be injured as a result of vascular deterioration.

"There are similarities to what happens in microgravity and what happens in old age," Delp points out. "When the elderly go to the emergency room, the reason is likely due to orthostatic intolerance, either directly or indirectly. They can't stay upright, and when they do go down, they injure themselves."

The eventual goal, he believes, is to develop devices or procedures for space travel that will pull blood down to the feet so that vessels will experience a rough equivalent of gravity levels at Earth's surface. In the short run, though, he hopes the experiment will provide information that can be used to counter microgravity's effects for astronauts living on the space station, who face longer periods of vascular recuperation after returning from extended station assignments. And for Delp, there is the personal satisfaction of understanding that which was unexplored and unknown.

"For me, this has been a great personal experience. It's been one of the highlights of my life," he says. "I like research so much because I love the sense of discovery. You get that with NASA."

On Less Than Solid Ground

credit: NASA

MGM Project Manager Buddy Guynes, also a researcher at Marshall Space Flight Center, has postponed retirement to oversee an experiment to test sand columns under microgravity conditions that cannot be mimicked on Earth.

The promise of discovery from the STS-107 mission has made Buddy Guynes delay his retirement "several times," as he awaits results from the flight of the Mechanics of Granular Materials (MGM) experiment. Guynes is a researcher at NASA's Marshall Space Flight Center, where he also serves as MGM project manager. "The possibility of retirement is appealing to me, but I want to work for a good while yet," Guynes says. "I'm expecting exciting results from the mission and would like to have a hand in getting the good news out to the public."

The physical phenomenon that MGM investigates can be experienced firsthand by anyone who buys a rock-hard package of vacuum-packed coffee at the local supermarket. Rip it open, says Guynes, and what was brick-solid suddenly becomes a soft and easily shifted mass of ground coffee beans. A straightforward change in environmental conditions — in this case, inrushing air that releases the contents from their confinement — drastically changes the properties of a bulk granular material. Once the vacuum is gone, the grains move about freely, almost like a liquid. What affects ground coffee can also affect saturated, loose soils during earthquakes, collapsing structures previously thought strong and stable.

"Before that air comes in, you can almost use that coffee [package] like a hammer," Guynes says. "As

credit: NASA

During hands-on crew training for the Mechanics of Granular Materials experiment, astronaut Kalpana Chawla connects electrical cables to a test cell in the right-hand locker of the experiment's twin double locker assembly. Three sand-filled test cells will be compressed during flight and their contents studied upon return to Earth.

soon as you let air in, it gets real loose. The soil [effects] you see in an earthquake can be similar, especially if there's water around. Water is a lubricant between the grains. When they're shaken, they also get loose."

The principal strength of soils beneath a house or sand under a rover's wheels on Mars is the friction and geometric interlocking between the faces of individual grains. But this geometry can also cause weakness: the grains' craggy surfaces stick and form small voids, making soils or powdery substances behave like a liquid when moisture and air are trapped within and particular conditions or stresses are encountered. Stresses can build faster than entrapped fluids can escape. As outside pressures increase, intergranular pressures decrease, weakening and softening the material. When the external loading equals the internal pressure in the spaces between the grains, the material liquefies. During liquefaction, soil-water composites momentarily become viscous, causing buildings to sink and tilt, bridge piers to move, and buried structures to float.

During the STS-107 flight, the MGM experiment will use microgravity to test sand columns under conditions that cannot be mimicked on Earth. In orbit, the weight of the specimen sand is no longer a factor, and stresses are uniform. This yields measurements that can be applied to larger problems on Earth. MGM scientists will study load, deformation, and fluid pressures, as well as changes in soil structure, including the formation of shear bands and changes in density.

The heart of MGM is three specimen cells containing columns of sand held in a latex sleeve and squeezed between metal plates made of tungsten. The specimen assembly is contained and compressed for more than one hour in a water-filled jacket made of an exceptionally strong plastic known as Lexan. A load cell measures forces, and three cameras videotape the experiments. The flight crew controls the experiment through a laptop computer. In all, nine experiments will be conducted on the trio of cells.

After return to Earth, epoxy will be injected to stabilize the sand columns for handling. The edge profiles will be photographed. Computer tomography scans then will produce a series of finely pixilated images rendered in three dimensions for detail. Finally, the columns will be sawed into 1-millimeter-thick disks for even closer inspection under an optical microscope.

MGM has flown on two earlier shuttle missions (STS-79 in September 1996 and STS-89 in January 1998). Those findings are already helping scientists test a number of hypotheses about soil behavior. Scans of earlier MGM specimens, for instance, have revealed internal features and patterns not seen in specimens tested on the ground.

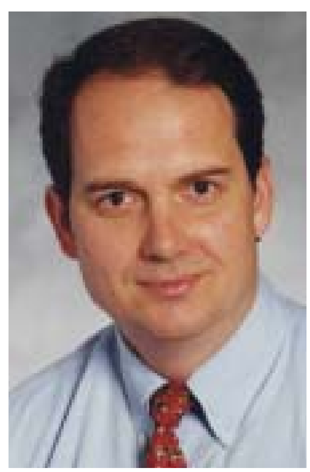
STS-107 marks the debut of SPACEHAB Inc.'s research double module, or RDM, which will double the volume available to, and substantially increase the amount and complexity of, module-borne experiments. Nestled within *Columbia*'s payload bay, the RDM is pressurized and will be accessible to astronauts via a tunnel from the shuttle's middeck. Together, the module and the middeck will accommodate the majority of the mission's payloads. Under an agreement with NASA, SPACEHAB has marketed 18 percent of the module's capacity of 9,000 pounds to various users, while NASA utilizes the remaining 82 percent for the variety of experiments it has approved.

Knowledge derived from the STS-107 MGM study will help scientists design models of soil movement under stresses. The models can then be applied to strengthening building foundations, managing undeveloped land, and handling powdered and granular materials in chemical, agricultural, and other industries. Eventually, scientists should better understand the geophysics of wind and water erosion of soil, slope development and decay, and the deposit of volcanic materials. Specialists may also improve techniques for the storage, handling, processing, and management of coarse-grained materials and powders, including those used in silos, powder feeders, conveyors, and systems for processing coal, ash, limestone, cement, grain, pharmaceuticals, and fertilizers. Also affected will be coastal and offshore engineering, and off-road vehicle engineering.

"This series of experiments could improve foundations for houses, protect buildings during earthquakes, and even prevent clogging in grain elevators. We might end up changing our building techniques," Guynes asserts. "This is one of the things that NASA is doing that has a very strong application for the guy on the street."

A Star-Set Course

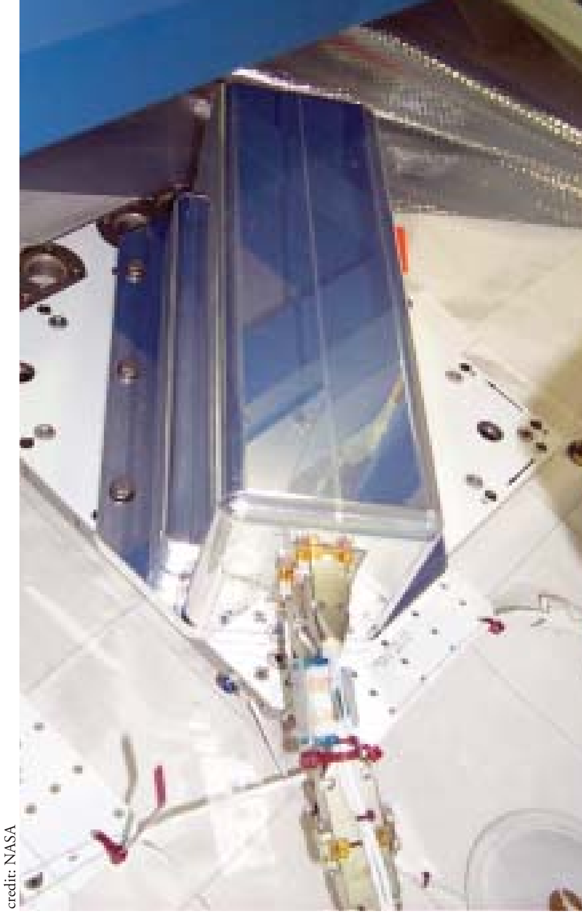
While Guynes dreams of solving some of the practical problems of builders on Earth, Michael Jacox, deputy director of Texas A&M's Commercial Space Center for Engineering, hopes STS-107 results will help point us to the stars. Jacox, who is the program manager for the mission's StarNav experiment, has been looking to the distant points of light since he was a boy. A self-described fan of *Star Trek*, Jacox says since youth he was intrigued by space exploration. "I grew up thinking I'd be Captain Kirk," he says. "I always had a fascination with the stars. I was an amateur astronomer as a kid." He remains an avid star-watcher and, as a father of five, has been known to take his children stargazing on clear Texas nights.



Michael Jacox, deputy director of Texas A&M's Commercial Space Center for Engineering, is directing the deployment onboard STS-107 of a next-generation navigation and tracking device, StarNav-1.

His stellar avidity has come in handy, as Jacox is directing the deployment onboard STS-107 of a next-generation navigation and tracking device, StarNav-1. StarNav began with a project, led by professors John Junkins and Tom Pollock, in the aerospace engineering department at Texas A&M University. NASA has utilized Junkins'

StarNav-1, seen here mounted on top of the SPACEHAB module pinpoints stars as reference points to determine the attitude and position of a spacecraft, taking pictures of the stars and matching their locations with a star catalog to aid in navigation.



credit: NASA

List of OBPR Experiments and Investigators for STS-107

Combustion Module-2 (CM-2). Ann Over, project manager, Glenn Research Center.

Laminar Soot Processes (LSP). Gerard Faeth, University of Michigan.

Structures of Flame Balls at Low Lewis-Number (SOFBALL). Paul Ronney, University of Southern California.

Water Mist Fire Suppression Experiment (MIST). Thomas McKinnon, Colorado School of Mines.

Space Acceleration Measurement System – Free Flyer and Orbital Acceleration Research Experiment (SAMS-FF & OARE). Ronald Sicker, Glenn Research Center.

Star Navigation (StarNav). Michael Jacox, Texas A&M University.

Mechanics of Granular Materials (MGM). Stein Sture, University of Colorado, Boulder.

Biotechnology Demonstration System-05 (BDS-05). Leland Chung, Emory University.

Critical Viscosity of Xenon (CVX-2). Robert Berg, National Institute of Standards and Technology.

Commercial ITA Biological Experiments (CIBX-2). Urokinase Protein Crystal Growth. Instrumentation Technology Associates Inc.

Bence Jones Protein Crystal Growth Project. Allen Edmundson, Oklahoma Medical Research Foundation.

Microencapsulation of Drugs. Dennis Morrison, Johnson Space Center.

Commercial Macromolecular Protein Crystal Growth (CMPCG). Lawrence DeLucas, University of Alabama, Birmingham.

Commercial Protein Crystal Growth-Protein Crystal Facility (CPCG-PCF). Lawrence DeLucas, University of Alabama, Birmingham.

Fundamental Rodent Experiments Supporting Health (FRESH-02). Rudy Aquilina, project manager, Ames Research Center.

Arterial Remodeling and Functional Adaptations Induced by Microgravity. Michael Delp, Texas A&M University.

Anatomical Studies of Central Vestibular Adaptation. Gay Holstein, Mt. Sinai School of Medicine.

Choroidal Regulation Involved in the Cerebral Spinal Fluid Responses to Altered Gravity. Jacqueline Gabrion, Centre National de la Recherche Scientifique, France.

Biological Research in Canister (BRIC): Development of Gravity-Sensitive Plant Cells in Microgravity. Fred Sack, Ohio State University.

Magnetic Field Apparatus (MFA/BIOTUBE): Application of Physical and Biological Techniques to Study the Gravisensing and Response System of Plants. Karl Hasenstein, University of Louisiana, Lafayette.

Bacterial Physiology and Virulence on Earth and in Microgravity (BACTER). Barry Pyle, Montana State University.

Physiology and Biochemistry Team (PhAB4) Protein Turnover During Spaceflight (PTO). Arny Ferrando, Shriners Burn Institute.

Calcium Kinetics During Spaceflight (CALKIN). Scott Smith, Johnson Space Center.

Renal Stone Risk During Spaceflight – Assessment and Countermeasure Validation (Renal Stone). Peggy Whitson, Johnson Space Center.

Incidence of Latent Virus Shedding During Spaceflight. Duane Pierson, Johnson Space Center.

Flight-Induced Changes in Immune Defenses. Duane Pierson, Johnson Space Center.

Sleep-Wake Actigraphy and Light Exposure During Spaceflight (SLEEP 3). Charles Czeisler, Brigham and Women's Hospital.

Microbial Physiology Flight Experiment (MPFE): Effects of Microgravity on Microbial Physiology. Randolph Schweickart, ICOS Corporation.

Microbial Physiology Flight Experiment (MPFE): Spaceflight Effects on Fungal Growth, Metabolism and Sensitivity to Antifungal Drugs. Michael McGinnis, University of Texas Medical Branch, Galveston.

algorithms, mathematical models, and control logic in a number of space missions, beginning with the Apollo missions to the Moon. Since founding Texas A&M's Center for Mechanics and Control in 1992, Junkins has concentrated on the creation of sophisticated devices, including patented laser sensing technology for applications in navigation, machine vision, and multimedia.

StarNav pinpoints stars as reference points to determine the attitude and position of a spacecraft. The device takes pictures of stars, matches them with a star catalog, and then uses those pictures to identify in which direction the craft — in this case, *Columbia* — is pointed. If the StarNav experiment on STS-107 proves its mettle, spacecraft could one day navigate autonomously, without human intervention. StarNav is relatively small, roughly the size of a shoebox, weighs much less than conventional star trackers, and when commercialized, is expected to retail for perhaps half the $1 million per-unit cost of conventional navigation devices.

The StarNav project is involving groups of elementary school students, who will be able to track stars on classroom computers during part of the mission. The collaboration is a result of a joint effort coordinated

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Research Update:
Bioastronautics Research

Research Examines Adaptations Of Cardiovascular System to Microgravity

Studies performed at the JSC Cardiovascular Laboratory reveal the disruptive adaptations of the heart and blood vessels to the upheavals caused by spaceflight and try to identify potential countermeasures to help protect the astronauts.

Humans have evolved to live in a world of gravity. The body has developed ways to combat gravity's downward force and has a complex and highly efficient set of mechanisms to assure the adequate flow of blood through the body. When a person is in a microgravity environment, as during orbit, the body must, in essence, completely rethink its battle plan.

One of the first adaptations of the body to spaceflight is the adjustment of the cardiovascular system. Janice Meck, director of the Cardiovascular Laboratory at Johnson Space Center in Houston, Texas, has been studying the body's cardiovascular responses to spaceflight for many years. "Our mission is to document the [detrimental] cardiovascular changes that occur as a result of spaceflight, determine the mechanism of those changes, and develop countermeasures to prevent those changes," Meck explains.

Meck and her colleagues have concentrated on one primary problem that has recurred in many astronauts, that of orthostatic hypotension, or low blood pressure upon standing or sitting. For the first few days after returning from a short-duration spaceflight, approximately 20 percent of astronauts find it difficult to maintain a proper blood pressure when they move from a lying down position to either sitting or standing. Their symptoms range in severity from simple lightheadedness, or presyncope, to actual fainting, or syncope. This problem has several mechanisms, all related to the body's responses and adaptations to microgravity. Orthostatic intolerance is caused by three factors that are related to each other: the volume of blood in the blood vessels, the ability of blood vessels to expand or constrict to maintain blood pressure, and the functioning of the heart itself. (For information on a study using rats to understand the mechanisms of these cardiovascular adaptations, see "The People of STS-107," p. 6.)

credit: NASA

When John Glenn flew as a payload specialist for the STS-95 mission aboard Space Shuttle *Discovery*, he became the oldest astronaut ever to go into space. His mission enabled NASA researchers to study the effects of aging on the cardiovascular system's ability to adapt to spaceflight.

Changes in Blood Distribution

On Earth, because of the downward pull of gravity, the body easily supplies blood to the lower limbs. The challenge is in supplying it to the upper extremities. To do this, the upper body is equipped with receptors that monitor and help maintain blood flow and pressure. In microgravity, blood volume shifts toward the head, resulting in more blood than is usual in the upper portion of the body. This increase triggers the receptors, which then cause the body to reduce the volume of the blood.

Once the blood volume is reduced, explains Meck, "then those receptors become happy again and there is a normal blood volume in the chest. However, there is less blood in the legs. Now that's just fine as long as you're up in space." But when astronauts return to Earth, the bulk of the blood goes back down to the legs, and because the total amount of blood has decreased, there isn't enough to fill up the whole system of blood vessels. This contributes to the occurrence of orthostatic hypotension.

Neurotransmitters "Forget"

Another contributor to this problem is the autonomic nervous system, which helps control blood pressure, among other things. Normally, this system is responsible for making minute and immediate adjustments to the cardiovascular system in order to maintain the blood flow and pressure. The system does this by releasing a neurotransmitter called norepinephrine that causes the blood vessels to constrict to keep the pressure at the appropriate level to supply an adequate amount of blood to the body's organs. "When you go up into space," explains Meck, "those mechanisms aren't really necessary, so besides the fluid shift that makes you lose the plasma volume, it seems that perhaps those mechanisms 'forget' [their function]." The degree of this "forgetfulness" appears to be directly proportional to the duration of the spaceflight.

Orthostatic hypotension is also caused by the blood vessels. "The vessels themselves can try to control the amount of blood getting to the organ they're serving," says Meck. She gives the example of a blood pressure cuff inflated to the point where there is no blood flow through the vessels of the arm. "The arm's vessels dilate to try to get flow going. If the cuff is suddenly released, the dilated vessels allow the blood to rush back into the arm. This increases shear stress, which actually stimulates the lining of the blood vessels to release additional vasodilators, ensuring that the arm will get better flow." This mechanism is called reactive hyperemia. Similarly, when an astronaut returns to Earth and blood rushes to his or her legs, the vessels might respond not by constricting, to force the blood back up, but by dilating further, which permits

Scientists at Johnson Space Center's Cardiovascular Laboratory use a controlled tilt test to replicate the body's responses to a shift from reclining to sitting or standing. Here, Janice Meck (far left) and Donna South (center) demonstrate the procedure with the help of Dominick D'Aunno (right).

credit: NASA

more flow downward and less pressure, resulting in less blood in the astronaut's upper body and head.

Changes in the Heart

The heart itself is also a factor in orthostatic hypotension. Some data from the Neurolab mission, which flew in 1998 with a payload exclusively geared toward life sciences research, suggest that in microgravity "the heart might be a little bit stiffer and not be able to maintain its output as well," explains Meck. Short-duration flights, such as shuttle missions, do not appear to have much of a detrimental effect on the heart.

The problem, as is only now becoming apparent, is with long-duration flights. "We're definitely seeing changes in the way the heart works [during long-duration flights]. . . . We've documented ventricular dysrhythmias [irregular heartbeats] after about a month in flight," explains Meck.

During their research into orthostatic hypotension, Meck and her colleagues have discovered that there are some identifying clues that can lead researchers to predict which astronauts will become presyncopal or syncopal after spaceflight. Astronauts who have lower vascular resistance and arterial pressure before flight do not have a sufficient resistance after spaceflight to maintain pressure and thus are presyncopal or syncopal on landing day.

Women More Susceptible

Another discovery made in recent studies is that there is a significant difference between women and men in their bodies' abilities to maintain blood pressure after spaceflight. Women generally have a higher heart rate and a lower vascular resistance than men. Thus, when female astronauts return from space, their vascular resistance, already low, is insufficient to combat the lower blood volume. In a recent postflight analysis after a short-duration spaceflight, 100 percent of female astronauts became syncopal versus only 20 percent of male astronauts.

Although much has been learned about the mechanisms involved, the problem of orthostatic instability has proved a hard nut to crack. One possible countermeasure is the drug midodrine. "Midodrine is a vasoconstrictor," says Meck, who is studying the drug's effects. "It's a really good candidate because it doesn't cross the blood/brain barrier. Most things that can act to constrict and raise blood pressure also affect the brain." Other advantages of midodrine are that it has its peak effect in an hour, reducing the risk of repeat doses due to delayed landings, and has a half-life of four hours, sufficient to help the astronauts during most of the critical landing day, when the effects of orthostatic instability are the greatest.

Multiple Solutions

The solution to orthostatic intolerance in astronauts will likely be more complex than a single drug prescription. "The cardiovascular problems associated with spaceflight are multifactorial. You might need four or five different countermeasures in some combination to solve the problem completely," says Meck.

Meck and her colleagues have many plans for future research investigating all the factors of orthostatic hypotension. Paramount is further exploration of the negative effects of long-term spaceflight on the heart itself and of why the autonomic nervous system seems to "forget" to maintain vascular resistance the longer an astronaut is in space.

Meck's research is especially valuable now that NASA is poised on the edge of longer-duration spaceflights. For long flights, the percentage of astronauts who suffer from orthostatic hypotension rises from 20 to 80. Meck's research may also benefit the half a million people on Earth who suffer from orthostatic intolerance. Some have symptoms so severe that they are unable to lead normal lives. Meck's research with the astronauts is closely watched by doctors treating these ground-based patients.

Carolyn Carter Snare

For more information on Meck's cardiovascular research, see *http://www.jsc.nasa.gov/sa/sd/facility/labs/Cardio/cardio.htm* on the World Wide Web.

John Glenn, World's First 77-Year-Old Astronaut

When John Glenn returned to space on shuttle mission STS-95 in 1998, Janice Meck, of the Cardiovascular Laboratory at Johnson Space Center, studied his cardiovascular response to spaceflight closely. Surprisingly, Meck discovered that the differences that age had made in his body better equipped Glenn to handle the cardiovascular adaptations to a microgravity environment.

When Glenn returned from orbit, far from feeling faint or suffering from cardiovascular stress, he was calm and downright chipper. Meck remembers, "He was standing there laughing at me when I was trying to tell him to be quiet during his tilt test. He was not in any stress at all.

"An older person has a different strategy than a young person in maintaining blood pressure," explains Meck. Glenn had a high release of norepinephrine, which helps maintain pressure, both before and after spaceflight. This response is typical of the elderly and for Glenn, this resulted in a normal level of vascular resistance. Glenn also had a higher cardiac output than the other male astronauts, possibly due to a greater venous return. This higher output, coupled with a normal vascular resistance, enabled Glenn to maintain an adequate blood pressure on landing day.

These research results were published in Rossum, A., Ziegler, M., & Meck, J. (2001). Effect of spaceflight on cardio-vascular responses to upright posture in a 77-year-old astronaut. *The American Journal of Cardiology*, 88, 1335–7.

Research Update: Fundamental Space Biology

The Avian Development Facility: A Successful First Flight

A new facility for incubating quail eggs in space had an "egg"-ceptionally successful first flight aboard the space shuttle, giving scientists new data for puzzling out the problems of bone loss and vertigo.

One of the primary missions of NASA's life sciences researchers is to develop an understanding of how to safely sustain human life in space. Over the decades since the first spaceflight, researchers have discovered that a low-gravity environment has multiple and variable effects on the human body. Because relatively few humans are exposed to a microgravity environment, researchers often use animal models to obtain useful data that can be applied to human problems. One such animal model is the Japanese quail — specifically, researchers study embryonic development in the species.

"The quails have a short incubation time of 15 days, which makes them an ideal species to be used on shuttle missions," says Principal Investigator (PI) J. David Dickman, of the Central Institute for the Deaf in St. Louis, Missouri, where he studies the effects of microgravity on the development of the vestibular system. This system is the part of the inner ear that provides humans, as well as other animals, with a sense of balance. Dickman's most recent experiment flew on STS-108, which launched on December 5, 2001. Dickman further explains why quail eggs are a good model for study in microgravity: "The quails' development happens very quickly, and during embryogenesis [development of the embryo], we want as much of the exposure to occur in the microgravity environment as possible."

PI Stephen Doty, of the Hospital for Special Surgery in New York, New York, studies the effects of microgravity on quail skeletal development and also flew an experiment on STS-108. Doty notes that quails are good models for his work because the data obtained from studies of Japanese quail skeletal development are relevant to humans and other organisms: "When looking at the cellular activity that controls mineralization [of bones], these cellular mechanisms are all the same, regardless of whether we are looking at a quail, a rat, or a human."

SHOT Into Space

To study the development of quail embryos in microgravity, researchers needed a means of getting the quail embryos into orbit. This is where Space Hardware Optimization Technology (SHOT) Inc., in Greenville, Indiana, came in. John Vellinger, one of SHOT's cofounders, had as a high school student conceived of a project to study the effects of microgravity on embryogenesis in chicken eggs. In 1983, Vellinger's research proposal became a national winner in the Shuttle Student Involvement Program, which was sponsored by NASA and the National Science Teachers Association. With a grant from Kentucky Fried Chicken, Vellinger paired with engineer Mark Deuser (also a SHOT cofounder) to develop an incubator for use in a space environment. Their first-generation hardware flew on STS-29 in March 1989 as the CHIX in Space experiment.

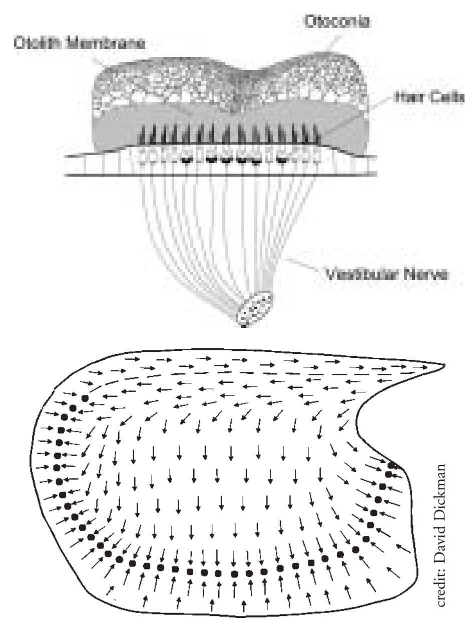
From this prototype was developed the Avian Development Facility (ADF), used by Dickman and Doty on STS-108. The ADF is an incubator designed to house 36 Japanese quail eggs and to fit in a space shuttle middeck locker.

Super Incubator

Kristina Lagel, a Lockheed Martin contractor at Ames Research Center at Moffett Field, California, was the project scientist for Dickman's and Doty's experiments on STS-108, as well as for the validation of the hardware. She describes her role as being a liaison between the PIs and NASA, helping the PIs to meet as many of their objectives as possible. Lagel expects that the ADF will be readily accepted by researchers because Vellinger sought input from the avian research community at the earliest stages of design and development and then tried to meet as many of their requirements as he could in constructing the ADF.

Although the ADF is similar to incubators found on Earth, it has some special features that are important for obtaining useful data for the PIs. The ADF features an onboard centrifuge that maintains half of the eggs under a 1-g force to simulate gravity while in orbit, thus providing a normal-gravity control that experiences all the same effects of spaceflight as the experimental animals, except for the microgravity conditions. Lagel notes, "An on-orbit control is what almost all science people would love to have." That sentiment is echoed by Dickman, who says, "The onboard centrifuge is the number one reason the ADF is a fantastic piece of hardware. For the first time we were able to expose all eggs [experimental and control] to exactly the same environment."

Lagel adds that another important feature of the ADF is its environmental controls. Temperature, humidity, oxygen, and carbon dioxide are all controlled by the ADF and maintained at optimal levels for embryo development. Eggs can be chilled



The vestibular system in birds contains six different receptor populations or organs. Three of these organs contain small "stones" or otoliths (top), which are sensitive to head movement relative to gravity and move in response to linear acceleration. Vestibular receptor cells (bottom) are normally organized in a fan-shaped pattern, which allows the cells to respond to directional movement.

to forestall the onset of development until the facility is in space, at which time a crewmember can enter a sequence on the ADF's push-button panel to bring the facility up to incubation temperature.

Dickman comments that, second to the capability to run onboard control experiments, the best feature of the ADF is the injection system that can be programmed to inject a fixative solution into specific eggs at specific times. "That gave us snapshots of development. Again, it was a first, and something that the astronauts didn't have to do," he adds.

Dickman and Doty chose to have embryos fixed at days four and seven of development, as well as day 12, when the eggs had returned to Earth. Because they were looking at different physiological systems, the researchers were able to share the eggs to obtain a maximum amount of data from a limited number of samples.

A Matter of Balance

The vestibular system in birds has six different receptor populations, or organs, within the inner ear (mammals have five). Three of these receptor populations in birds contain small "stones," or otoliths. The otoliths are sensitive to the movement of the head relative to gravity and move in response to linear acceleration (such as is experienced during a space shuttle launch or when accelerating a car). The other three receptor organs are sensitive to rotational movements of the head and do not respond to gravity or linear acceleration. These properties of the vestibular system are what give animals their sense of balance, and disturbances in the vestibular system can give rise to problems for humans such as motion sickness and a malady known as benign positional vertigo (BPV).

Dickman's experiment in the ADF looked at four different aspects of the vestibular system and how their development was affected by a microgravity environment. The first was the formation of the otolith particles, or otoconia, which the researchers hypothesized would be larger and more numerous than those grown under the influence of gravity. The researchers also wanted to see how the neurons that carry signals from the receptor cells of the vestibular system to the brain formed. In normal cases, the vestibular receptor cells are organized into a specific fan-shaped pattern that allows the cells to respond to directional movement in space. Says Dickman, "We thought that this organizational pattern would be purely genetic, and we wanted to see if microgravity actually influenced the development of that pattern." The fourth area of interest was the formation of synapses, small vesicles filled with neurotransmitter chemicals that carry information from the receptor cell to the nerve fiber. Again, the researchers were interested in whether embryogenesis in a microgravity environment would affect the number of synapses that developed.

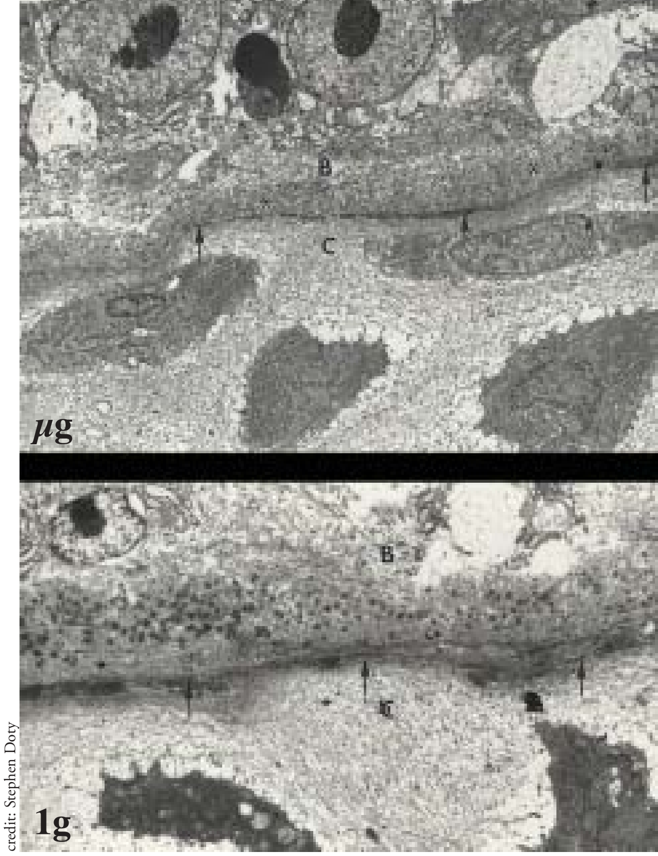
As yet, it's too early for Dickman to make any real conclusions from this study; however, one trend that the researchers have noted is that the otoconia in the embryos that developed in microgravity do appear to be larger than those of their control counterparts. Dickman was surprised to see that there are indications that the fan-shaped arrangement of receptor cells may also be altered under the influence of microgravity.

How will this research ultimately benefit astronauts or people on Earth? Dickman uses the example of people affected by BPV, in which the otoconia become dislodged from the otolith receptor and stuck in the rotational sensor parts of the vestibular system. Says Dickman, "If we understand the process of how the otoconia are made in microgravity and hypergravity, and then begin to look at the genetics that actually control otoconia growth, we might be able to apply that knowledge directly to BPV here on Earth."

Astronauts also develop vestibular system deficits during long-duration space missions. "We do think they adapt back [upon return to gravity]," notes Dickman, but "we think that gravity is necessary for the proper development of the vestibular system." For the future, if humans expect to colonize space, then the question of normal development of the vestibular system in the absence of normal gravity will take on even greater significance.

What About Bones?

Under microgravity conditions, bones demineralize, resulting in osteoporotic conditions. Doty sees the study of embryos that develop in a microgravity environment as an important piece of the osteoporosis



credit: Stephen Doty

Electron micrographs of quail limb bones that formed under the influence of microgravity show decreased mineralization compared to bones formed in normal gravity. The letters "B" and "C" indicate bone and cartilage sides of the sample, respectively, with the arrows marking the junction between bone and cartilage cells. The asterisks indicate where mineralization begins. The bone that developed during spaceflight (top) shows less mineral compared to the control sample (bottom); the control sample clearly shows mineral deposits (dark spots) that are absent in the flight sample.

puzzle: "If you try to study osteoporosis in a normal model, it might take many months or years to reach an osteoporotic state. In these spaceflight conditions, we are developing osteoporosis in these models almost immediately."

One of the things that Doty and his team are looking at is development of the limbs in quail embryos. Having conducted studies on the Russian Space Station *Mir,* Doty can say that when an embryo is allowed to develop fully, the development of the limbs does not appear to change much in microgravity. During the early periods of development, from days seven to nine, development does appear to slow, only to catch up later.

"At the cellular level, however," notes Doty, "it looks like the mineralization process may very well be affected. Even though the limb development is normal with respect to size, the degree of mineralization may actually be less."

Using the Japanese quail model in the ADF is important to Doty's research because all of the quail skeletal development occurs during spaceflight. "One of the problems we've had with studying rodents and humans is that they already have a

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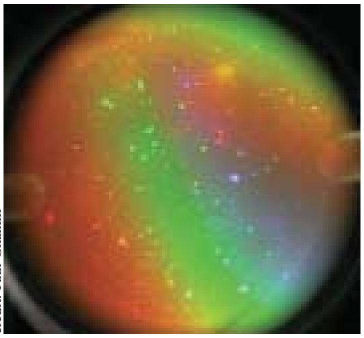
Building Momentum For Colloid Engineering

What researchers have learned about hard sphere colloidal crystals from experiments conducted in space is leading them to ways to control crystal growth for the creation of novel structures, one particle at a time.

For researchers like Paul Chaikin and Bill Russel, of Princeton University, understanding the structure of a material at the atomic level is crucial to understanding its properties. That's because all of the physical properties of matter, such as weight, hardness, color, elasticity, and the ability to conduct heat and electricity, are determined by the kinds of atoms present in the substance, the way they interact with each other, and the type of arrangements the atoms form once they have reached equilibrium.



credit: Paul Chaikin

Like atoms but on a larger scale, small particles in a colloidal solution assemble to form an ordered crystalline structure, such as the 1-micron, opalescent crystalline particles shown here. Paul Chaikin and William Russel study how the particles interact to learn how — and perhaps eventually to influence how — atoms reach a state of equilibrium.

But atoms are small and very difficult to study. What researchers need is a system that models the behavior of atoms on a larger scale. Colloidal suspensions provided Chaikin and Russel with just such a model. Colloids are a category of complex fluids consisting of micron-sized particles suspended in a liquid or gas. Chaikin and Russel's model system consists of hard plastic spheres suspended in a liquid. Like atoms, the suspended solid particles move around, bump into one another, and settle into positions where the forces acting on the particles are in balance or equilibrium.

This balancing of forces is what gives a solid material its structure, allowing it to keep its shape even though the atoms of which it is composed are in constant motion. At equilibrium, each particle has positioned itself in a way that provides the maximum elbow room between it and its nearest neighbors. This happens when particles bump into each other and are forced into a sort of pocket of space surrounded by the other particles. Atoms prefer to maintain a certain distance from their neighbors, but due to the presence of other atoms in close proximity, the best they can do, Chaikin explains, is for each one of them to have pockets of exactly the same shape around them. These equally sized pockets, one right after the other, form an ordered, or crystalline, structure.

While studies focusing on the structure of a material in equilibrium are useful to researchers for understanding the properties of a substance, by learning how a material reaches this state, Chaikin and Russel hope to be able to influence the process and eventually engineer useful structures with predictable, controllable properties.

Losing Weight

Although their colloidal model allows free movement of the spheres, Chaikin explains that it has a serious limitation: "Weight is a factor and causes the spheres to settle to the bottom of the container." This results in a greater density of spheres at the bottom of the container than at the top. The concentration gradient makes it impossible to study a uniform sample in equilibrium. The problem was how to study these hard spheres without the interference of gravity. The researchers determined that studying the colloid samples in microgravity would not only eliminate sedimentation, it would also reduce the amount of swirling that takes place in the fluid as the hard spheres move. "This swirling motion, called convection, also puts the system out of equilibrium," says Chaikin. "Microgravity gets rid of that motion too."

Chaikin and Russel first flew their colloid samples in microgravity onboard space shuttle flight STS-73, which launched

credit: Paul Chaikin

A colloid crystal grown in space develops into a snowflake-like structure called a dendrite, a form that it cannot attain on Earth, since gravity causes the fragile arms of the crystal to break off as it comes into contact with other crystals.

in October 1995. For this experiment, called the Colloidal Disorder-Order Transition (CDOT), the researchers wanted to see what the crystal structure would be when a colloid sample reached equilibrium in microgravity. "We were expecting to see that the samples would form nice big crystals of a particular type," Chaikin recalls. "What we thought would happen didn't happen, but all sorts of other things did, so it was terrific. It was all unexpected."

Prior to CDOT, two different theories of the type of crystalline structure that would form from hard sphere colloids at equilibrium held sway. One predicted a sixfold axis of rotation, or a hexagonal crystalline structure; the other predicted a fourfold axis of rotation, like a cube. CDOT yielded crystals large enough for qualitative measurements of their structure to be made, which led to theoretical work showing the fourfold axis of rotation to be the most likely structure. This was later confirmed by the Physics of Hard Spheres Experiment (PHaSE), described below.

Other theories of crystallization were also being put to the test by the results of the CDOT experiment. Chaikin and Russel were able to answer some questions about how crystallization actually begins. "The way that people thought that the crystals would grow is that you would have a little seed that was like a sphere, and once you got the radius of the sphere beyond a certain size, it would just continue to grow. The picture we got down immediately from the space shuttle showed that that wasn't what was going on," says Chaikin.

Instead the researchers discovered snowflake-like structures called dendrites, which hadn't been seen before in colloidal experiments conducted on Earth. With these results in hand, the team was later able to show mathematically that dendrites should in fact grow but that the reason they had not been seen on the ground is because the crystals are very fragile. As the dendrites grow in laboratories on Earth, they settle onto other crystals, and the forces on the arms of the dendrites cause them to break off, leaving a spherical structure.

CDOT yielded another surprise for the team of researchers. Chaikin explains that on Earth, if hard sphere colloid samples are too concentrated, they don't crystallize at all. These colloids are said to be in a glass state, because they solidify before they can form crystals. Samples of colloids that had failed to crystallize after months on Earth were sent to space in the CDOT experiments. "We sent them up and they crystallized very quickly," Chaikin recalls. "We still don't understand why, but we do understand some possibilities. On Earth, gravity may pull the particles together even though they are not dense enough in the fluid to be touching one another on their own, jamming them against one another so that they can no longer move."

When crystalline samples return to Earth from space, most get destroyed by the gravitational forces on landing because they are so fragile. "What was really neat about that experiment," says Chaikin, "is that when the samples came back . . . the glass sample [that had crystallized in space] was very strong because it was made from a very high concentration of hard spheres. It survived landing."

In order to be certain that the unusual results obtained in space were not the result of a mix-up in samples, the team decided to stir half the crystallized sample. The portion that was stirred so that it no longer contained any crystals grown in space has remained a glass sample in the lab at Princeton. The portion that crystallized in space has remained crystalline. "That's how we knew that in fact it wasn't a bad sample or anything that resulted in the unexpected crystallization in space — it was the effect of gravity that kept the glass portion of the sample from recrystallizing."

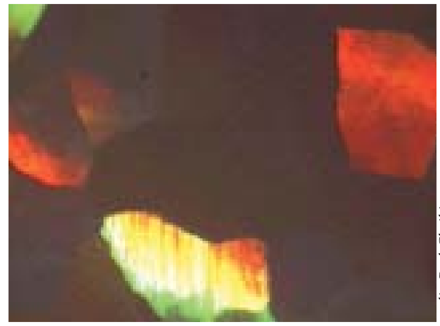
A Sharper Image

Although a highly successful experiment, CDOT yielded only very rough images of the structure of the hard sphere crystals, so Chaikin and Russel knew the next step would be to sharpen those images. "A whole new apparatus was designed with state-of-the-art optics and some clever designs to help us determine the crystal structure and also to watch the nucleation [the very beginning stages of crystal growth] and later growth of the crystals," says Chaikin. William Meyer, of Glenn Research Center (then called Lewis Research Center); David Cannell, of the University of California, Santa Barbara; and Anthony Smart, of Titan-Spectron, were instrumental in designing the new apparatus and procedures. This time, the team wanted to know even more about the crystalline samples, like how elastic they are, when nucleation occurs, and how quickly the crystals grow. The Physics of Hard Spheres Experiment, designed to answer these questions and to give researchers a chance to see the crystallization process, flew onboard space shuttle flight STS-94 in July 1997.

It's a Matter of Size

What PHaSE revealed to the research team was again both unexpected and exciting. As it turns out, crystals don't just start growing and then continue on that path until they fill up all available space in the sample container. What's actually going on is a much more competitive process. In a given colloid sample, nucleation begins at what appear to be several random points within the fluid. The crystal nuclei that begin growing the earliest can be quite large by the time other nuclei begin to grow.

"What happens," explains Chaikin, "it that the bigger ones slowly eat away at the little ones until the crystallite gets bigger and bigger. This is a very slow process, and finally, if you waited long enough, you would get a single crystal." Although it was known prior to flight that the bigger nuclei should consume the smaller nuclei, no one expected that this



credit: Paul Chaikin

Measuring approximately one centimeter in width, the large single crystal in the foreground is the largest hard sphere colloidal crystal grown to date. Researchers were able to grow this "giant" crystal by separating a single nucleus from the colloidal solution, thereby controlling part of the nucleation and growth process.

would be happening at such an early stage in the growth of a crystal.

In fact, says Chaikin, this process is known to happen in other systems as well. For example, "if you breathe on glass you get a fog," he describes. "Initially in that fog there are tiny water droplets that condense onto the glass from water vapor. Immediately what happens is the larger ones start growing and the smaller ones disappear. The large ones grow until you get really big droplets. The same thing happens in a colloid. It's called coarsening.

"What's cool," he continues, "is that once you know that something is happening, you can figure out ways to prevent it. For instance, the dendritic growth we saw in the early research did bother some of our experiments because we wanted to study other phenomena and because we wanted to grow big crystals and because we didn't want to have this coarsening phenomenon. Since we knew what was going on and we knew what caused it, we could figure out a way around it."

To eliminate the problem of competition between growing crystallites, the team grew a single crystal from one nucleus, resulting in the "world's biggest hard sphere colloidal crystal," according to Chaikin. Measuring approximately a centimeter in width, Chaikin admits that the single crystal wasn't enormous, but it proved the theory that the nucleation and growth processes were within the researchers' control.

Building Steps On Solid Principles

The next step for Chaikin and Russel is to use all that they have learned about the nucleation and growth processes to control the outcome of crystallization. Advanced engineering like this requires equally advanced tools. For forthcoming

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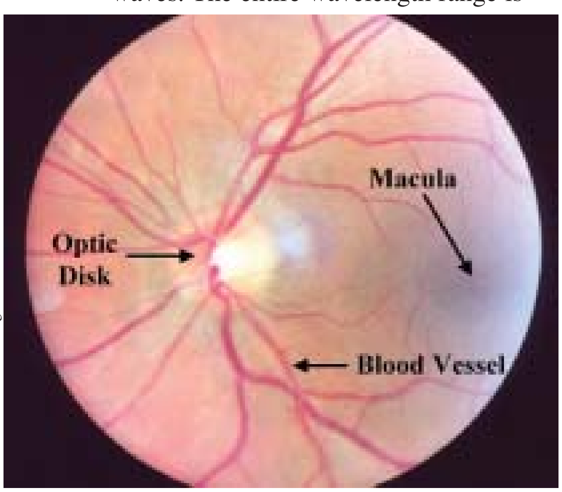
Downsized Technology Reveals Secrets From Slices of Light

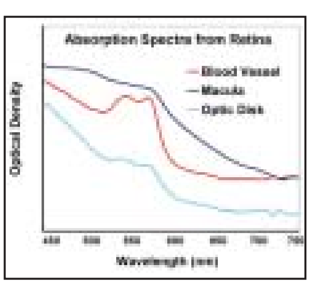
A new breed of portable hyperspectral imaging sensors is being developed to enhance the health of astronauts as well as to identify counterfeit money and contaminated food without damage to the sample.

It has been known for centuries that light produces a rainbow of color when passed through a prism. However, it was not until the 19th century that scientists began to understand the physical characteristics of light — primarily that light has wave properties. In 1801, Thomas Young, a British physician, was the first to determine that lights of different colors have different wavelengths. Each color of a rainbow corresponds to a light wave with its own unique wavelength, measured from the crest to the trough of the wave. The shorter the wavelength, the higher the energy.

However, it was not until the middle of the 19th century that scientists determined that visible light is just one of several forms of electromagnetic radiation, or energy. Other forms include X-rays and radio waves. The entire wavelength range is called the electromagnetic spectrum and is separated into groups, such as visible light or infrared, depending on the length of the wave and its effect on material objects. All objects and substances give off electromagnetic radiation, either from within or as a reflection from another source. If this energy can be detected and analyzed, it can reveal an enormous amount of information about a sample or object.



credit: ProVision Technologies



ProVision's hyperspectral imaging system can scan the human eye and produce a graph showing optical density or light absorption, which can then be compared to a graph from a normal eye. Scans of the macula, optic disk or optic nerve head, and blood vessels can be used to detect anomalies and identify diseases in this delicate and important organ.

In the early 1960s, a technique was used that did just that. It was discovered that by using various color filters on the imaging apparatus of satellites, much more detail could be detected than with regular film cameras. This new technology was called multispectral imaging because it was capable of picking up several spectrally noncontiguous color bands, or bands that are not within a continuous wavelength range. This was a great improvement over previous technology and was used to study agriculture, topography, and even the atmosphere.

Twenty years after the first satellites went into space, the technology was further improved. Hyperspectral imaging (HSI) was first used by the Airborne Imaging Spectrometer, developed at NASA's Jet Propulsion Laboratory. Hyperspectral imaging captures hundreds of contiguous color bands, thus enabling it to detect much greater detail than multispectral imaging. However, this sensitivity initially limited the use of HSI because it picked up changes and variations in the sample that the computers could not separate or analyze. It would take time for the analytical technology to catch up with HSI's optical abilities.

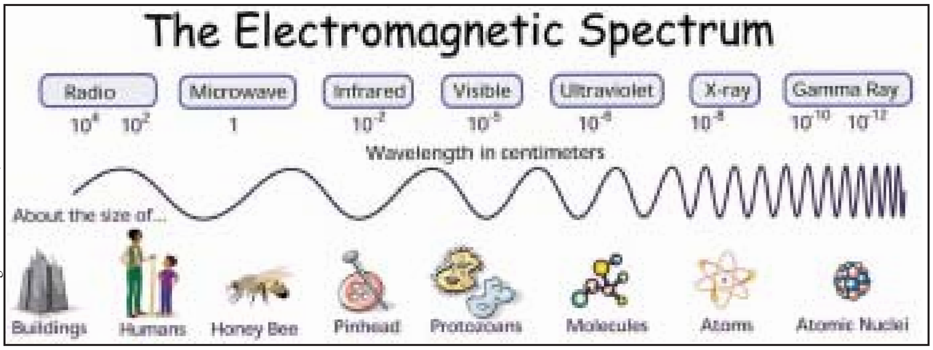
From a Buick To a Breadbox

While hyperspectral imaging had greatly enhanced capabilities, the sheer weight of the instruments involved originally limited it to satellite and aircraft use. A typical apparatus could weigh as much as a ton. However, George May and his colleagues at ProVision Technologies, a NASA commercial space center at Stennis Space Center in Mississippi, have been working on this technology for three years and have developed a new system that is much smaller. The new apparatus is about the size of a breadbox, small enough to hold in your hands or put on a tripod.

May's downsized HSI system also has advanced analytical capabilities. The sensors read the reflected electromagnetic radiation from the surface of a sample and separate it into spatial components of data that correspond to sections of the sample, or data blocks. The spatial resolution of a sensor is determined both by the optics of the sensor and the distance between the sensor and the sample. For example, if a sensor had a resolution of 1 meter and it took a reading of a 10-meter by 10-meter garden, it would pick up 100 individual blocks of data. A sensor examining a mountain for mineral deposits would have a different spatial resolution than one examining mold for a toxin.

Once the sensor has scanned an object, the data is separated into blocks, which are then broken down into as many as 1,024 spectra, or increments of the wavelength range of the instrument. Image analysis software then analyzes these data and produces a spectral signature that shows the detected electromagnetic energy reflected off the sample. The more spectra from a particular sample, the more data there are to analyze, so ProVision's HSI system is an improvement over the multispectral imaging system.

The instrument's greater sensitivity allows ProVision to generate more spectra that are unique to particular substances. With these spectra, scientists are building a signature "library," which can be used as a reference when scanning for target substances on a sample. For example, a raw chicken on an assembly line can be scanned to look for the unique signature of fecal material, which is on record in the spectral library. As technology progresses and sensors can pick up more and more detail, the unique signatures can be refined, but at this time,



credit: Imagine the Universe, NASA

Hyperspectral imaging scanners detect a specified range of energy wavelengths from the electromagnetic radiation spectrum.

there are still substances that give off signatures indistinguishable from others.

Inside the System

ProVision has done more than just downsize its HSI system. Originally, in order to gather an image, either the sensor or the subject itself had to be moving. The ProVision team has changed the mechanism so that neither the sensor nor its target needs to move. "Everything can be stationary and the movement is in what we call the focal plane array, which is part of the sensor system. The focal plane array is actually moving," May explains.

In addition, ProVision Technologies' system is sensitive to energy wavelengths ranging from visible light to near-infrared, a broader range than the original technology. The team is also working on new sensors that can pick up both ultraviolet and middle-infrared wavelengths with hopes to eventually expand that range so that the sensors can detect wavelengths from ultraviolet to thermal or far-infrared.

Ground-Based Applications

With an HSI system that is small, portable, and able to detect a wider range of wavelengths, ProVision Technologies has opened up a whole new world of imaging opportunities. May and his team have already started to apply this new technology on Earth to the fields of food safety, skin health, and vision and are seeking ways to apply it to space research as well. To do this, ProVision is using its role as a commercial space center. Commercial space centers (CSCs) are part of the Space Product Development Program, which is in turn part of the Research Integration Division in the Office of Biological and Physical Research. The CSCs were formed to encourage the commercial development of space through partnerships with business and academia. While NASA provides the centers' base funding, research funding comes almost entirely from private industry.

ProVision Technologies' research on food safety has been very successful. ProVision is working with Sanderson Farms of Mississippi and the U.S. Department of Agriculture to adapt the HSI system for identifying contaminated chickens as they go down an assembly line. ProVision has a record in its spectral library of the unique spectral signature of fecal contamination, so chickens can be scanned and those with a positive reading can be separated. HSI sensors can also determine the quantity of surface contamination. Research in this application is quite advanced, and ProVision is working on a licensing agreement for the technology. The potential for future use of this equipment in food processing and food safety is enormous.

Hyperspectral imaging sensors are being used to scan chickens during processing to help prevent contaminated food from getting to the table.

Another application of HSI with great potential, both on Earth and in space, is the analysis of human skin. ProVision has worked on three projects in this area. The first is a partnership with the wound care clinic of the Gulfport Memorial Hospital in Gulfport, Mississippi. "We have a lot of work going on in wounds where we're trying to characterize the healing process," describes May. This also has potential as an application in space, as astronauts do not heal as fast in space as on Earth. During long-duration spaceflights, images of a wound could be sent down to doctors on the ground so they could determine whether or not the wound is healing properly.

The second skin health project is the analysis of burns. Currently, a doctor must determine visually if a burn is first-, second-, or third-degree. To verify a second- versus a third-degree burn, a doctor can do a punch biopsy, a procedure that is very painful for the patient. However, with an HSI sensor, there is the potential for a doctor to scan the burn and quickly determine its severity, without causing any pain for the patient. "It's really important, because usually a third-degree [burn] must be grafted, and the faster a doctor can determine a burn is third-degree and go to grafting, the higher the probability that [the graft] will stick," says May.

ProVision's third skin project is with the cosmetics company Estée Lauder. Estée Lauder worked with ProVision "to see if we could fine-tune the chemical composition of their cosmetics based on having looked at human skin, mainly

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ProVision Technologies Joins the Fight Against Terrorism

ProVision Technologies is applying its HSI system toward efforts to protect the United States from the many substances or objects that could potentially be used in a terrorist attack. ProVision has been working with the Federal Bureau of Investigation to test HSI sensors' abilities to differentiate between inks used in authentic documents and those used in altered or counterfeit documents such as money, passports, or other means of documentation potentially used by terrorists. In addition, ProVision is working with the U.S. Department of Agriculture to develop methods of identifying molds that give off toxins that, if added to a shipment of grain or other food, could be used to threaten the health of the people who consume it.

ProVision is trying to develop a fiber-optic probe for the HSI system that could examine shipments of grain or potentially suspicious packages without damaging the contents and that would reduce the exposure of testers to potential hazards. HSI could also be used on the space station to give more accurate mapping information to supplement other space intelligence activities.

For more information about the HSI sensor and its use in anti-terrorism efforts, please see *http://spd.nasa.gov/news/provision_01_02.html.*

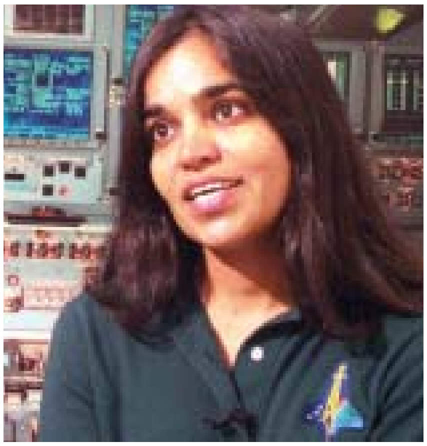
Space Theater Brings a Piece Of the Sky Down to Earth

Live performances and NASA outreach engage museum visitors and students around the world, helping them to see the light in space research.

Coming to a museum near you in the summer of 2002, *Space Research and You* is a multimedia presentation that highlights a sampling of space research scheduled for space shuttle mission STS-107, slated to fly this summer.

Developed as a museum presentation program on compact discs, *Space Research and You* was designed by McLain Science Education for the Office of Biological and Physical Research (OBPR) to make information from the orbital research community accessible to everyone. The presentation discs are full of video clips, sound bites, animations, and interviews that feature astronauts and principal investigators discussing the science behind several of the projects studying biology, combustion, and physics. A live host and a virtual host lead the fast-paced presentation, which also engages a few volunteers from the crowd in hands-on demonstrations that showcase several experiments and concepts.

A KC-135 low-gravity aircraft demonstration illustrates how the jet's roller-coaster trajectory creates brief moments of microgravity for training astronauts and conducting preliminary experiments. Astronauts, along with others who have ridden NASA's low-g aircraft, have dubbed it the "Vomit Comet," because the fluctuation in gravity environments causes nausea.



credit: McLain Science Education

Mission Specialist Kalpana Chawla, an STS-107 crewmember featured in *Space Research and You*, talks about conducting experiments in microgravity.

In one of the hands-on opportunities, a volunteer turns a crank on a makeshift bioreactor — a clear, water-filled cylinder with bits of crinkled paper inside — illustrating how biologists use fluid physics to grow cells three-dimensionally, a task difficult to achieve on a grand scale on Earth due to gravity. In this demonstration, the paper represents cells and the water the nutrient media.

Space Research and You

Each module of the museum presentation contains a suite of information, activities, photos, and video interviews. The presentation covers these four research modules:

- Understanding Microgravity,
- Cardiovascular and Musculoskeletal Adaptations,
- Bioreactor and Water Mist Fire Suppression Experiment
- Senses and Sleep

The resource CD-ROM contains material that corresponds with the content of the four modules listed above as well as two additional modules: bacterial physiology and protein crystallography.

The hands-on activity is based on the Bioreactor Demonstration System, developed by a team of engineers at Johnson Space Center. Inside an incubator, a fluid-filled cylinder rotates horizontally at the appropriate speed, while the cells within remain gently suspended in the solution as the force of gravity is randomized. With buoyant forces acting on the cells, the cells escape the effects of gravity and grow as they do in the human body. "On Earth, the period of growth is limited due to the increasing size and mass of the aggregates, which causes the cells to fall through the fluid," says Thomas Goodwin, project scientist for the Bioreactor Demonstration System. "When that happens, turbulence and fluid shear are increased, damaging the fragile aggregates of tissue, and the tissues can no longer grow properly."

"The real crowd-pleasers are the rotating chair activity and the fluid-filled glovebox," says Brad McLain, creator of the multimedia program and cofounder of McLain Science Education. The rotating chair demonstrates the way microgravity can disturb how a person's inner ear organ controls balance. One at a time, volunteers sit in a free-spinning chair with their hands in front in a thumbs-up position. While the volunteer either shuts his or her eyes or wears a blindfold, the chair is spun in a certain direction. While spinning, volunteers point their thumbs in the direction in which they think they are turning. This experiment relates to NASA's continuing investigation of the body's adaptation to microgravity. In the fluid-filled glovebox activity, visitors can insert their hands into gloves that are attached to a sealed workbench. The gloves lead to the interior of the box, which is filled with a fluid, allowing visitors to experience neutral buoyancy.

With the permission of Lucasfilm Ltd., R2-D2™ serves as the virtual host of the program. The helpful droid whistles his trademark bleeps when asked to fetch a file or carry out a task.

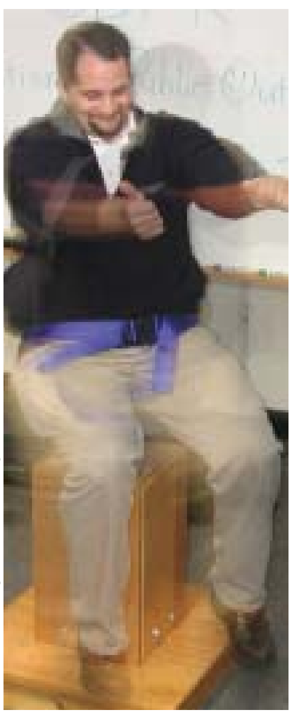
Space Research and You is rated "E" for entertaining and educating everyone, and McLain describes the program as a form of "edutainment." The presentation invites audiences of all ages into the world of astronauts and researchers, where it sparks the interest to learn and teaches the value of this research in everyday life.

The animated museum production debuted internally at the Denver Museum of Nature and Science April 9–12 to members of the NASA Space Biology Museum Network and their guests. Thirteen museums and science centers in the United States and Canada received a copy of the discs and a training certificate that enables them to train others as hosts of the museum presentation once the presentation is released to the public. "We plan on using a 'train the trainers' model for distribution," says Gary Coulter, director of the network. "After the presentation passes all the necessary approvals, we hope to release it to the public in June. The distribution process will work like ripples in a pond."

As part of *Space Research and You,* a concept-based resource disc provides lesson plans, experiments, schematics, and background information about NASA and the STS-107 mission. (See insert.) "This gives museums and science centers the flexibility to adapt material beyond presentations," says McLain. "For example, the resource disc provides sufficient materials similar to the presentation activities for the development of workshops." The text-based CD-ROM also includes a virtual space science library, activities that can be printed, and schematics to build demonstration props. The goal is to help show today's science and space research to the scientists of tomorrow.

NASA May Brighten Life Science Lighthouse

Navigating through the sea of science and research resources can be difficult, but with a few lighthouses, educators can get where they want to go efficiently and effectively. The National Association of Biology Teachers (NABT) serves as a guiding light for life science educators by providing an abundant supply of experiment procedures, research articles, and helpful hints to ultimately improve science education in the United States.



credit: Dave Dooling, Infinity Technology Inc.

Spinning in a rotating chair, a participant points his thumbs either to the left or to the right, illustrating how the body's system of balance is affected by microgravity.

Partnering with NABT, OBPR's Educational Outreach Program is developing ways to bring space research to educators. OBPR supplies a variety of materials that showcase the science of shuttle mission STS-107 and are designed to capture the interest of both students and the general public through hands-on, minds-on activities in science centers, museums, and classrooms. "We see NASA research as an incredibly engaging way to bring people into the world of science," says Wayne Carley, executive director of NABT. "NABT is unique to other [educational organizations], because it can target the specific disciplines in biology. It has a content-based approach from the middle school classroom to the college campus." NABT's membership, 9,000 strong, comprises 70 percent high school teachers, 20 percent college professors, and 10 percent junior high or middle school educators.

Plans are under way for OBPR to exhibit at the association's annual fall conference, held this year in Cincinnati, Ohio, where educators get the opportunity to share experiences and explore the latest issues in the science of life. With a roll call of about 2,000 teachers, the four-day forum will begin October 30, 2002, and feature more than 300 presentations, general sessions, invited speakers, hands-on workshops, demonstrations, and field trips. It also will have about 100 exhibits with products and services to help biology teachers in the classroom and the laboratory. One such exhibit, the OBPR booth with the theme "Space Research and You," will immerse educators in the science concepts of STS-107 research.

"Selection of the science concepts for STS-107 educational outreach development was based upon three main points," states Bonnie McClain, chief of educational outreach for OBPR. "The goal was to highlight science research subjects that are included in high school curricula, subjects that demonstrate the impact space research has on people every day, and ones that are the focus of additional investigations flown aboard the International Space Station. Connecting these research concepts to the classroom is not time-sensitive to this one space mission. We believe these materials are substantive, high-interest learning tools that teachers and students will value." Carley finds the cutting-edge fundamental biology research NASA conducts especially valuable to NABT members: "We have members who teach subjects such as neurobiology and human performance and could use direct examples of space research in these areas in their lesson plans."

NABT publishes *American Biology Teacher* and *News & Views* to keep its membership informed and provide teaching resources. The organization's

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OBPR Gives Oncologists Lesson in Space Health Care

In addition to the multimedia *Space Research and You* initiative for museums and schools, OBPR has been active in its support of public outreach events. NASA had a significant presence in the exhibit area of the American Society of Clinical Oncology's (ASCO's) annual meeting May 18–21, 2002, in Orlando, Florida. This included the two-trailer mockup of crew living and galley facilities within the International Space Station as well as the Destiny Lab. In tandem with the trailer exhibit, a number of OBPR research participants talked to ASCO attendees about space research in circulatory systems, biotechnology research, spin-off technology collaboration in light-emitting diode research to support cancer treatment using photosensitive chemicals, and work in crew health, telemedicine, scanning technologies, and other fields. In addition, OBPR invited astronauts Roger Crouch and Chiaki Mukai to share their personal experiences of spaceflight. Participation in the ASCO meeting is in keeping with OBPR's public outreach commitment to reach professional and technical organizations as well as the general public to convey what OBPR research is taking place, why it is taking place, and how such research can benefit life on Earth.

John Emond

Hypergravity, Linear Acceleration, and More...

The Center for Gravitational Biology Research at Ames Research Center provides ground-based research facilities for studying the effects of gravity on living systems. CGBR is available to all qualified researchers.

When people think of space research, they usually visualize the research that goes on in low Earth orbit aboard the space shuttle or the International Space Station (ISS), but much of the research that is geared toward providing a safe environment for humans venturing into space occurs right here on Earth. Because of limited time and space, especially while the space station is still under construction, getting research studies into orbit is costly and difficult. But much can be learned from ground-based research, and the Center for Gravitational Biology Research (CGBR) at Ames Research Center (ARC) at Moffett Field, California, is designed to support researchers studying the effects of gravity on living systems.

According to Duncan Atchison, an experiment coordinator at CGBR, the center supports both stand-alone ground-based research and research that supports future flights, such as studies of how potential ISS hardware might withstand the gravitational forces involved in a shuttle launch and landing. Says Atchison, "In terms of subjects, we support everything from cells to insects to worms to mice to rats to humans." Atchison also points out that the center is ISO 9001 certified, which means that it meets rigorous quality standards as set out by the International Organization for Standardization (ISO).

Credit: NASA

The 20-G Centrifuge, used for hypergravity research at the Center for Gravitational Biology Research, is 58 feet in diameter. The cabs, located at either end of the rotating arm and at the center of the arm, can accommodate humans or other test subjects.

More Than a Roller Coaster Ride

Gravity is a force that arises from the mutual attraction of matter, and thus gravitational acceleration can vary depending on circumstances. At Earth's surface, we experience gravity as an acceleration equal to 1 g; astronauts in orbit experience a much lower force, known as microgravity, due to the fact that they are in a state of freefall. At the surface of an extremely massive planet like Jupiter, the force of gravity would produce an acceleration much greater than 1 g. But even without visiting Jupiter, humans can experience accelerations greater than 1 g in several ways: by riding roller coasters in an amusement park; by flying in airplanes, most notably jet fighters; and by taking off and landing in the space shuttle, for example.

Since humans first traveled into space, scientists have noted that a microgravity environment induces certain physiological responses, including bone and muscle loss and problems with the vestibular system. Researchers have postulated that the normal development of certain biological systems, such as in the vestibular system (see "The Avian Development Facility," page 14), and their functions are gravitropic, meaning that gravity must be present in order for those systems to develop and function normally. Scientists are interested in studying just how gravity affects an organism's systems, both during development and as an adult. And although microgravity might have a different effect on a biological system than hypergravity, researchers who are interested in gravitational effects generally are interested in the effects along the entire gravity continuum.

CGBR offers a number of different centrifuges for hypergravity research. They range in size from a centrifuge that is 1 foot in diameter to a centrifuge that is 58 feet in diameter. The 1-Foot Diameter Centrifuge is used for testing the effects of hypergravity on cell cultures and small organisms. It provides speeds from 45 to 1,000 revolutions per minute — an acceleration of 1.4 to 180 g — and is equipped with temperature, humidity, and carbon dioxide level controls. An incubator is available for noncentrifuged control samples.

The 24-Foot Diameter Centrifuge has 10 radial arms, each of which holds up to two enclosures that can contain as many as four cages for rodents or other similar-sized animals. Payloads of up to 100 pounds can be placed within the enclosures, which can be moved to one of 16 locations on each arm to provide varying levels of acceleration up to a maximum of 4.15 g. The centrifuge also has three smaller enclosures at the center of rotation that can be used to house control animals during experimental runs. Additionally, eight stationary animal enclosures are situated around the centrifuge room so that controls can experience the same environmental conditions as experimental animals without experiencing either the angular velocity or altered gravity produced by the centrifuge.

The Low-Vibration Rotational Device (LVRD) is a single-arm centrifuge with a 10-foot radius that runs on a hydrostatic oil-film bearing, which allows for precise angular accelerations and minimal vibration. This centrifuge has a swing frame that can be positioned at the end of the arm, and experiment-specific payloads can be placed at various distances from the hub of the instrument to provide acceleration levels up to 4.5 g. Researchers may also use this centrifuge to study the effects of hypergravity on cell cultures by using an onboard carbon dioxide incubator. The LVRD has a 10-foot radius and can carry a maximum payload of 500 pounds.

The largest centrifuge at CGBR, the 20-G Centrifuge, measures 58 feet in diameter, has three enclosed cabs, and as the name implies, provides accelerations of up to 20 g. One cab is mounted at the end of the rotating arm and contains a modified jet fighter seat to be used by a human subject. A second cab, mounted on the other end of the rotating arm, contains a swing frame and can be used to test a human subject in a non-seated position or to house other test subjects, such as animals or other payloads. The third cab is located near the center of rotation and is designed to be used as a near-center control for angular acceleration or as a means for studying gravity gradients or short-radius effects. A medical monitoring system allows humans to be safely studied at accelerations up to 12.5 g. The centrifuge can be controlled either manually or through a preset computer program.

CGBR also has specialized centrifuges, including the Human-Powered Centrifuge (HPC) and the ISS Test Bed (ISSTB) Centrifuge. According to John Greenleaf, a research physiologist at ARC, the HPC is used as a countermeasure for postflight orthostatic intolerance as well as a means of providing exercise for astronauts. The HPC contains two recumbent seats situated so that the subjects' heads are near the center of the centrifuge. Both people aboard the centrifuge may pedal a modified cycle mechanism, but only one of them actually powers the centrifuge. A maximum acceleration of 5 g is experienced at the subjects' feet during centrifuge operation.

The ISSTB is designed for testing enclosures that are destined for the ISS. It will be used for ground-based testing and simulation of ISS experiments. The centrifuge has four radial arms, each capable of holding one space station-type enclosure. The setup mimics the station as closely as possible — the enclosure's interfaces (e.g., for data, video, cooling control), the acceleration controls, and the environmental conditions of the room are all designed to match those found on the ISS. Non-ISS hardware can also be accommodated.

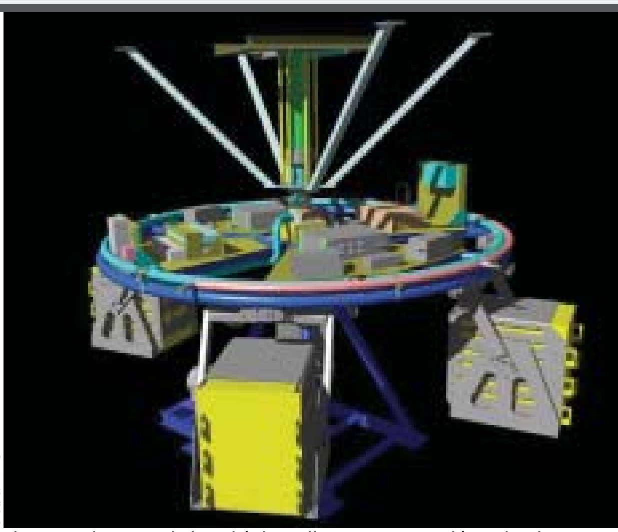
A Balancing Act

Our sense of balance is tied to the vestibular system, structures within the inner ear that sense head motion as well as the body's position relative to the surface of the Earth (see "The Avian Development Facility," page 14). Disturbances to this system can cause disturbances in balance and can lead to problems such as motion sickness or vertigo. In microgravity, the vestibular system does not function exactly as it does on Earth, leading to the problem of space motion sickness, but the system readjusts to the effects of gravity upon an astronaut's return to Earth. The quest to understand the vestibular system's ability to react to gravitational forces, as well as the hypothesis that development of the system requires gravity to function normally, has led to much interest in conducting research in this area. CGBR has an entire facility devoted to vestibular research. The Vestibular Research Facility (VRF) contains a multi-axis centrifuge and two linear sleds, one of which is programmable.

The Multi-Axis Centrifuge provides four axes of motion: the main spin axis, an outer high-performance spin axis, an inner high-performance spin axis, and an inner positioning axis. The centrifuge can deliver combined motion simultaneously from two axes, or if the main spin axis is not used, then simultaneous rotation can occur around both the inner and outer high-performance axes. These various combinations allow researchers to study the physiological responses to complex angular accelerations.

One of the linear sleds consists of a slab of granite that is 30 feet long with a chair that rides back and forth along the slab on air bearings so that there is virtually no friction. The lack of friction on the 30-Foot Linear Sled allows researchers to isolate the role of the vestibular system in aiding humans to determine their orientation. Subjects ride back and forth on the sled in the dark so researchers can study how the human system orients itself when there is no visual cue.

The Programmable Linear Sled also uses an air bearing to provide nearly frictionless motion. It can be operated in either a horizontal or a vertical orientation. A platform on the sled holds the specimen test container; the platform itself is equipped with a locking turntable that allows repositioning of the test subjects around an Earth-vertical axis. The sled has motors that can be programmed to deliver sinusoidal (S-shaped) motion over a range that encompasses normal human head movements.



credit: NASA

This computer-generated model shows the carriage assembly and racks of the ISSTB centrifuge, which accommodates up to four space station development habitats for ground-based studies.

All Together Now

Use of CGBR is not restricted just to NASA-funded principal investigators. Outside researchers can also gain access to the facilities if their research is in alignment with NASA's mission. This commonly occurs through other federal sources (e.g., the National Institutes of Health) that use a peer-review process to select experiments for funding based on their scientific merit. Once a researcher has obtained approval to perform research at CGBR, the center staff will work to ensure that the researcher's needs are met and that the experiments run as smoothly as possible.

CGBR is a full-service gravitational studies facility. Researchers are not restricted to using only the devices of a particular facility but can combine instruments and facilities as needed. For example, researchers using the 1-Foot Diameter Centrifuge may also use incubators in the CGBR Cell Culture Facility or a vibration table. This type of flexibility helps to maximize the usefulness of the entire facility.

Julie K. Poudrier

For additional information on CGBR, visit *http://lifesci.arc.nasa.gov/cgbr/home.html* on the World Wide Web or contact Tianna L. Shaw, manager of the Facilities Utilization Office, at *tshaw@mail.arc.nasa.gov.*

RESEARCH OPPORTUNITIES

http://research.hq.nasa.gov/code_u/code_u.cfm

Advanced Technologies for Bioastronautics Research

The research opportunity in the Advanced Human Support Technology Program funds the development of advanced technologies for use on the International Space Station (ISS) or on long-duration human exploration missions. Proposals for the Bioastronautics Research Division's NRA (NRA-02-OBPR-01) were due by June 18, 2002. More information is available on the World Wide Web (WWW) at *http://research. hq.nasa.gov/code_u/nra/current/NRA-02-OBPR-01/index.html*.

Research Opportunities in Physical Sciences

The Physical Sciences Division now issues only one research announcement a year; it includes information for proposing to each research program. The discipline sections are as follows:

- **Biotechnology:** NRA-01-OBPR-08-B opened June 3, 2002, with proposals due September 3, 2002. The NRA involves research to produce bioproducts that will enhance human health and welfare.
- **Combustion Science:** NRA-01-OBPR-08-C proposals were due March 22, 2002. The NRA solicited research into fire safety, pollution reduction, and combustion-related product development.
- **Fluid Physics:** NRA-01-OBPR-08-D opens September 2, 2002, with proposals due December 2, 2002. The NRA seeks research that explores fundamental physics and the dynamics of simple and complex fluids.
- **Fundamental Physics:** NRA-01-OBPR-08-E proposals were due April 12, 2002. The NRA sought research that investigates the basic laws that determine the properties of the physical world.
- **Materials Science:** NRA-01-OBPR-08-F proposals were due June 3, 2002. The NRA solicited proposals that study and develop new materials or new uses for known materials.
- **Special Focus Theme, Materials Science for Advanced Space Propulsion:** NRA-01-OBPR-08-G opened June 3, 2002, with proposals due September 3, 2002.

Further information on these announcements can be found on the WWW at *http://research.hq.nasa.gov/code_u/nra/current/NRA-01-OBPR-08/index.html*.

NASA Funds Study for Life-Support Ecosystem in Space

NASA has selected Purdue University to receive a grant to lead a NASA Specialized Center of Research and Training for Advanced Life Support to develop self-sustaining technology for long-duration space missions and the possible human colonization of space. Life support technologies would include such techniques as solid-waste processing and water recovery. The grant is for five years and totals $10 million. Purdue University will work with Alabama A&M University and Howard University. For additional information, visit *http://spaceresearch.nasa.gov/general_info/OBPR-02-048.html* on the WWW.

TECHNICAL MEETINGS

Sixth Microgravity Fluid Physics and Transport Phenomena Conference

Cleveland, Ohio
August 14–16, 2002
http://www.ncmr.org/events/fluids2002.html

Hosted by NASA's Glenn Research Center, this biannual conference will center on the research priorities and plans of NASA's Office of Biological and Physical Research as well as research on the ISS. Invited presentations will focus on such subjects as fluid interfaces, multiphase flow and phase change dynamics, colloids and soft condensed matter, complex fluids, dynamics and instabilities, and biological fluid physics.

World Space Congress 2002

Houston, Texas
October 10–19, 2002
http://www.aiaa.org/wsc2002/

The theme for this year's meeting is "The New Face of Space." The World Space Congress is a joint gathering of the International Astronautical Federation, the International Academy of Astronautics, the International Associates of Space Law, and the Committee on Space Research. Instead of holding a separate conference on ISS utilization during the meeting, this year's organizers have incorporated this theme into existing sessions. In addition, there will be more than 16 plenary sessions with such themes as space commercial applications, life sciences and biomedicine, and the vision for the next 25 years of scientific investigations in space.

18th American Society for Gravitational and Space Biology Annual Meeting

Cape Canaveral, Florida
November 6–9, 2002
http://asgsb.org/newsletter/v18_1/markcalendars.html

Scientists from such diverse fields as cardiovascular research and botany will gather this November for the American Society for Gravitational and Space Biology's annual meeting in Florida. Symposium topics include "The Biological Effects of Space Radiation," "Mechanoreception in Biological Systems," and "The Advanced Space Concepts for the Future of Space Exploration." Also on the agenda are poster sessions, exhibits, and various educational activities.

PROGRAM RESOURCES

General Site

Office of Biological and Physical Research (OBPR)
http://spaceresearch.nasa.gov

- Latest biological and physical research news
- Research on the International Space Station
- Articles on research activities
- Space commercialization
- Educational resources

Descriptions of Funded Research Projects

Science Program Projects
http://research.hq.nasa.gov/taskbook.cfm

Commercial Projects (also includes a description of the Commercial Space Center Program and other information)
http://cscsourcebook.nasa.gov

Space Life Sciences Research Resources (for literature searches)
http://spaceline.usuhs.mil/home/newsearch.html

STS-107 *continued from page 11*

by the Society of Mexican American Engineers and Scientists with the participation of the engineering center. “The whole project is a combination of advancing a key technology for spacecraft systems while motivating kids to go into careers in space and engineering,” says Jacox. “The innovation is the algorithm. The software we call LISA, for Lost-in-Space Algorithm.”

There are particular challenges putting together a tracking camera that will perform well while holding up to the harsh environment of space. Special kinds of thermally stable steel were used to hold the lenses in place, and care was taken to isolate the interior microprocessors to protect them from the vibration of launch. Plastic components were coated to resist off-gassing — in the absence of atmospheric pressure, organic compounds will evaporate into space — and copper wiring was installed to channel heat to cooler areas.

Two StarNav versions are under development. StarNav-1 will fly on STS-107, and an upgraded successor version, StarNav-2, is slated to fly on a NASA Earth-observing satellite scheduled for launch in late 2004.

“Our goal here is to commercialize space technology. There are real opportunities in space,” Jacox says. “More fundamentally, I think human beings need to explore. Space is the real frontier. Exploration doesn’t just open up new opportunities. It also provides us with hope.”

James Schultz

For an overview of OBPR experiments scheduled for flight on STS-107, go to *http://spaceresearch.nasa. gov/research__projects/sts107.html* on the World Wide Web. For a summary of the sleep research being conducted by Czeisler, Barger, and other team members, see *http://peer1.nasaprs.com/cfpro/peer__review/ltb1__00.cfn?id=417*. To read about Delp’s ground research on blood vessels conducted in preparation for STS-107, go to *http://research.hq.nasa.gov/taskbook/search/retrieve__task.cfm?task__id=147*. For information on how NASA cardiovascular research is benefiting science in space and on Earth, see *http://www.asgsb.org/factsheets/cardiovascular.html*. For more information on the Spacelab orthostatic intolerance studies, see Buckley, J., et al (1996). Othostatic intolerance after spaceflight. *Journal of Applied Physiology*, 81, 7–18. To find out more about the Mechanics of Granular Materials experiment, see *http://mgm.msfc.nasa.gov/mgm.html*. To find out more about StarNav, go to *http://jungfrau.tamu.edu/~html/StarNav/index.html*, and to learn more about Texas A&M’s Commercial Space Center for Engineering, see *http://engineer.tamu.edu/tees/csce/*.

Avian facility *continued from page 15*

significant amount of bone formed prior to exposure to microgravity,” says Doty. That makes it more difficult to determine which changes, if any, are the result of exposure to microgravity.

Like Dickman, Doty says it’s too early to make any definitive statements about his results from the STS-108 experiments. He was able to make one observation: more of the embryos that were exposed to 1 g during the experiment appeared to have reached their “true” developmental state of 12 days at experiment end than did the embryos exposed to microgravity, which showed a greater variation in their “staging” (the age they appeared to be).

Doty would like to fly additional experiments in the ADF to study bone development from generation to generation to see how bone would respond in the absence of gravity from embryogenesis to adulthood and on to the next generations.

A Future for ADF

Both Dickman and Doty are eager to perform additional experiments using the ADF. Says Dickman, “It’s a beautiful piece of hardware, it performed flawlessly, and we got back some tremendous animals with which to collect our data.” Doty concurs. “We would be ready to do another experiment tomorrow,” he says.

In the meantime, both researchers will continue to analyze the data they obtained from their first ADF experiments and plan for future research when the ADF is once again available.

Julie K. Poudrier

For additional information on the ADF, visit *http://spaceresearch.nasa.gov/research__projects/ros/adf.html* on the World Wide Web. For more information on David Dickman’s research, visit *http://thalamus.wustl.edu/Neuroweb/dickman.htm* or *http://dbbs.wustl.edu/RIB/Dickman.html*. For information on Stephen Doty’s research, visit *http://www.hss.edu/htdoc/research/dotys.asp* or *http://www.fundamentalbiology.arc.nasa.gov/Doty.html*.

Light *continued from page 19*

female, of the face and cheeks and around the eyes,” says May.

HSI may also be useful to ophthalmologists. May feels HSI could be a tool to study and diagnose eye health, both on Earth and in space, by examining the back of the eye to determine oxygen and blood flow quickly and without any invasion. ProVision has already developed a relationship with the University of Alabama at Birmingham, but is still on the lookout for a commercial partner in this application.

Advantages for Space Program

This new technology also holds promise for the space program in disciplines other than health research. “Environmental issues, mineral exploration, and agriculture could all benefit from having this tool on the space station,” explains May. Another possible use of this equipment on the space station is to attach it to the Canadian arm or out on a truss, to check the station externally for damage or malfunctions without a space walk.

ProVision Technologies has many plans for its technological baby. “We believe the future of this technology is quantifying problems and processes by their spectral properties,” explains May. “It’s a nondestructive, quick way of doing things.”

Carolyn Carter Snare

For more information on ProVision Technologies, please see *http://www.pvtech.org/who.htm* on the World Wide Web.

Building Momentum *continued from page 17*

experiments that will be conducted on the International Space Station, Chaikin and Russel will use microscopy to study the crystalline structure of hard sphere colloidal crystals. Their instrument, called a confocal microscope, allows the researchers to get a look at a crystal as it grows, particle by particle.

"Along with this," says Chaikin, "what is even neater, I think, is we've got a set of laser tweezers." Laser tweezers, he explains, consist of a very tightly focused beam of laser light. If the beam is small enough, particles can be sucked into the focus of the beam. "It's like the force of static electricity that draws objects together," explains Chaikin. "The particles like to be where the electric field is intense."

"We can actually take the particles that we are looking at with the microscope and grab one, grab another, and bring them together. So instead of letting the particles nucleate as they want to, we want to form the nuclei and watch them grow particle by particle. We want to see why the glass forms or doesn't form. We want to see if we can make different kinds of crystal structures, maybe even nonequilibrium crystal structures. We are going to be able to do all sorts of things with this apparatus," says Chaikin excitedly.

One promising avenue of research the team is pursuing involves fabricating plastic structures of micron scale to be used as templates for crystal growth. "One of the things we want to do is have in the microscope not only the ability to grab particles in three dimensions, but also the ability to have on the substrate — on the glass slide that we are looking up through — the pattern on which the colloidal particles will nucleate," says Chaikin. These templates would allow researchers precise control of the placement of the individual particles, yielding precisely engineered crystalline structures. With this capability, it might be possible to engineer a crystal in which the spacing between the particles is comparable to a specific wavelength of light. Such precise spacing of particles would permit improved control over directing light for applications like long-distance telephone connections.

Building on more than a decade of research in microgravity, this team of researchers is poised to make the most of their opportunities for research in space. "The more sophisticated we get," says Chaikin, "the more we will be able to do."

Jacqueline Freeman-Hathaway

For more information on Chaikin and Russel's colloid research, visit *http://pupgg.princeton.edu/www/jh/research/Chaikin_paul.htmlx* and *http://microgravity.grc.nasa.gov/6712/comflu/chaikin/phase.htm*. Results of research on the growth of hard sphere colloidal crystals were published in Cheng, Z., Russel, W.B., Chaikin, P.M. (1999). Controlled growth of hard-sphere colloidal crystals. *Nature*, 401, 893-895.

Space Theater *continued from page 21*

web site, at *http://www.nabt.org*, has links to science updates, experiment guides, professional opportunities, and much more. "Soon the web site will serve as a platform for members to interact," Carley says. "We're developing an electronic journal to bring new kinds of content to the community."

Both NASA and NABT are excited about the potential this partnership holds. As NABT's mission statement declares, the association empowers educators to provide the best possible biology and life science education for all students. Its navigation and resource capabilities continue to flourish in partnership with NASA's Office of Biological and Physical Research.

For more information about the availability of the multimedia program *Space Research and You*, consult one of the following museums and science centers.

American Museum of Natural History
Rachel Connolly, Astrophysics Education Program manager; Phone: (212) 496-3637; *connolly@amnh.org*

Canadian Space Resource Centre
Steve Lang, coordinator;
Phone: (416) 396-2421; *csrc@interlog.com*

Center of Science and Industry
Jennifer Donaldson, resource and development team leader;
Phone: (614) 228-2674, ext. 2461;
jdonaldson@mail.cosi.org

The Children's Museum of Indianapolis
Karol Bartlett, director of educational programs; Phone: (317) 334-3821;
karol@childrensmusem.org

Denver Museum of Nature & Science
Robert Payo, outreach coordinator; Phone: (303) 370-8285; *rpayo@dmns.org*

Fernbank Science Center
Pam Preston, Life Science Department representative;
Phone: (404) 378-4708, ext. 223;
pam.preston@fernbank.edu

Kansas Cosmosphere and Space Center
Daniel Bateman, public presentations and outreach coordinator;
Phone: (620) 662-2305; *danielb@Cosmo.org*

Liberty Science Center
Kayla Dove, director of educational outreach; Phone: (201) 451-0006, ext. 211;
kdove@lsc.org

Maryland Science Center
Luke Bate, exhibit manager, SpaceLink;
Phone: (410) 545-2997; *lbate@mdsci.org*

McWane Center
Kermit Farmer, manager; Phone: (205) 714-8343; *challenger@mcwane.org*

Museum of Science, Boston
Michael Shiess, program manager; Phone: (617) 589-0369; *mschiess@mos.org*

Space Center Houston
Raquel Jenkins, educational programs specialist; Phone: (281) 244-2147;
raquelj@spacecenter.org

The Tech Museum of Innovation
Susan Baron, programs specialist; Phone: (408) 795-6369; *sbaron@thetech.org*

Chris McLemore

Profile: John Charles

John Charles has spent a career dedicated to realizing the potential of space exploration and helping people to travel in space safely.

As a child, John Charles dreamed of being an astronaut and exploring space. Like many other children of the 1960s, he avidly followed the "space race," especially John Glenn's journey into space. Although he never became an astronaut, he has fulfilled his dream in other ways. From investigating crew health and supporting research on the Russian Space Station *Mir* to training John Glenn for a return trip to orbit and overseeing the upcoming STS-107 science mission, Charles has worked to discover and solve the challenges that will arise as humans take the next step into space.

Says Charles, "At about age 10, I decided to quit dreaming and actually focus on a career in the space business." Charles was interested in physics but knew that he was not strong enough in math to be successful in that course of study. He also had an interest in biology, especially physiology, and realized that a career as a research physiologist could combine with his desire to do space-related work. To that end, he obtained a bachelor's degree in biophysics from Ohio State University in 1977 and a Ph.D. in physiology and biophysics from the University of Kentucky in 1983.

Charles arrived at Johnson Space Center (JSC) in Houston, Texas, in 1983 as a postdoctoral fellow in the medical research branch. He was hired as a full-time employee in the cardiovascular laboratory in 1985. Several years later, he became the director of that lab. Charles spent a large part of his lab career at JSC looking at the problem of orthostatic intolerance, the feeling of faintness that astronauts experience on their return to Earth from orbit. The condition is caused by insufficient blood pressure in the brain resulting from the body's inability to adjust blood pressure after adapting to reduced gravity. Charles' team helped to formalize a postflight test of orthostatic function and developed the lower body negative pressure (LBNP) technique to pull fluids out of the upper body and back into the lower body.

credit: NASA

Charles left the cardiovascular lab in 1994 when he joined the shuttle/*Mir* program, which encompassed a series of 11 U.S. space shuttle missions to the Russian space station. He worked as a deputy to Peggy Whitson, the project scientist for the program, and took over her position when she was selected for the astronaut corps. After his tour with the shuttle/*Mir* program, Charles was assigned to be the liaison between the Human Space Life Sciences Programs Office (now the Office of Bioastronautics) and the Mars Exploration Planning Office at JSC. He also became the lead for the Bioastronautics Critical Path Roadmap Project. Charles notes that this project, a collaborative effort with the National Space Biomedical Research Institute that was conceived in 1997, was originally designed to target physiological problems that need to be solved to make a crewed mission to Mars possible.

"The critical path roadmap is currently focused on the problems of the space station," says Charles, "and I view that as also providing a very strong foundation for any subsequent decision to move beyond low Earth orbit. Many of the problems that would confront humans going to Mars are the same problems we would have on any long-duration space station mission. It's really not apples and oranges; it's really one size apple versus a different size apple."

In addition to his planning work for NASA, Charles has continued to contribute to the success of the shuttle program. He served as project scientist for the experiments that John Glenn conducted during the flight of STS-95 in 1998 and is the mission scientist for STS-107, scheduled for flight this summer (see "The People of STS-107," page 6). He defines his role as mission scientist as "being an advocate for the mission experiments that come through the Office of Biological and Physical Research." He believes that his years of lab work at JSC provided him with a greater capacity for representing the scientists in dealing with program offices, mission planners, and management: "I'd like to make sure that the people who are actually answering the questions are not forgotten in the big bureaucratic shuffle that seems to surround huge programs like the space shuttle or the space station."

Charles describes a high point of his career with NASA: "I have to rate as one of the highest the chance to work with John Glenn, because he inspired me way back in 1962 to be interested in spaceflight. Then 36 years later, when he flew on the shuttle, I dealt with him on a fairly regular basis to prepare our experiments for him to do in flight. It was always a thrill for me to see and speak to him. It was sort of a full circle, going from being inspired by him to working with him and having him consider me a part of his team."

Charles sees himself remaining part of the NASA team for the future and expects to continue to be involved in strategic planning to help find the answers to the problems of long-duration spaceflight. "My job is to have the answers ready. When they say, 'We want to send people to Mars or the Moon. Are we ready to do that?' I would like to be in the position to help the life sciences [people] say, 'Yes, and here are the answers to the questions.'"

Julie K. Poudrier

For additional information, you may contact John Charles via e-mail at *john.b.charles1@jsc.nasa.gov.*