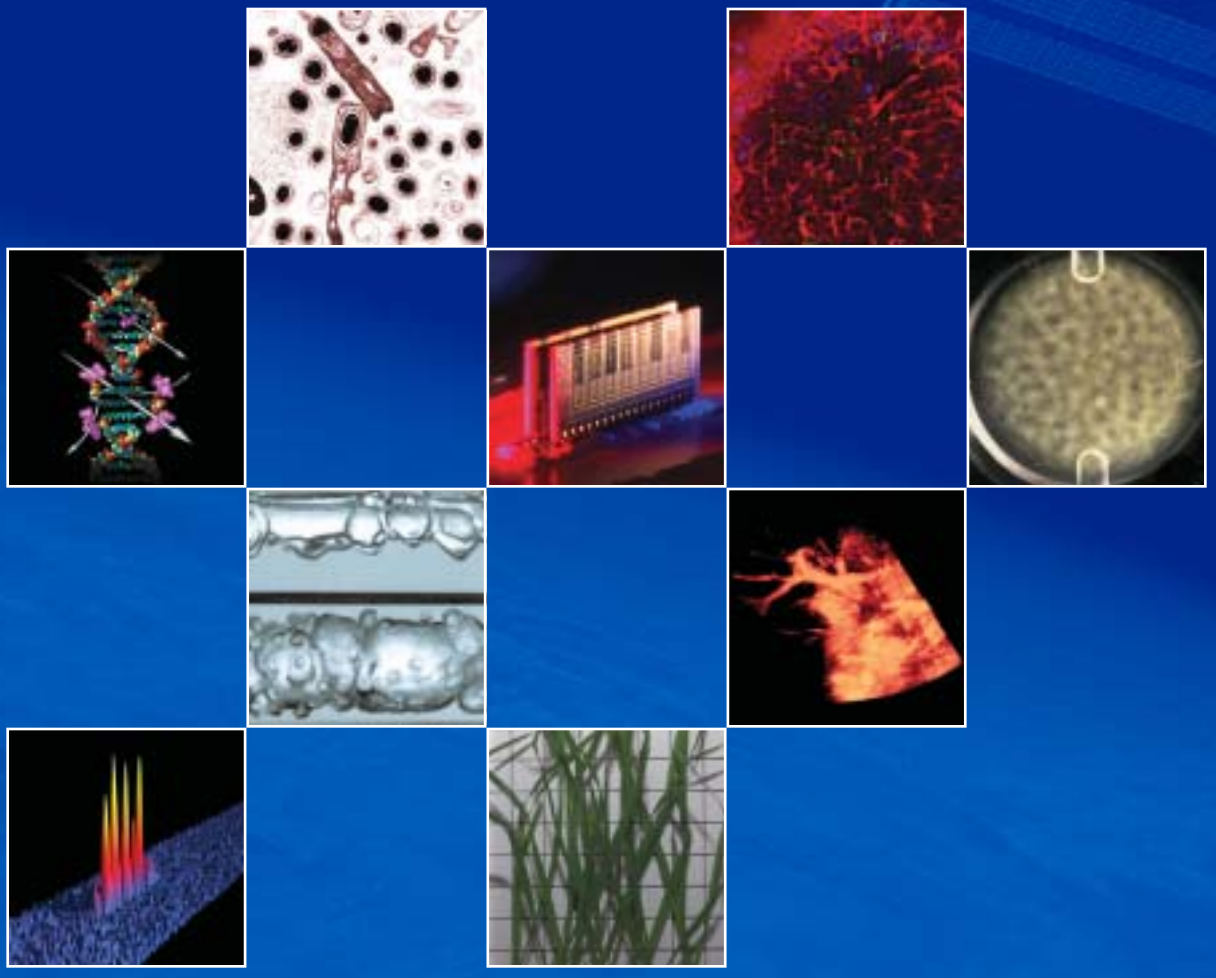
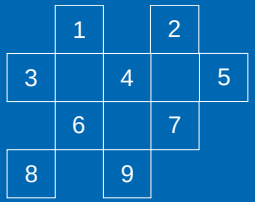
NASA's Biological and Physical Research

SPACE RESEARCH: TRANSFORMING TOMORROW TODAY



1. Anthrax spores—NASA is developing air-cleaning devices to destroy such spores and other pathogens. 2. *Salmonella typhimurium* cultured in the modeled microgravity environment of a bioreactor. 3. Artist's rendering of the damaging effects that cosmic radiation can have on DNA. 4. ENose sensor to monitor air quality, and especially to identify deadly chemicals, in enclosed environments such as the ISS or specialized workplaces on Earth. 5. Colloidal system beginning the phase separation process, which was observed to completion on the ISS (not possible on Earth). 6. Gas liquid two-phase flows in normal gravity and microgravity—Stratified flow observed in normal gravity (upper image) is absent in microgravity. Light regions represent gas; darker regions represent liquid phase. 7. Echocardiographic image of the beating heart—An echocardiograph unit is part of the Human Research Facility on the ISS. 8. Three-dimensional rendering of an image of a matter wave soliton train, which may be useful as the atom laser input to an atom interferometer. 9. Dwarf wheat grown on the ISS—The goal is to produce a greater yield in a smaller area, important to future space missions and terrestrial farming.



National Aeronautics and Space Administration

Headquarters
Washington, DC

NASA's Biological and Physical Research

Transforming Tomorrow Today

Since its founding in 2000, the Office of Biological and Physical Research (OBPR) has embodied NASA's commitment to the essential roles science and technology will play in the 21st century and to the support and fulfillment of the NASA Vision:

To improve life here,
To extend life to there,
To find life beyond.

OBPR focuses on three major research areas with emphasis on high-impact results:

- Strategic, to enable NASA's mission to explore the universe and search for life;
- Fundamental, to address the role of gravity and the unique aspects of the space environment in biological and physical processes; and
- Commercial, to develop new or improved products derived from space research.

Advances in the sciences, analytical tools, and information systems have opened unprecedented opportunities to bring ground-and space-based knowledge to benefit human life on Earth. This increased understanding will improve the technological foundations of society as well as the space program. Concurrent with these major research areas, OBPR will work proactively with the organization chartered to manage the utilization of the International Space Station (ISS), the user communities, and a focused science advisory committee. Our advisory committees will help us shape our strategic course while working with their discipline communities to craft and obtain answers to compelling, timely, multidisciplinary research questions that support the Agency vision and unite the research communities. The OBPR direction is summarized below.

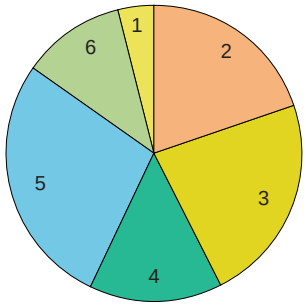
Humans will extend the exploration of space. To prepare for and hasten the journey, OBPR must answer these questions through its research:

- How can we ensure the survival of humans traveling far from Earth?
- What must we know about how space changes life-forms so that humankind will flourish?
- What new opportunities can our research bring to enrich lives and expand our understanding of the laws of nature?
- What technology must we create to enable the next explorers to go beyond where we have been?
- How can we educate and inspire the next generations to take the journey?

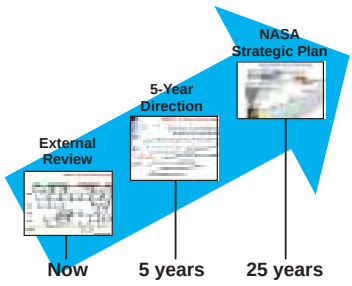
We invite you to read on and learn about the crucial discoveries NASA is making now through OBPR research to fulfill the Agency's mission:

To understand and protect our home planet,
To explore the universe and search for life,
To inspire the next generation of explorers
. . . As only NASA can.

FY02 OBPR Budget by Program ($M)



1. Space Product Development	32.4
2. ISS Multi-User Systems & Support	162.8
3. Institutional Support	187.7
4. Bioastronautics Research	119.7
5. Physical Sciences Research	228.4
6. Fundamental Space Biology	93.1
Total	**824.2**



OBPR's vision for the program's future is focused on achieving a 5-year direction that enables a longer term future for NASA.

For more information on OBPR's "biophysical" world, please visit our Web site at

http://SpaceResearch.nasa.gov

Quail eggs are small (shown above at actual size) and develop quickly, making them ideal for space experiments. The Avian Development Facility supports 36 eggs in two carousels, one of which rotates to provide a 1-g control sample to be compared with eggs grown in microgravity.

Astronaut Peggy Whitson, here inspecting soybean plants grown as part of a commercial venture, was named the first ISS Science Officer.

FY 2002 Accomplishments

Soaring overhead every 90 minutes is the largest human-engineered object ever to orbit Earth: a fully functioning international spacecraft and laboratory, built with contributions from more than a dozen nations around the world. Since the launch of the Service Module in July 2000, there have been 27 successful U.S. and Russian missions to the ISS.

As 2002 closes, a fifth Expedition crew is conducting 25 research investigations, operating the onboard systems, and participating in the ongoing assembly and outfitting of the space station.

To date, 97 discrete research investigations have been implemented on the ISS. These represent the full cross section of OBPR research disciplines, including physical sciences research, bioastronautics, fundamental space biology, space product development, and international partner research experiments. Further, the Office of Space Flight has conducted technology development investigations. Lastly, substantial education and public outreach activities took place.

Significantly, NASA has designated Peggy Whitson, a mission specialist on Expedition 5, as the first in a series of ISS Science Officers to help achieve maximum scientific research returns. OBPR also conducted its first fully interactive telescience experiments utilizing the multi-user Microgravity Science Glovebox (MSG).

Research Maximization and Prioritization

Guidance for setting OBPR's research priorities was provided by the Research Maximization and Prioritization (ReMaP) Task Force in 2002. Recommendations were also made on maximizing the scientific returns on many NASA programs, including ISS. ReMaP ranked research disciplines by priority within medical, biological, and physical sciences research specialities. The highest priority research in OBPR spans two broad categories—that which enables human exploration of space and that which has intrinsic scientific merit. ReMaP encouraged NASA to continue coordination with the ISS international partners and to expedite the implementation of the ISS Centrifuge Facility (to be provided by Japan), which provides a variable gravitational field essential to biological research. The task force determined that different evaluation criteria are needed to adequately assess commercial research. Other ReMaP findings and recommendations focused on the OBPR organization and management, with an emphasis on conducting interdisciplinary research, exploring alternative solicitation methods, and attracting quality scientists and commercial research partners.

STS-107

The STS-107 Space Shuttle mission scheduled for launch in early 2003 will build on highly successful results from Spacelab in the 1980s and 1990s, and it will complement ongoing long-duration investigations aboard ISS. OBPR is the primary sponsor for the mission and is responsible for 30 investigations comprising outstanding peer-reviewed and commercial research. STS-107 was recommended by the National Research Council and approved by the U.S. Congress to ensure continuing flight opportunities for the NASA space research community while NASA develops new capabilities aboard the ISS.

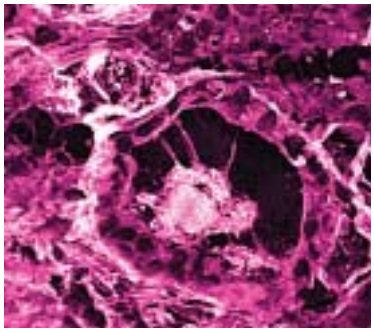
Mission specialist Kalpana Chawla trains in the SPACEHAB double module for the STS-107 research mission scheduled for early 2003.

ISS Utilization Management Concept Development

Starting in March 2002, the ISS Utilization Management Concept Development Team studied options for an organization to most efficiently run ISS research operations. In order to comply with the study, which was mandated by Congress, the Concept Development Team reviewed input from a NASA-hosted public workshop, then assessed which ISS utilization functions could be performed under each management option. As a result of the Team efforts, OBPR will pursue a phased approach to implementing recommendations.

Collaborations with Other Agencies

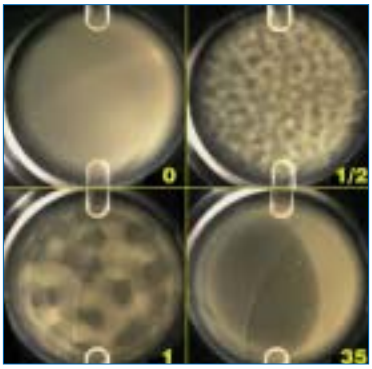
OBPR currently has 14 collaborative agreements with eight Government agencies: National Institutes of Health, the Food and Drug Administration, the Geological Survey, the Department of Agriculture, the National Oceanographic and the Atmospheric Administration, the Centers for Disease Control, the Department of Energy, and the Department of Defense. In addition, OBPR has agreements with the White House Office of Science and Technology Policy and nonprofit organizations including the American Federation for Aging Research, College of Sports Medicine, the American Library Association, and national teacher associations. OBPR will continue to develop new collaborative agreements with other agencies and organizations to further its interest in research supporting NASA's goals and missions.



Under an interagency agreement, the NASA-NIH Center for Three-Dimensional Tissue Culture has developed advanced prostate cancer models for drug testing based on NASA technology that provides unique advantages for biomedical research.

Education and Outreach

OBPR and the American Library Association will inaugurate a public community "NASA At Your Library" campaign across the country, starting in early 2003. OBPR also will further develop its strategic approach to public outreach, focusing on research initiatives that have the most significant impact on professional and general public communities. OBPR continues to assess opportunities for reaching diverse audiences.



Space provides the rare opportunity to study microscopic particles suspended in a liquid as they naturally separate without the settling effects caused by gravity on Earth. This 35-day run on the ISS is one of several colloidal physics experiments that should help improve processes in the pharmaceutical, food, and other industries.

The planned Primary Atomic Reference Clock System is one of several atomic clocks planned for ISS. Their combined data will provide a rigorous test—possible only in space—of several aspects of Einstein's Theory of Relativity.

THE PHYSICAL SCIENCES RESEARCH PROGRAM sponsors multidisciplinary research in applied and fundamental sciences, driving technological innovation for space exploration and Earth-based applications and advancing understanding in the physical sciences.

Purpose

The programs's two goals are to conduct research in the physical sciences that supports NASA's exploration goals and to use the space environment as a unique laboratory for fundamental and applied research. Elements of the program include the following:

- combustion science,
- fluid physics and engineering,
- fundamental physics,
- interdisciplinary biotechnology, and
- materials science.

Approach

The Physical Sciences Research Program brings cutting-edge experimental facilities to laboratories in low-Earth orbit and beyond. It uses low gravity as a unique tool in experimental research to build a path for the development of new aerospace technologies critical for the future of space exploration.

Results

The Physical Sciences Research Program completed a number of basic and applied research projects on the ISS in the past year, including the following:

- The Physics of Colloids in Space (PCS) experiment returned information about the development and dynamics of colloid materials. These data, not obtainable on Earth, are important to the future production of materials for storing, transferring, and processing information in a way that is more efficient and faster than electric currents such as optical switches, filters, and lasers for advanced telecommunication networks and displays. Other potential uses include improvements in the shelf life of foods, cosmetics, and paints, common products made of colloid-based materials.

- Cellular Biotechnology Operations Support System (CBOSS) lab hardware was operated on the ISS from August 2001 through June 2002, during which seven investigations were completed. This was the first ISS hardware dedicated to cultivating living tissue cells, enabling researchers to study changes in human and animal immune systems. Cells grown in low gravity more closely resemble cells found in living bodies and are being used for the study of human diseases such as cancer. Samples from the seven investigations were returned to Earth, and data analysis is proceeding.

THE BIOASTRONAUTICS RESEARCH PROGRAM sponsors research to improve space flight crew health, safety, and performance and to increase reliability and efficiency.

Purpose

The program's first goal is to perform scientific and technical research that will expand medical knowledge and technologies required to develop countermeasures that will preserve health, morale, performance, and safety of space flight crews. This effort includes both ground- and space-based studies. In addition to solving problems in space exploration, the research will enrich life on Earth through the use of space technology and applied biomedical knowledge. We support space research involving critical studies in the following:

- radiation health,
- behavior and performance,
- physiology,
- clinical/operational medicine, and
- environmental health.

The second goal is to develop enabling technologies for safe and productive human habitation of space while using microgravity as a laboratory to test the essential principles of physics, chemistry, and biology. We support critical technological research in the following areas:

- advanced environmental monitoring and control,
- advanced life support,
- space human factors engineering, and
- advanced extravehicular activity.

Approach

The program supports research that answers essential questions about the following:

- medical requirements and risks for human health during space flight,
- biomedical system performance in microgravity,
- preventive countermeasures for the negative aspects of space flight, and
- technologies to enable humans to live and work in space safely and effectively.

The research provides rational tests and evidence that enable the development and implementation of therapeutics, procedures, techniques, or equipment required to reduce flight medical, safety, and performance risks to acceptable levels. Technology development to augment spacecraft habitability, environmental controls, planetary habitability, and space systems technology is an essential element of the work.

Results

NASA's Bioastronautics Research program provides important space and Earth benefits by addressing astronaut health issues and those of the general biomedical research community. Atmosphere detectors developed for NASA also have potential applications in detecting harmful chemicals that might be in the environment. NASA investigators have successfully tested a drug, Midodrine, that reduces the effects of dizziness and fainting and is a potential medical breakthrough in bone therapy for astronauts and patients on Earth interested in the treatment and prevention of osteoporosis.

Computerized dynamic posturography tests how astronauts use cues we take for granted to maintain their balance before and after flight. The lessons are being applied on Earth for people with balance disabilities.

ENose sensors are tailored so they conduct electricity differently when an air stream carries a particular chemical across them. JPL has designed and built a 3-pound flight version.

Brassica rapa sprouts grown in the Biomass Production System aboard the International Space Station.

Although no longer than this dash "—", the *C. elegans* worm shares many genetic and other features with humans. This makes it ideal for research in responses to different gravity levels, such as hypergravity (20 g) in a centrifuge.

THE FUNDAMENTAL SPACE BIOLOGY PROGRAM seeks to answer one of NASA's fundamental strategic questions: What are the roles of gravity and cosmic radiation in biological processes?

Purpose

The program's goal is to address biological questions in space and on Earth to expand our understanding of biological processes and to enable a long-duration human presence in space. The knowledge and technology gained are applied to improve our Nation's competitiveness, education, and quality of life on Earth. All levels of biological complexity, including the following, are studied on cells, plants, and some animals:

- cellular and molecular biology,
- organismal and comparative biology,
- developmental biology,
- gravitational ecology, and
- evolutionary biology.

Approach

Critical biological questions addressed by the program include the following:

- Gene function and activity: Expression of the genetic code is a critical process and may be altered in space. Are specific genes activated or deactivated in space? What biological functions are involved?

- Cell activity: How are the building blocks for biological organization—intracellular processes, cell growth, and cell-to-cell communication—affected in space? Are only certain types of cells in certain tissues affected? What are the consequences?

- Long-term exposure to space: What are the effects of chronic exposure to altered gravity and/or other space-related factors on normal physiology, metabolism, and performance of animals and plants?

- Effects on development: Are normal development and function of biological organisms and their organs, the capacity of organisms to reproduce, and senescence (aging) processes that form the cycle of life affected in space? What can we learn about these processes by studying them in space? Of particular interest are systems that sense, respond, and use gravity (e.g., balance system, bone, muscles, control of movement).

Results

The answers to these questions will result in novel information about biological processes on Earth and provide a more thorough understanding of the consequences of human exposure to space. In addition, this fundamental knowledge is directly applicable to issues of human health and safety on Earth and in space. Finally, understanding biological processes at each of the levels described will enable the application of biological principles to technology development.

THE SPACE PRODUCT DEVELOPMENT PROGRAM provides access to the unique environment of space for commercial researchers to develop new or improved products and services on Earth.

Purpose

The commercial utilization of space offers a unique economic opportunity for industry. Commercial expansion into space will enable benefits on Earth and enrich the everyday lives of Americans. These opportunities in space commercialization and commerce ensure the continued economic growth of the United States and enable new advances, technological understanding, products, and jobs for the public. Research areas include the following:

- biotechnology,
- agribusiness,
- advanced materials, and
- engineering research and technology development.

Approach

NASA funds Commercial Space Centers charged with attaining and sustaining partnerships with industry to foster the commercial development of space, providing opportunities for research and commerce in space. Many partner companies are particularly interested in discovering the benefits that come from research conducted in an environment where the effects of gravity are reduced or eliminated. By using conditions available on special aircraft (short periods of low gravity), the Space Shuttle, or the ISS, businesses gain insight that will enable new or improved product development.

Results

Collaboration with Commercial Space Centers on microgravity research or unique ground-based equipment has resulted in products such as these that are available to the public:

- Ford Motor Company has used the program to help improve its cast parts, resulting in more reliable products at lower cost.

- WTC-Ecomaster has produced a new generation of water purification technology that is benefiting everyone from hikers to municipal water treatment operations.

- Light-emitting diodes developed by Quantum Devices, Inc., provide a more reliable, efficient source of light in photodynamic cancer therapy.

More than 60 product lines are currently under development by the Space Product Development Program's industrial partners, which invest over $50M annually. The Space Product Development Program is working to capitalize on the long-duration exposure that ISS affords to maximize the utilization of both the depth and breadth of commercial involvement with space. Through partnerships among the Commercial Space Centers and industry, the benefits of space are brought down to Earth and fuel more investments.

The Ford Motor Company used materials data supplied by researchers (above) at the Solidification Design Center, a Commercial Space Center, to design new, high-quality sand molding processes for creating precision automotive parts.

A team from the Medical College of Wisconsin uses a special probe, containing light-emitting diodes, in photodynamic therapy to treat cancer.

Aleksandar G. Ostrogorsky, a materials science investigator, inspects a specimen in the Microgravity Science Glovebox on the International Space Station.

A contestant shows part of her experiment setup during the Dropping In a Microgravity Environment (DIME) education event.

Outreach and Education

OBPR's outreach goals are 1) to convey the excitement of research in space; 2) to communicate what experiments are taking place, why they are taking place, and how such research benefits life on Earth; and 3) to actively involve students and educators in OBPR's research in both formal and informal learning environments.

The audiences for public and educational outreach are as diverse as OBPR's research portfolio. They range from the technical/professional communities whose membership interests mirror OBPR research disciplines to a vital, large, but less defined audience, the general public. As research results become available from OBPR-supported studies aboard the ISS, those results will be shared with the public to communicate the benefits of living and working in space.

OBPR plays a strategic role in stimulating the interest of children in America in the fields of science, math, and engineering. Through continuous collaboration among scientists, engineers, and educational outreach staff, the OBPR educational outreach program develops and sponsors activities and materials that support the national standards and enhance learning at all levels from 6th grade to lifelong learners. OBPR programs allow students to have "real-time" experiences with science labs and procedures.

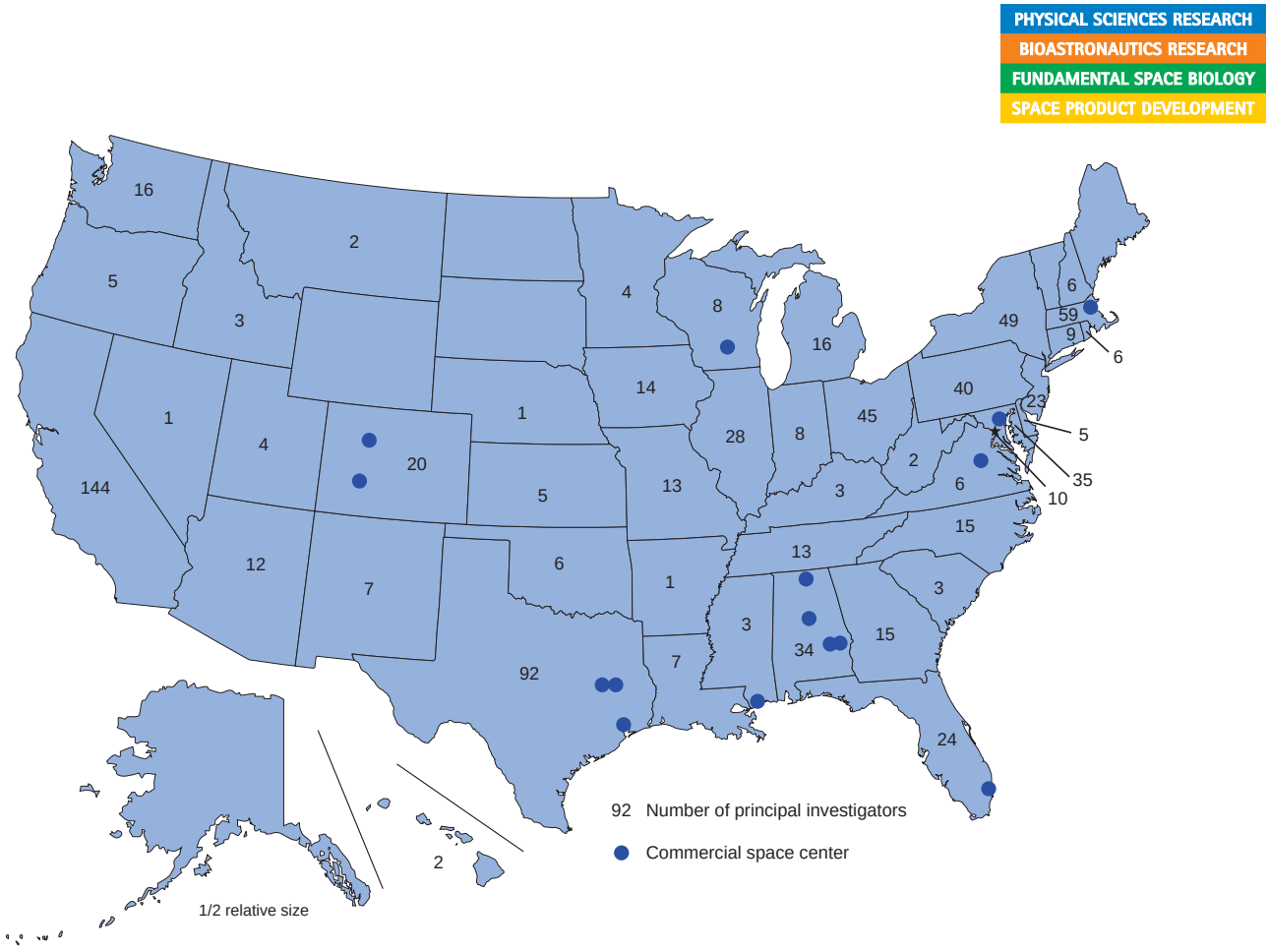
Teacher workshops focus on activities that connect space research with national standards curricula. At the higher learning level, OBPR provides undergraduates with summer internships in research at one of the NASA Centers and invites applications from promising graduate students to participate in annual fellowship programs. Doctoral students are provided with opportunities to perform research on problems compatible with the research interests of OBPR. Several Commercial Space Centers directly involve students in all stages of research and flight hardware development and operations.

During the past year, OBPR public outreach actively participated in health-related conferences including the American Society of Clinical Oncology, the National Medical Association, and the American Public Health Association. It diversified its public outreach by participating in conferences of the American Association for the Advancement of Science; the International Health, Racquet and Sports Club Association; the American Library Association; and the Golden State Museum. OBPR also supported NASA's exhibit at the Black Family Reunion event in Washington, DC, as well as a variety of events that affected local and national audiences. *Space Research*, OBPR's newsletter, expanded coverage to over 25,000 to include research highlights that communicate important research efforts to the professional, technical, and general public.

National Aeronautics and
Space Administration

Office of Biological and Physical Research

NATIONAL DISTRIBUTION OF NASA BIOLOGICAL AND PHYSICAL RESEARCH

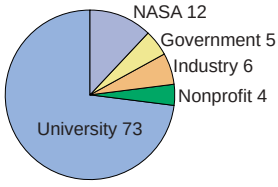


Principal Investigators

(For FY 2001: 830 investigators,
1,104 investigations in 44 States and DC)

Principal Investigators	830
Co-investigators	1,176
Postdoctoral students	534
Doctoral students	803
Graduate students	589
Undergraduate students	912
Corporate partners	197
Peer-reviewed articles	1,144
Awards	67
Books (or chapters)	82
Dissertations and theses	63
Patents	22

by institution (%)



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Commercial Space Centers

BioServ Space Technologies, Boulder, CO
Center for Biophysical Sciences and Engineering, Birmingham, AL
Center for Commercial Applications of Combustion in Space, Golden, CO
Center for Microgravity Materials Processing, Boston, MA
Center for Satellite and Hybrid Communication Networks, College Park, MD
Center for Solidification Design, Auburn, AL
Center for Space Power, College Station, TX
Center for Space Power and Advanced Electronics, Auburn, AL
Commercial Space Center for Engineering, College Station, TX
Consortium for Materials Development in Space, Huntsville, AL
Medical Information and Technology Applications Center, Richmond, VA
ProVision Technologies, Stennis Space Center, MS
Space Communications Technology Center, Boca Raton, FL
Texas Center for Superconductivity at the University of Houston, Houston, TX
Wisconsin Center for Space Automation and Robotics, Madison, WI

EDUCATION AND OUTREACH

PHYSICAL SCIENCES RESEARCH
BIOASTRONAUTICS RESEARCH
FUNDAMENTAL SPACE BIOLOGY
SPACE PRODUCT DEVELOPMENT

Why is it important?

Communicating diverse research goals to a range of communities of varying levels of technical background is a challenging but essential task. OBPR is obligated and committed to describing to the public what comes from investments in space.

What is NASA doing?

In the past year, OBPR heightened the visibility of OBPR outreach by:

- expanding Microgravity News—now Space Research—to span all of OBPR's research disciplines;
- sponsoring activities related to STS-107 investigations, such as the "Space Research and You" in Rosslyn, VA, bioreactor and soil mechanics classroom activities, and a special CD for science museums;
- developing a new classroom drop tower using small TV transmitters and laptop computers to capture video;
- holding the second Dropping In a Microgravity Environment (DIME) competition to give Ohio-area high school teams the opportunity to use NASA Drop Tower facilities;
- exhibiting at conferences as diverse as the American Library Association, the National Medical Association, and the American Public Health Association;
- delivering a kid-scale mockup of the Microgravity Science Glovebox for use in museums; and
- signing a Memorandum of Understanding with Biotechnology Industry Organization for potential collaboration.

A youngster (above) finds that a simple child's puzzle is not so simple when special goggles give him a mirror image of the world. Below, a high school student prepares a basic fluids experiment for two seconds of freefall in the NASA Drop Tower. Both activities give students insight into the basics of space research.

What are the benefits?

Outreach and education activities explain to the taxpayer 1) what research is taking place, 2) why it is taking place, and 3) how it benefits the taxpayer.

What is next?

In addition to continuing activities initiated in 2002, OBPR in 2003 will

- pursue a joint venture with the American Library Association and local communities nationwide through a "NASA At Your Library" exhibit campaign (by 2005, it should reach 120 communities),
- participate in Centennial of Flight events in 2003, and
- work with professional organizations to build upon the positive reactions received during conferences in 2002.

NASA contact: John Emond (202-358-1686) or Bonnie McClain (202-358-2181)

National Aeronautics and
Space Administration

Office of Biological and Physical Research

MIMICKING THE BIRTH AND GROWTH OF PLANETS AND RINGS

PHYSICAL SCIENCES RESEARCH
BIOASTRONAUTICS RESEARCH
FUNDAMENTAL SPACE BIOLOGY
SPACE PRODUCT DEVELOPMENT

Why is it important?

Understanding the release of dust and the rebound of colliding particles is crucial to understanding the evolution of planetary rings and the origins of the planets themselves. Collisions between the small particles in planetary rings occur at very low speeds, often less than 2 feet per minute (1 cm/s). Similar collisions occur in the early stages of planet formation, when the colliding rock and ice particles are so small that there is very little gravitational pull between them. As a result, even slow collisions can result in material being ejected or the particles bouncing apart instead of sticking together.

What is NASA doing?

To study the question of low-speed dust collisions, NASA sponsored the COLLisions Into Dust Experiment (COLLIDE) at the University of Colorado. It was designed to spring-launch marble-sized projectiles into trays of powder similar to space or lunar dust. COLLIDE-1 (1998) discovered that collisions below a certain energy threshold eject no material. COLLIDE-2 was designed to identify where the threshold is.

The COLLIDE apparatus—largely developed and built by graduate students at Colorado—carries six Impactor Box Systems. Each launches a pellet at a different speed into a small tray of dust. All six systems worked well. The slowest impactor ejected no material and stuck in the target. The faster impactors produced ejecta; some rebounded, while others stuck in the target.

What are the benefits?

COLLIDE investigations support work in several areas, including the following:

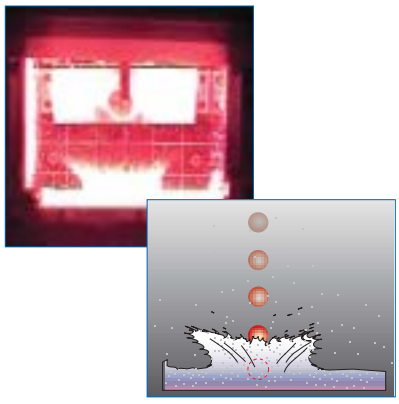
- providing a broader context for interpreting ground-based research into planet formation and growth;
- producing a video record of unique impacts in microgravity for education purposes;
- providing graduate students, who did much of the engineering work, with valuable flight experience; and
- developing applications for space flight and experimentation.

What is next?

The data from COLLIDE-2 are being analyzed, and options for a third flight are being studied. A ground-based investigation, PRIME, is flying on the KC-135 low-g aircraft for tests that can be run in less than 20 seconds of low-g.

NASA contacts: Dr. Francis Chiaramonte (202-358-0693) or Dr. Brian Motil (216-433-6617)

Clues to the formation of planets and planetary rings—like Saturn's dazzling ring system (above—may be found by studying how dust grains interact as they collide at low speeds. In COLLIDE-2, scientists nudged small projectiles into dust beds and recorded how the dust splashed outward (below). As depicted in the drawing, the projectile came from the top of the video frame.



National Aeronautics and
Space Administration

Office of Biological and Physical Research

USING SPACE TO GET A SOLID FOOTING

PHYSICAL SCIENCES RESEARCH
BIOASTRONAUTICS RESEARCH
FUNDAMENTAL SPACE BIOLOGY
SPACE PRODUCT DEVELOPMENT

Why is it important?

Rip open a vacuum-packed pouch of coffee and you experience a fundamental aspect of soil mechanics or granular materials in general: once pressures are released, the grain assembly moves about freely, almost like a liquid. This can happen to saturated, loose sand in an earthquake or to grains in a silo. During soil liquefaction, a soil-water composite momentarily acts like a viscous liquid as particles lose contact with one another and the material is balanced by the water, allowing buildings to sink and tilt, bridge piers to move, and buried structures to float.

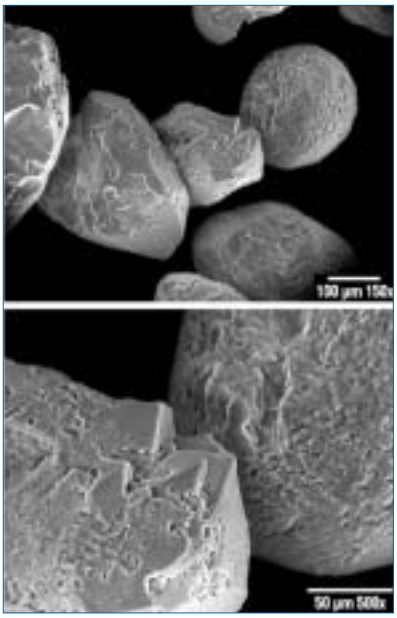
Detailed understanding of this phenomenon is needed to improve techniques for evaluating building sites here on Earth and to improve industrial processes with powdered materials. But on Earth, gravity-induced stresses complicate the analysis and change loads too quickly for detailed study, especially when instabilities occur.

Soil liquefaction during the October 17, 1989, Loma Prieta earthquake made this apartment building in San Francisco's Marina District sink.

What is NASA doing?

A fundamental model of soil behavior in earthquakes is not available in ground-based experiments. However, experiments in space allow low, confining stresses to be maintained for extended measurements. In the first two flights (1996, 1998), the Mechanics of Granular Materials (MGM) experiments showed the following results:

- volume change properties three times larger than predicted,
- very high stiffness properties nearly 10 times greater than predicted, and
- strength properties and instability phenomena quite different from theory.



What look like boulders are sand grains used in the MGM experiments. Countless microscopic faces cause friction until fluid pressure separates the grains and lets them briefly flow like a liquid.

What are the benefits?

Many natural and industrial processes will involve granular materials such as these:

- soil mechanics, geotechnical engineering;
- earthquake engineering;
- mining (open pits, strip mines, tunnels, shafts);
- grain silos, powder feed systems, coal, ash, pharmaceuticals, and fertilizers;
- coastal and offshore engineering;
- wind and water erosion of soil, slope development and decay, volcanic deposition;
- planetary geology; and
- microgravity handling of powders.

What is next?

The MGM-III experiments on STS-107 in 2003 will study earthquake liquefaction behavior. The hardware uses a new specimen reformation technique that allows multiple test runs. NASA is pursuing several investigations of different aspects of granular materials.

NASA contact: Dr. Francis Chiaramonte (202-358-0693)

National Aeronautics and
Space Administration

Office of Biological and Physical Research

SOLVING A HOT PARADOX

PHYSICAL SCIENCES RESEARCH
BIOASTRONAUTICS RESEARCH
FUNDAMENTAL SPACE BIOLOGY
SPACE PRODUCT DEVELOPMENT

Why is it important?

The last place you want to be in traffic is behind the bus or truck that is belching large clouds of soot onto your freshly washed car. The mechanisms of soot formation are among the most important unresolved problems of combustion science because soot affects contemporary life in so many ways.

Besides looking and smelling bad, soot is a health hazard. Soot also is wasted energy, and therein lies an interesting paradox: soot forms in a flame's hottest regions where you would expect complete combustion and no waste. Soot enhances the emissions of other pollutants and radiates unwanted heat to combustion chambers, among other effects.

What is NASA doing?

The Laminar Soot Processes (LSP-2) experiments use the microgravity environment of space to eliminate buoyancy effects and thus slow the reactions inside a flame so that they can be more readily studied. LSP-2 will expand on surprising results developed from its first two flights in 1997. The data suggest the existence of a universal relationship, the soot paradigm, that, if proven, will be used to model and control combustion systems on Earth.

What are the benefits?

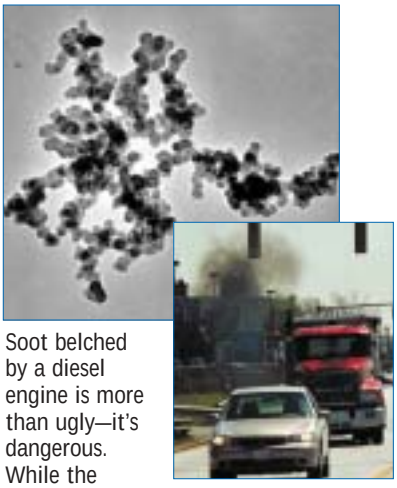
NASA anticipates that improved understanding of soot formation in combustion processes will have industrial and environmental benefits, including the following:

- controlling soot production in combustion processes,
- reducing radiative heat transfer that damages engines,
- improving electric power generation while maintaining complete soot burnout (no emissions),
- enhancing soot production in processes for carbon black used in tires and other applications, and
- enhancing combustion studies to design new systems and to retrofit existing systems.

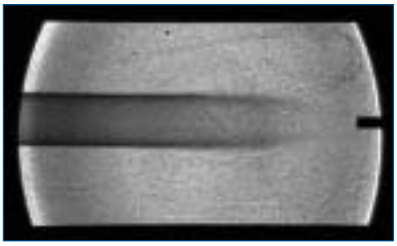
What is next?

LSP-2 will fly on the STS-107 Space Shuttle mission in 2003 to build on the results from its highly successful 1997 mission. NASA plans additional soot formation experiments using the International Space Station's Combustion Integrated Rack.

NASA contact: Dr. Merrill King (202-358-0817)



Soot belched by a diesel engine is more than ugly—it's dangerous. While the largest particles (like this one from LSP's 1997 flight experiment, shown 50,000 times its actual size) may wash out of the air when it rains, smaller particles linger and possibly endanger human health and the environment.



"Laminar" means a simple, smooth fuel jet burning in air, somewhat like a butane lighter. This classical flame (seen here in LSP's 1997 flight) is difficult to study on Earth with gravity making hot air rise and cold air flow in behind it.

BUBBLING UP TROUBLE

Why is it important?

Ninety percent of all the manufactured goods we use every day contain at least one cast metal part. These parts are vital to manufacturing, science, medicine, aerospace, and many other fields. However, millions of dollars' worth of castings become scrap every year because of defects such as voids that reduce the part's strength or cause it to fail prematurely.

Voids form when gases generate bubbles as the molten metal cools in its mold. On Earth, some of these bubbles rise to the top of the casting and pop; others are pushed toward the center of the casting and can cause detrimental voids in the center of the part.

What is NASA doing?

Scientists are using the microgravity environment on the International Space Station to study how these bubbles form, move, and interact. The Pore Formation and Mobility Investigation (PFMI) in the Microgravity Science Glovebox aboard the International Space Station uses a transparent material called succinonitrile that behaves like a metal to study this problem. Video images sent to the ground allow scientists to watch the behavior of the bubbles as they control the melting and freezing of the material. The bubbles do not float to the top of the material in microgravity, so the scientists can study their interactions.

What are the benefits?

The PFMI provides a unique opportunity to

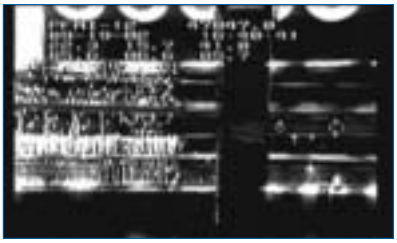
- observe how bubbles form and move as a material changes from liquid to solid without the buoyancy effects of gravity,
- understand pore formation in previous microgravity experiments,
- design better microgravity experiments for the future, and
- apply the knowledge gained to help reduce voids in castings produced on Earth.

What is next?

The PFMI is scheduled to process 12 to 15 samples with different compositions and under various processing conditions. Information from the first samples processed on the ISS show exciting results that will be incorporated into the next sample runs. The samples and recorded video will return to Earth for additional analysis.

NASA contacts: Dr. Michael Wargo (202-358-0822) and Linda Jeter (256-544-7392)

Pores and voids often form in metal castings on Earth (above), making them useless. A transparent material (in the glass ampoule, below) that behaves at a large scale in microgravity (bottom) the way that metals behave at the microscopic scale on Earth, will help show how voids form and help us learn how to prevent them.



National Aeronautics and
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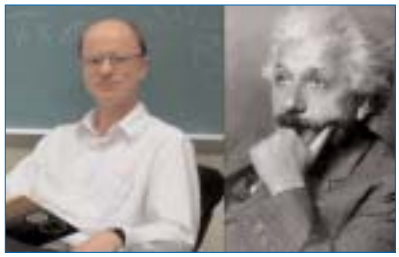
WAS EINSTEIN WRONG? SPACE STATION MAY FIND OUT

PHYSICAL SCIENCES RESEARCH
BIOASTRONAUTICS RESEARCH
FUNDAMENTAL SPACE BIOLOGY
SPACE PRODUCT DEVELOPMENT

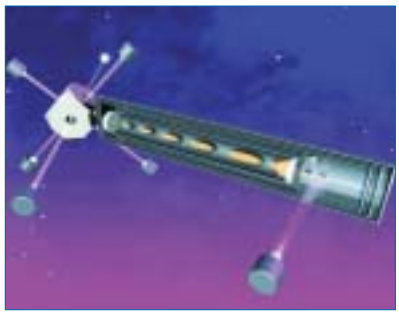
Why is it important?

Einstein's Theories of Relativity have withstood a wide range of tests in the more than 90 years since they were first offered. Although they are widely accepted as fact, significant aspects regarding gravity are unverified because testing is not possible deep within Earth's gravitational field. Further tests are needed because

- gravity is one of the four known fundamental forces of nature and thus requires the best possible verification of our theories;
- the better we understand gravity and the implications of our observations regarding it, the more likely we will be to unify it with the other three forces; and
- any verifiable violation of the Theory of General Relativity is potentially fatal and would require developing a new theory of gravity.



Alan Kostelecky of Indiana University has analyzed the experiments testing Einstein's theories that can be performed on the ISS with high-resolution clocks.



The Primary Atomic Reference Clock in Space experiment will test predictions of Einstein's theories of relativity regarding the fundamental nature of time and space. It will become the most accurate clock in the world, with performance disseminated worldwide through the Global Positioning System.

What is NASA doing?

There are two initiatives in NASA to push the envelope of observations of gravity. The Office of Biological and Physical Research has supported laboratory-style investigations of general relativity for decades. The Office of Space Science, on the other hand, has recently formed a Fundamental Physics thrust that includes gravity and general relativity as prime subjects for exploration. This discipline supports gravity wave detection, investigation and modeling of high-density cosmological objects like black holes and neutron stars, and tests of general relativity like Gravity Probe B. Tests of the equivalence principle, such as the Satellite Test of the Equivalence Principle and Laser Lunar Ranging, are ongoing. Also, both ground-based laboratory and theory investigations of general relativity are supported. Now NASA is planning to place high-precision clocks on the ISS to improve the tests of gravity theories.

What are the benefits?

NASA provides investigators with a unique environment for testing this weakest of the natural forces. Test precision advances ranging to one part in one million aboard the ISS will give scientists considerable new knowledge of the properties of gravity. Entirely new ranges of test parameters can be explored in this "gravity-free" environment.

What is next?

NASA is planning to fly atomic clock experiments such as the Primary Atomic Reference Clock in Space (PARCS) on the ISS to test general relativity predictions. As well as supporting experiments requiring precise time standards, PARCS will open the way for experiments requiring the use of similar devices. In addition, Gravity Probe B is scheduled to test aspects of Einstein's theory of relativity in April 2003.

NASA contact: Dr. Mark Lee (202-358-0816)

National Aeronautics and
Space Administration

Office of Biological and Physical Research

HELPING ASTRONAUTS AND THE ELDERLY KEEP THEIR BALANCE

PHYSICAL SCIENCES RESEARCH
BIOASTRONAUTICS RESEARCH
FUNDAMENTAL SPACE BIOLOGY
SPACE PRODUCT DEVELOPMENT

Why is it important?

Being able to keeps one's balance is crucial to normal activity. Yet partial loss of this ability is a problem shared by astronauts and elderly people, as well as other people suffering from balance disorders. Research on astronauts in space is providing insight into this problem for people on Earth as well as travelers in space.

Our sense of up and down comes from the brain's interpretation of many signals from sensors in the inner ear and other parts of the body. In orbit, the signal pattern changes and may cause temporary disorientation and motion sickness in many astronauts until the brain adapts. On return to Earth, the brain must re-adapt, putting astronauts on the same footing as patients with posture problems.

What is NASA doing?

NASA researchers use a computerized dynamic posturography (CDP) system to assess how the brain handles input from the ear, eyes, and other sensors throughout the body, and how it commands muscles to stand upright. The astronaut stands on a tiltable posture platform and looks at an artificial horizon. Eye and muscle reflexes are measured as this mini-world changes. Astronauts are tested several times before and after a mission. NASA is collaborating with the National Institute on Aging on similar balance studies in the Baltimore Longitudinal Study on Aging.

What are the benefits?

Research with the CDP has accomplished the following:

- provided a means of evaluating when astronauts may return to duty after flight,
- shown that veteran astronauts re-adapt faster,
- provided a means to measure a patient's progress in therapy,
- assisted in diagnosing a fluid leak from the balance organs to the inner ear that causes balance problems (perilymphatic fistula or PLF).

What is next?

CDP shows promise as a technique for detecting whether a person is at risk for falling disorders. Because most falls are thought to arise directly or indirectly from balance organ abnormalities, preventing falls could significantly reduce fall-related deaths and injuries. Research will continue with astronauts before and after long missions aboard the International Space Station.

NASA contact: Dr. David Tomko (202-358-2211)

Computerized dynamic posturography tests how astronauts use cues we take for granted to maintain their balance before and after flight. The lessons are being applied on Earth for people with balance disabilities.

National Aeronautics and
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NASA DEVELOPS SMALLEST, LIGHTEST CHEMICAL ANALYZER

PHYSICAL SCIENCES RESEARCH
BIOASTRONAUTICS RESEARCH
FUNDAMENTAL SPACE BIOLOGY
SPACE PRODUCT DEVELOPMENT

Why is it important?

Detecting trace levels of toxic chemicals before they reach harmful levels in the atmosphere is crucial to astronaut health on long missions and important for humans on Earth as well. One highly accurate and reliable tool that can quickly and automatically analyze complex mixtures of gases is the mass spectrometer. However, mass spectrometers are large, expensive devices demanding large power supplies. A handheld model was needed to monitor the environment outside the International Space Station (ISS) during spacewalks.

What is NASA doing?

Ara Chutjian and his colleagues at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, CA, revolutionized the mass spectrometer by developing a miniature version just 3 inches tall and weighing about 4 ounces (a world record). With its associated gear, the system weighs only 3 pounds. This new Trace Gas Analyzer (TGA) was delivered to the ISS in February 2001. It can detect leaks of ammonia from cooling systems, propellant from thrusters, and air leaks from seals and micrometeorite holes in the spacecraft structure.

What are the benefits?

The U.S. Environmental Protection Agency uses mass spectrometers to monitor contamination from Superfund sites and factory emissions on Earth. These devices are only used sparingly because of their large size and high cost, and the samples are often brought back to labs for analysis. Chutjian and his colleagues hope to make their small, inexpensive unit available for readily detecting contaminants here on Earth. They are working with Consolidated Edison to develop field-deployable prototypes to detect PCBs (polychlorinated biphenyls) at contaminated sites.

What is next?

NASA will be able to use the combined gas chromatograph-mass spectrometer (GCMS) on human missions beyond low-Earth orbit. It would constantly monitor the spacecraft's air to detect the accumulation of hazardous gases such as carbon monoxide, benzene, and formaldehyde. The device can also be used to study the chemical composition of the materials collected from a Martian or asteroid surface. Chutjian and his colleagues are designing a second-generation mass spectrometer with 50 times the sensitivity and 3 times the resolution of the current model.

JPL technologists responded to a request for a quick, low-cost innovation by creating the smallest mass spectrometer yet produced for either human or robotic space flight (above, about actual size). It is used inside a handheld tool (inset) used by astronauts to check for leaks outside the International Space Station.

NASA contact: Dr. Charlie Barnes (202-358-2365)

SNIFFING OUT AIR QUALITY WITH AN ELECTRONIC NOSE

PHYSICAL SCIENCES RESEARCH
BIOASTRONAUTICS RESEARCH
FUNDAMENTAL SPACE BIOLOGY
SPACE PRODUCT DEVELOPMENT

Why is it important?

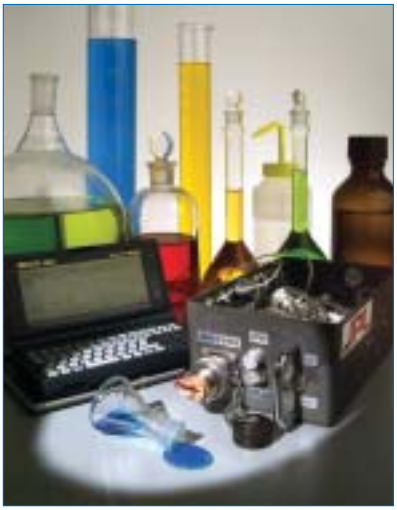
Air quality monitoring is a priority when operating in closed environments such as the International Space Station (ISS) or many specialized workplaces on Earth. Rapid detection of deadly chemicals or overheating electrical equipment has been done in the past by the crew's collective sense of smell. However, the human nose becomes numb to pungent smells after a short time. We need a reliable nose that is always on duty and never becomes insensitive to dangerous odors.

What is NASA doing?

Margaret Amy Ryan and a team of scientists and engineers at NASA's Jet Propulsion Laboratory (JPL) have developed an electronic nose that is similar to our own noses in the way it reacts to certain chemicals. The active parts are 32 sensors, each with a different mix of polymers saturated with carbon. When certain chemicals latch onto a sensor, they change how the sensor conducts electricity. This signal tells how much of a compound is in the air.

The electronic nose flown aboard STS-95 in 1998 was capable of successfully detecting 10 toxic compounds. This device can potentially reduce the health risks for astronauts on the ISS by detecting toxic chemicals; it can also help them determine when the air is breathable again.

ENose sensors (above) and their support system compose a package about the size and weight of a large paperback book. The sensors are tailored to conduct electricity differently when an air stream carries a particular chemical across them. JPL has designed and built a 3-pound flight version (below, with palm-size control and data computer).



What are the benefits?

The electronic nose is an exciting technology with many potential applications on Earth:

- food processing, to monitor food quality and freshness;
- industry, in process and quality control;
- medicine, as diagnostic tools;
- agriculture, as plant growth monitors;
- workplace and environmental safety; and
- bioterrorism early warning.

What is next?

The JPL team is improving the electronic nose in several ways:

- adding 15 compounds to the detection list,
- creating new software to analyze data in a way that classifies the characteristics and class of a compound,
- reducing the mass and volume of ENose to one-half of the version flown on STS-95, and
- increasing sensitivity and extending capability to separate mixtures.

NASA contact: Dr. Charlie Barnes (202-358-2365)

CHECKING HEARTS VIA THE INTERNET

PHYSICAL SCIENCES RESEARCH
BIOASTRONAUTICS RESEARCH
FUNDAMENTAL SPACE BIOLOGY
SPACE PRODUCT DEVELOPMENT

Why is it important?

One thing that astronauts share with explorers of past generations is their separation from hospitals and caregivers. The distance from the International Space Station to the nearest emergency room is measured not in its 220-mile altitude above Earth, but in the precious hours it would take to get to the hospital. On Earth, many people share this situation in remote villages or work sites. Modern communications, including the Internet, can close part of the distance by sending lifesaving information to physicians.

What is NASA doing?

NASA is developing techniques to improve the echocardiography available for diagnosing sick astronauts and to study the long-term effects of space travel on their health. Echocardiography uses ultrasound, generated in a sensor head placed against the patient's chest, to produce images of the structure of the heart walls and valves. However, ultrasonic imaging creates an enormous volume of data, up to 220 million bits per second. This volume can challenge ISS communications, as well as Earth-based providers.

Compressing data for rapid transmission back to Earth can degrade the quality of the images. Researchers at the Cleveland Clinic Foundation are working with NASA to develop compression techniques that meet imaging standards now used on the Internet and by the medical community, and that ensure that physicians receive quality diagnostic images.

What are the benefits?

The ability of physicians on Earth to view real-time echocardiograms of astronauts will improve the following:

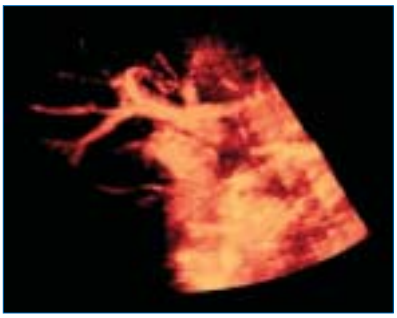
- diagnoses during medical emergencies in space,
- understanding of long-term space exposure effects on the heart, and
- opportunities for use in remote locations on Earth.

Digital echocardiography offers significant savings in storage space and physician review time and provides greater diagnostic accuracy compared with images stored on traditional analog videotape.

What is next?

This capability will be made available on the ISS and in other remote locations, where it might not be possible to have a physician available on site, thus reducing the need for costly and inconvenient travel by patients.

NASA contact: Dr. David Tomko (202-358-2211)



Echocardiographic images provide quick, safe images of the heart as it beats (above). Although a state-of-the-art echocardiograph unit is part of the Human Research Facility on the ISS (below), quick transmission of images and data to Earth is a challenge.

National Aeronautics and
Space Administration

Office of Biological and Physical Research

EYE TRACKING BRINGS VISUAL PERCEPTION INTO FOCUS

PHYSICAL SCIENCES RESEARCH
BIOASTRONAUTICS RESEARCH
FUNDAMENTAL SPACE BIOLOGY
SPACE PRODUCT DEVELOPMENT

Why is it important?

For air traffic controllers, pilots, astronauts, and others, the ability to track a moving target amidst many nontargets is essential. Perceptual errors during critical flight maneuvers—such as landing at night or docking with a space station—can lead to a disaster. NASA research into the link between eye movements and visual perception has application for the improved training and safety of anyone who depends on accurate vision and motor control.

What is NASA doing?

Dr. Leland Stone and other researchers at NASA Ames Research Center adapted computer monitors and infrared video cameras to measure eye movements without having to affect the crewmember. A computer screen provides moving images that the eye tracks while the brain determines what it is seeing. A video camera records movement of the subject's eyes. Researchers can then correlate perception and response. A particular concern is how returning from the microgravity of orbit to Earth can affect an astronaut's ability to fly safely.

Early results challenge the accepted theory that "smooth pursuit"—the fluid eye movement that humans and primates have—does not involve the higher brain. NASA results show that

- eye movement can predict human perceptual performance,
- smooth pursuit and saccadic movement (jerky eye tracking in nonprimates) share some signal pathways, and
- common factors can make both smooth pursuit and visual perception produce errors in motor responses.

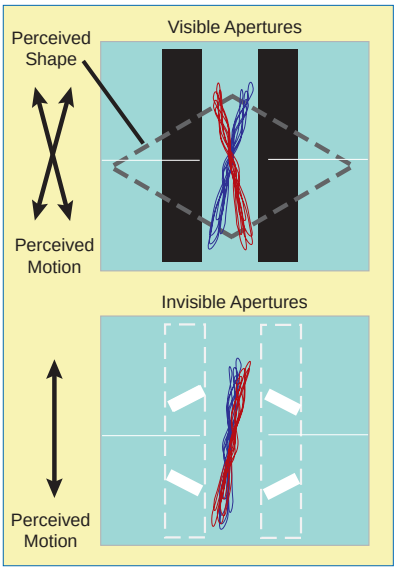
What are the benefits?

In a complex landing system like those of the Space Shuttle and advanced jetliners and other aircraft with head-up displays, the pilot must watch a computer-generated image superimposed on the view of the outside world and then move the joystick to line up with the target for a safe landing. Understanding how errors might occur will let NASA improve training and displays, and thus will enhance flight safety.

What is next?

NASA scientists are expanding their studies to include crew responses on joysticks. With advances in the eye tracking techniques, scientists can apply rigorous measurements to human responses and advance our understanding of visual perception.

NASA contact: Dr. David Tomko (202-358-2211)



Test subjects perceive different images when a moving object is covered by a mask that is visible or invisible (above). Tracking air traffic through a head-up display (below) can be more challenging.

National Aeronautics and
Space Administration

Office of Biological and Physical Research

GROWING PLANTS IN SPACE

PHYSICAL SCIENCES RESEARCH
BIOASTRONAUTICS RESEARCH
FUNDAMENTAL SPACE BIOLOGY
SPACE PRODUCT DEVELOPMENT

Why is it important?

Alternative agricultural systems that can efficiently produce greater quantities of high-quality crops in a small area are important for future space expeditions. Also, regenerative life-support systems that include plants will be an important component of long-term space missions. Data from the Biomass Production System (BPS) and the Photosynthesis Experiment and System Testing and Operations (PESTO) will advance controlled-environment agricultural systems and will help farmers produce better, healthier crops in a small area. This same knowledge is critical to closed-loop life support systems for spacecraft.

What is NASA doing?

The BPS comprises a miniature environmental control system for four plant growth chambers, all in the volume of two Space Shuttle lockers. The experience with the BPS on orbit is providing valuable design and operational lessons that will be incorporated into the Plant Growth Units.

The objective of PESTO was to flight-verify the BPS hardware and to determine how the microgravity environment affects the photosynthesis and metabolic function of Super Dwarf wheat and Brassica rapa (a member of the mustard family).

What are the benefits?

Analysis is underway on the first BPS specimens grown on orbit. Expected benefits include determining the effects of microgravity on wheat, including the following:

- carbon dioxide and light response curves;
- metabolism and electron transport processes associated with photosynthetic and respiratory gas exchange;
- carbohydrate partitioning; and
- gas exchange, including water, over range of atmospheric vapor pressure deficits.

What is next?

BPS has been returned to Earth for detailed study of its components and for analysis of its specimens. Continued research is planned using the Plant Research Unit when it is placed aboard the ISS.

NASA contact: Dr. David Liskowsky (202-358-1963)

Dwarf wheat (above) and Brassica rapa plants were photographed aboard the International Space Station in April 2002. Lessons from onorbit research on plants will have applications for terrestrial agriculture as well as long-term space missions.

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Space Administration

Office of Biological and Physical Research

"MODELED MICROGRAVITY" INCREASES BACTERIAL VIRULENCE

PHYSICAL SCIENCES RESEARCH
BIOASTRONAUTICS RESEARCH
FUNDAMENTAL SPACE BIOLOGY
SPACE PRODUCT DEVELOPMENT

Why is it important?

The potential for infectious disease among space crews is an important medical risk and is a relatively new and unexplored area of fundamental space biology research. An individual's vulnerability to infectious diseases can be increased by a weakened immune system and by the virulence of a microbe or other infectious agent. Space travel is known to affect the function of the human immune system. At the same time, evidence suggests that bacteria become more active in the low-g environment of space.

What is NASA doing?

Dr. Cheryl Nickerson of Tulane University is studying the effects of simulated low-g on a well-known pathogen, Salmonella typhimurium, a bacterium that causes two to four million cases of gastrointestinal illness in the United States each year. Thus, a simple case of food poisoning could disrupt a space mission.

Using the NASA rotating-wall bioreactor, Nickerson cultured S. typhimurium in modeled microgravity. Mice infected with the bacterium died an average of 3 days faster than the control mice, indicating that S. typhimurium's virulence was enhanced by the bioreactor. Earlier research showed that 3 percent of the genes were altered by exposure to the bioreactor.

Nickerson's work has earned her a 2001 Presidential Early Career Award for Scientists and Engineers.

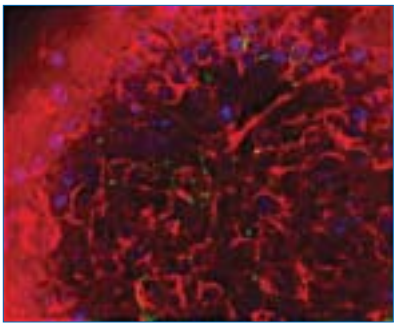
What are the benefits?

This research ultimately will provide significant insights into the molecular basis of salmonella virulence and may have the potential for vaccine development and other novel countermeasures for prevention and treatment of disease caused by salmonella.

What is next?

An experiment planned for the Space Shuttle, eight test tubes of salmonella will be carried in a containment module that isolates them from the crew. The bacteria will be cultured for two days on orbit, then fixed for postflight analysis of changes in the bacteria's genetic makeup.

NASA contact: Dr. David Liskowsky (202-358-1963)



Salmonella typhimurium (above) appears green in human intestinal tissue (stained red) cultured in a NASA rotating-wall bioreactor (below).

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Space Administration

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SPACE MAGNETS ATTRACT INTEREST ON EARTH

PHYSICAL SCIENCES RESEARCH
BIOASTRONAUTICS RESEARCH
FUNDAMENTAL SPACE BIOLOGY
SPACE PRODUCT DEVELOPMENT

Why is it important?

The familiar growth of plants—stems up, roots, down—is controlled by several mechanisms that we do not fully understand. We know that gravity is a primary controller, but we are uncertain how this is sensed and used within plants.

What is NASA doing?

Plant growth under low-gravity conditions in space has a been a keystone of fundamental space biology research. Current research indicates that the position of subcellular starch grains (amyloplasts) in plant cells plays a major role in a plant's sense of up and down. On Earth, amyloplasts in plant cells accumulate in the direction of gravity, causing a change in the cell's growth.

Amyloplasts can be moved by strong magnetic fields. Thus, a high-gradient magnetic field (i.e., concentrated at a specific point) could provide an artificial sense of "up" and "down" (not artificial gravity). As the root grows, the starch grains should be repelled by the magnetic gradient, causing the roots to curve in the direction of the displaced starch grains.

What are the benefits?

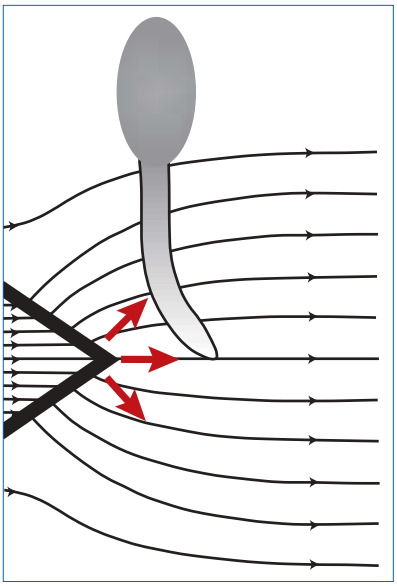
The BioTube/Magnetic Field Apparatus experiment addresses three major questions:

- Are amyloplasts (the starch grains) the organelles in plant cells that perceive gravity?
- Does the position or movement of the amyloplasts (caused by sedimentation on Earth or response to a high-gradient magnetic field in orbit) affect the root growth direction?
- Does gravity exert an effect on the deposition of cell wall material and the organization of plant cell organelles?

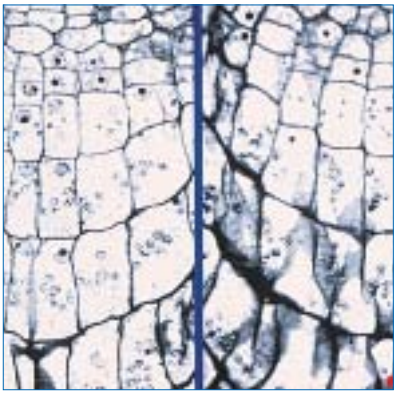
What is next?

The BioTube/Magnetic Field Apparatus investigation on the STS-107 research mission in 2003 will germinate and grow dry flax seeds in magnetic fields for 48 hours, then fix them for postflight analysis. As with all basic research, this study will contribute to an improved understanding of how plants grow and will have implications for improving plant growth and productivity on Earth. Similar flight experiments could be conducted on the ISS to increase our knowledge of how biological processes are affected by microgravity.

NASA contact: Dr. David Liskowsky (202-358-1963)



The tip of a wedge-shaped magnet will produce a strong magnetic gradient. Amyloplasts in the root tips should move away from the wedge edge, causing the root tips to curve (above). In simulated low-g, amyloplasts are randomly distributed (below, left), but displaced to one side when a magnetic field is applied (below right).



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"EGG"-CEPTIONAL SUCCESS FOR AVIAN FACILITY ON ISS

PHYSICAL SCIENCES RESEARCH
BIOASTRONAUTICS RESEARCH
FUNDAMENTAL SPACE BIOLOGY
SPACE PRODUCT DEVELOPMENT

Why is it important?

Over the decades since the first space flight, 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 key area of interest is how microgravity affects normal development.

What is NASA doing?

The Avian Development Facility (ADF) was designed to incubate up to 36 Japanese quail eggs, 18 in microgravity and 18 in artificial gravity, so that the two sets of eggs are exposed to otherwise identical conditions, the first time this has been accomplished in space. Eggs are preserved at intervals to provide snapshots of their development for later analysis. Quails incubate in just 15 days, so they are an ideal species to be studied within the duration of Space Shuttle missions. Further, several investigators can use the same specimens.

The ADF originated in NASA's Shuttle Student Involvement program in the 1980s and was developed under the NASA Small Business Innovation Research program. In late 2001, the ADF made its first flight and carried eggs used in two investigations:

- development and function of the inner-ear balance system in normal and altered gravity environments and
- skeletal development in embryonic quail.

Quail eggs are small (shown above at actual size) and develop quickly, making them ideal for space experiments. The Avian Development Facility supports 36 eggs in two carousels (below), one of which rotates to provide a 1-g control sample for comparing to eggs grown in microgravity.

What are the benefits?

Bones from the quail eggs are being analyzed for changes in mineralization, cell cycle timing, collagen synthesis, rate of bone formation, and the conversion of cartilage to bone during development. The ears are being analyzed to determine whether microgravity affects the development of the balance organs and what changes may take place in how they connect to the nervous system. The results from both studies should yield fundamental insights into basic animal development.

What is next?

Investigations with the ADF specimens continue. The ADF itself is now flight-qualified hardware available to support future investigations on the Space Shuttle or the ISS. With minor modifications, it can also support research on insects, plants, and fish.

NASA contact: Dr. David Liskowsky (202-358-1963)

IT'S A FILTER; IT'S A SPONGE

PHYSICAL SCIENCES RESEARCH
BIOASTRONAUTICS RESEARCH
FUNDAMENTAL SPACE BIOLOGY
SPACE PRODUCT DEVELOPMENT

Why is it important?

Zeolites are porous crystals that can act as storage cells until they are heated and release their contents. Zeolites (zeo lithos, "the rock that boils") are a $2-billion-a-year component of the world's trillion-dollar chemical processing industry worldwide. Virtually all of the world's gasoline is produced or upgraded using zeolites. Even a 1-percent improvement in the yield of gasoline from oil zeolites could have an economic impact exceeding tens of millions of dollars. However, gravitational effects on Earth restrict zeolites to the size of bacteria, thus limiting studies of their structures.

What is NASA doing?

The Center for Advanced Microgravity Materials Processing (CAMMP), a NASA-sponsored Commercial Space Center, is working to improve zeolite materials by using the microgravity of Earth orbit. Flights in 1992, 1993, and 1995 grew larger, higher quality zeolites than were possible on Earth. Studies continue with a Zeolite Crystal Growth Furnace Unit aboard the ISS and a similar unit on the STS-107 research mission in 2003.

What are the benefits?

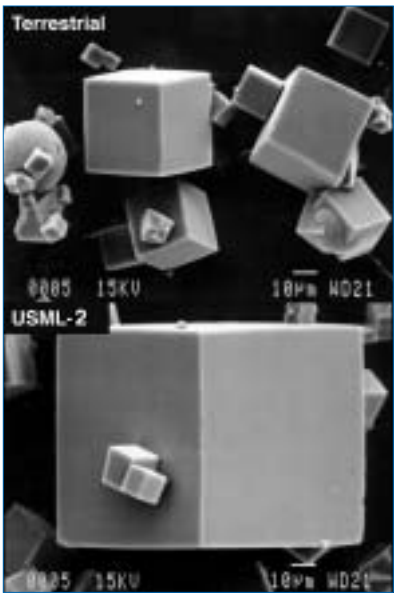
An exciting long-range possibility is to use zeolites to store and transport new, environmentally friendly fuels such as hydrogen. Current applications include the following:

- petroleum and petrochemical processing;
- animal feed supplements, decontamination of radioactive wastes, and a range of household products such as air-fresheners, kitty litter, and laundry detergents;
- air and water filters that help clean up the environment; and
- fillers for composite paper, rubber, plastics, or ceramics, and specialty lightweight ceramic and concrete products.

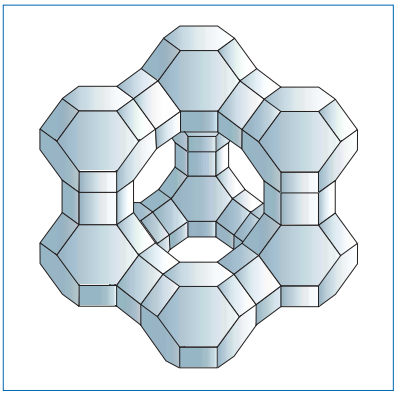
What is next?

When enough is known about how to manipulate both the nucleation and growth of zeolites, CAMMP can custom-design them for specific applications and reduce production costs and pollution. CAMMP plans to target zeolite membranes toward reactions—isomerization, dehydrogenation, and desulfurization—that are critical to the worldwide processing of petroleum and petrochemical products. In addition, novel applications are being developed to use zeolite membranes to separate and purify gases and liquids for pollution control.

Contact: Dr. Al Sacco, Director of the Center for Advanced Microgravity Materials Processing (617-373-7910)



Zeolite crystals grown on Earth (top) are smaller than those grown by Dr. Sacco on the Space Shuttle in 1994. What appears to be solid blocks are quite porous, as illustrated by the drawing (below). Understanding the exact atomic structure and how to control it are keys to tailoring zeolites to a wider range of uses.



WORKING TO PLANT THE FUTURE

Why is it important?

Researchers face 1,000-to-1 odds in trying to transfer desirable genes for disease resistance and other improvements into important crops. Instead of older methods, researchers now use bacteria to transfer the gene carrying the desired traits to seedlings. These seedlings, in turn, allow subsequent generations of the crops to stably inherit the trait.

Previous commercial flight research has shown that microgravity can greatly improve the success rate of gene transfer. The increase is due in part to the fact that microbes thrive in microgravity. Learning how to control bacteria so they can develop without harming the seedlings requires further research.

What is NASA doing?

The Wisconsin Center for Space Automation and Robotics (WCSAR) at the University of Wisconsin-Madison, one of NASA's Commercial Space Centers, is a primary center for commercial agribusiness research in microgravity. It has developed the ASTROCULTURE™ commercial plant growth research hardware, a completely self-contained system for growing plants that includes lighting, temperature control, atmospheric control, nutrient delivery, and more.

What are the benefits?

Several enhancements have been observed in six Space Shuttle missions to date:

- enhanced seed production, such as reducing soybean growth cycle from an average of 110 days to an average of 62 days, a significant improvement, and
- increased shelf-life of perishable items by a week, providing a significant savings by reducing the amount of food or other materials that spoil.

What is next?

The STS-107 Space Shuttle mission in 2003 will carry an ASTROCULTURE™ plant growth unit and glovebox to validate microgravity's impact on soybean transformation. It is hoped that the results will provide benchmark information for the future development of a commercial space-based gene-transfer system. The Advanced ASTROCULTURE™ experiments aboard the ISS started in April 2001 and will continue through mid-2003. The plants on board the ISS also demonstrate multigenerational research that longer duration exposure in microgravity can provide.

Contact: Dr. Weija Zhou, Director of the Wisconsin Center for Space Automation and Robotics (608-262-5526)

The development of new crops is being enhanced through commercial microgravity research. Arabidopsis plants (below) were grown on the STS-104 mission.

National Aeronautics and
Space Administration

Office of Biological and Physical Research

ANNIHILATING ANTHRAX

PHYSICAL SCIENCES RESEARCH
BIOASTRONAUTICS RESEARCH
FUNDAMENTAL SPACE BIOLOGY
SPACE PRODUCT DEVELOPMENT

Why is it important?

Bioterrorism is a major threat facing modern society. As shown by the post-September-11 anthrax attacks, deadly bacteria are easy to introduce into a building and difficult to clean up. The challenge is to neutralize the bacteria spores, not just sequester them.

What is NASA doing?

A result of NASA- and industry-sponsored research to develop small greenhouses for space research is the unique AiroCide TiO2 system that kills anthrax spores. In the 1990s, University of Wisconsin professor Marc Anderson and colleagues from the Wisconsin Center for Space Automation and Robotics (WCSAR), a NASA Commercial Space Center, made a crucial discovery: ultrathin layers of titanium dioxide (TiO2) exposed to ultraviolet light efficiently eliminate ethylene, a gas that plants emit and that would build up in a closed greenhouse. Titanium dioxide, a harmless, nontoxic coloring agent, converts ethylene into water vapor and carbon dioxide.

Additional tests showed that airborne dust mites were killed as well. Ultraviolet light generates positive and negative charges on titanium dioxide surfaces. Those charges split nearby water molecules into hydrogen and the hydroxyl ion. Hydroxyl, in turn, disrupts organic molecules and kills dust mites, anthrax, and many other pathogens. The bright ultraviolet lamps also kill pathogens as they swirl through the maze of coated plastic tubes in the AiroCide TiO2 unit.

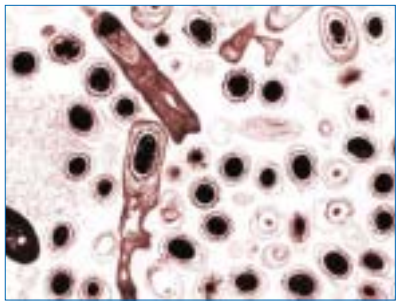
What are the benefits?

"Spores that pass through the box aren't filtered, they're fried," says Hayman. "That's appealing for people who don't want to change an anthrax-laden air filter." Tests show that as many as 93 percent of anthrax spores that enter AiroCide TiO2 are destroyed. Survivors circulate out of the chamber, where they are likely to be sucked back in again for another pass.

What is next?

Hospital operating rooms, emergency rooms, jails, and veterinary clinics are just a few of the current facilities utilizing the AiroCide TiO2 unit. Currently, other potential markets are being examined. Clearly, this capability to destroy harmful bacteria will aid future long-term human space missions involving closed environments.

Contact: Dr. Weija Zhou, Director of the Wisconsin Center for Space Automation and Robotics (608-262-5526)



Anthrax spores (above) are inactive forms of Bacillus anthracis. They can survive for decades inside a spore's tough protective coating; they become active when inhaled by humans. the AirTcide TiO2 air cleaner (below, being assembled and shown installed) is a compact air cleaning system that "fries" anthrax spores and other pathogens.

National Aeronautics and
Space Administration

Office of Biological and Physical Research

FIGHTING FIRE IN MICROGRAVITY

PHYSICAL SCIENCES RESEARCH
BIOASTRONAUTICS RESEARCH
FUNDAMENTAL SPACE BIOLOGY
SPACE PRODUCT DEVELOPMENT

Why is it important?

Since World War II, the most effective fire-fighting method has been high-pressure water sprays. How the droplets interact with the flames is largely unknown, partly because in Earth's gravity, a fire's heat generates air currents that make it difficult to study combustion. In space, however, water must be sprayed sparingly since it will not run off but can accumulate and be difficult to clean up.

What is NASA doing?

Environmental Engineering Concepts, Inc., and Arizona Mist, Inc., have partnered with the Center for the Commercial Applications of Combustion in Space (CCACS), a NASA-sponsored Commercial Space Center, to investigate the use of fine water mists in fighting a fire. The Water Mist experiment employs a two-part chamber with water on one side and a fuel-air mixture on the other. In microgravity, scientists will be able to study how a flame front moves into the mist and is extinguished, all without the convection that would occur on Earth. The first flight will be on STS-107 in 2003.

What are the benefits?

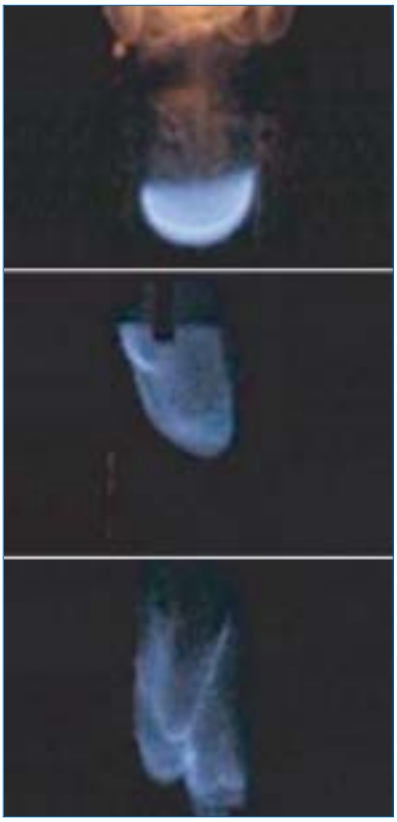
Replacing halon gases (banned by the 1987 Montreal Protocol) is expected to become an increasingly large part of the $2-billion-a-year fire suppression industry; the research being done on STS-107 is of great commercial interest. Potential benefits include the following:

- enabling the next generation of environmentally friendly and low-cost fire-fighting systems,
- minimizing water damage by using less water, and
- developing crew- and equipment-safe fire-control systems for use on spacecraft.

What is next?

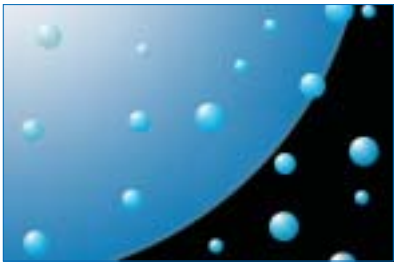
Data from the investigations on STS-107 will be used on the ground to improve computer and mathematical models and allow detailed simulations to test theories and obtain more accurate results. Water mist investigations on the International Space Station will be able to use different water injection systems, droplet sizes, and other fire scenarios to support this important research.

Contact: Dr. F.D. Schowengerdt, Professor of Physics and Director of the Center for Commercial Applications of Combustion in Space (303-384-2091)

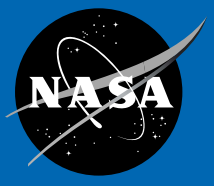


A low-gravity test of the Mist experiment shows (from top to bottom) a flame after ignition, encountering water mist, and slowing down and breaking up. Space experiments will allow longer, more definitive experiments than are possible on Earth.

The drawing to the right illustrates the fine scale of the droplets that will be formed in Water Mist as compared to 1-mm droplets formed by conventional water sprays. Small droplets have more surface area to absorb heat, but the dynamics of fire extinction are poorly understood.



http://SpaceResearch.nasa.gov/



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