Volume 7, Number 5 September/October 1999

Aerospace Technology

INNOVATION

SPECIAL EDITION

NASA Contributes to the Medical Field

Bioinformatics May Forever Change Medicine

The Future of Medical Research

New and Improved Robots for the Operating Room

NASA

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INNOVATION

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Contents

About the Cover:
America's space program continues to help revolutionize the practice of medicine.

On-Line Edition: Go to **http://nctn.hq.nasa.gov** on the World Wide Web for current and past issues.

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COMMERCIAL DEVELOPMENT MISSION UPDATE

Date*	Flight	Payload	Sponsor/Coordinator
12/99	STS-101	ASTROCULTURE™ Commercial Protein Crystal Growth	Wisconsin Center for Automation and Robotics Center for Macromolecular Crystallography

* As of October 1999.
Key STS—Space Transportation System

Space Technology Commercialization in the Medical Field

by Carl G. Ray
Commercial Technology Executive
NASA Headquarters

TODAY, NASA IS WORKING HARDER THAN ever to ensure that the products of its technology and research reach U.S. companies to strengthen the nation's economy. With a proactive and focused program of distribution and outreach activities resulting in the application of NASA-generated technologies, the space agency is leading the way for the development of commercially available products and services. For more than 30 years now, the commercial use of NASA technology and its impact on the economy and global competition continue to be primary goals of NASA's Commercial Technology program. NASA's Commercial Technology program continues to focus its efforts on the transfer of our technologies into state-of-the-art products and services.

NASA'S COMMERCIAL TECHNOLOGY PROGRAM CONTINUES TO FOCUS ITS EFFORTS ON THE TRANSFER OF OUR TECHNOLOGIES INTO STATE-OF-THE-ART PRODUCTS AND SERVICES.

This special issue of *Aerospace Technology Innovation* focuses on "space technology commercialization in the medical field." The issue includes examples of how NASA technology is contributing to the medical industry with evolutionary innovations and development.

The medical field has significantly benefited from NASA research—for example, research areas on how space flight affects the cardiovascular system. On Earth, cardiovascular disease is prioritized as a leading cause of death in the United States. Techniques derived from this space research have led to more sophisticated, less costly and less painful methods of treatment. We have previously reported on breakthrough discoveries in the understanding and treatment of the cardiovascular system, which have proven fruitful in significantly enhancing this area of medicine.

This issue of *Innovation* is also focused on several examples of cutting-edge technology applied to common but important products and services that have and will improve our health and well-being. In this edition, we show examples of NASA research and contributions from the Space Shuttle and the Russian space station *Mir*, as well as links to future medical research aboard the International Space Station. But more importantly, we hope to provide some knowledge of how these significant impacts of NASA development will eventually contribute to the medical industry.

While we have assembled examples in such illness areas as cancer (including breast biopsy), diabetes, heart disease, osteoporosis and other diseases, it is also a focus of this issue to provide an understanding of the commitment of NASA's Commercial Technology program to spur the enhancement of today's medical industry with tomorrow's discoveries and innovations. We also show how the success of NASA's research and development programs, coupled with the discipline of technology transfer, is transitioning innovative results into state-of-the-art products and services. Such products and services provide the catalyst for "spinoff" technologies and progress that improve our everyday lives.

Get more information on medical-related NASA spinoffs by visiting the Spinoff web site at *http://www.sti.nasa.gov/tto/spinoff.html*

NASA Contributes to the Medical Industry

IN AEROSPACE DESIGN, EVERY SUBSYSTEM MUST be super-efficient and ultra-reliable, yet as small and light as technology permits. Many types of medical devices share these requirements. That is one reason why the field of health and medicine has been a particular beneficiary of aerospace spinoffs. The United States leads the world in the technology of building complete, reliable aerospace systems in incredibly tiny packages, and that technology has spawned a line of life-saving medical adaptations. For example:

- A line of cordless surgical instruments needing no power source, lines or hoses was spawned by the same NASA-contracted company that produced a line of cordless tools for consumer and industrial use based on a lunar drill. For lunar exploration, the Apollo astronauts needed a compact, lightweight, battery-powered long-use drill to extract core samples from beneath the lunar surface.
- Newborn premature babies are warmed, without noise or burn hazard, in cradles whose electricity-conducting canopies provide controlled radiant heat, an offshoot of NASA technology developed for heated cockpit canopies and astronaut helmet faceplates.
- A contractor developed an automatic gas analyzer to monitor Apollo astronauts' respiratory gases; it is now used in hospitals for the analysis of anesthetics.
- A tiny mote of dust could trigger a malfunction in a sensitive spacecraft system, so NASA developed contamination control technology for the assembly of sensitive flight equipment in hospital-like "clean rooms." One of several offshoots of that technology base is a line of advanced, disposable, inexpensive anti-contamination garments for hospitals and pharmaceutical clean rooms.

These are just a few examples of how a technology developed for space research generates new technology for the manufacturing of everyday products. Described here are only a few of thousands of applications of aerospace technology that have provided extraordinary benefits to the field of health and medicine.

NASA Crusades for Women's Health

NASA, in partnership with the National Institutes of Health (NIH), has taken the lead in women's illnesses by outlining a commitment to identify, develop and transfer NASA technologies to benefit women's health in major areas of concern: cancer, reproductive health, pregnancy, osteoporosis and education. Outlined in a NASA agreement with the Office of Women's Health in the U.S. Department of Health and Human Services, a cooperative framework with Ames Research Center was established to team industry, academia and government. Several NASA biomedical experiments have resulted in successful new technology programs among NASA, NIH, the National Cancer Institute and the Office of Women's Health.

The Fight Against Cancer

There is almost no word as terrifying to a person as cancer. NASA is working with medical researchers and institutions to help understand, diagnose and treat various types of cancer, such as colon, prostate, breast and ovarian. Breast cancer is the leading cause of death for women age 35 to 50, and recent studies have shown an increase in melanoma.

Finding Breast Cancer With Hubble Technology

NASA has contributed nearly a dozen breakthroughs in the understanding, diagnosis and treatment of breast cancer. Silicon chips used in the Hubble Space Telescope were adapted so physicians can better detect tiny spots in breast tissue. Doctors can then take biopsies using a needle rather than subject a patient to expensive and painful surgery. This new procedure eliminates scarring or disfigurement, requires half the time of traditional techniques, reduces exposure to x-rays and dramatically cuts costs. For more information, visit *http://www.nctn.hq.nasa.gov/innovation/Innovation41/HubbleFights.html*

New Drug for Melanoma

In January 1998, the Food and Drug Administration approved Proleukin® for the treatment of patients with metastatic melanoma cancer. Human clinical trials are also under way for other treatment therapies, such as an adjunct treatment for AIDS. Protein crystals researched for the new drug were grown in space.

NASA Bioreactor for Cancer Treatment

NASA and the University of South Florida are funding research focused on the development of three-dimensional tissue models of breast and ovarian cancer. Using the bioreactor, a special tissue culture chamber designed by NASA, scientists are able to grow cells that form themselves into structures similar to tissues found in the human body. This informa-

tion is useful in testing sensitivity to chemotherapy and hormonal therapy, which is important to the treatment of breast and ovarian cancer.

Smart Robot Probe for Cancer Detection

NASA technology being developed to perform surgery on astronauts in space is being adapted to robotic technology to help physicians operate on delicate parts of the human body, including the brain and the breast. Led by the NeuroEngineering Group at NASA's Ames Research Center, scientists have developed a robot that can map physical characteristics of the brain, allowing the surgeon to make precise movements during surgery. The technology is being modified further to have the robot feel tumors in other parts of the body to determine severity and appropriate treatment. The experimental robot can use a smaller, less invasive probe, and it can make more delicate and precise movements than a human, thus reducing damage to healthy tissue and arteries.

"To enable the instrument to recognize cancer and predict its progress, we use special neural net software that is trained and learns from experience," said Robert Mah of Ames Research Center's Neuroengineering Laboratory at Moffett Field, California. He added that scientists can teach the breast cancer diagnosis device to predict how aggressive the disease may be.

"We hope to use this device not only to detect cancer, but to understand the nature of an individual cancer," said Dr. Stefanie Jeffrey, an assistant professor of surgery and Chief of Breast Surgery at Stanford University School of Medicine in Stanford, California. Dr. Jeffrey is working with Mah to develop the device. "This information may help us determine the distinctive features of a malignancy and how the disease may progress; more knowledge about the cancer may guide us to better individualizing treatment."

The breast cancer tool is a spinoff from a computerized robotic brain surgery "assistant" that was previously developed by Mah and Dr. Russell Andrews, a neurosurgeon. The larger brain surgery device is a simple robot that can "learn" the physical characteristics of the brain and may soon give surgeons finer control of surgical instruments during delicate brain operations.

Using Light to Treat Tumors

Special lights developed to grow plants in space are helping treat brain tumors in children. In this aggressive therapy, the doctor injects a light-sensitive, cancer-fighting drug into the bloodstream. The drug attaches to the affected tissue. The doctor places a device the size of a small finger near the tissue. The device emits light, activating the drug. The drug penetrates and destroys only affected tissue. This innovative, photodynamic procedure will be used in critical medical cases. See the "Small Business/SBIR" section of this issue of *Innovation* for more information, or visit *http://techtran.msfc.nasa.gov/new/tumorsrel.html*

Top:
This breast cancer probe, a spinoff of a larger computerized robotic surgery assistant, is designed to "see" a lump, determine by its features whether it is cancerous and predict the cancer's progress.

A Matter of the Heart

Cardiovascular disease is a big killer in the United States. NASA's work is going a long way in understanding how space flight affects the cardiovascular system in both men and women.

The Beat of Your Heart

NASA's bidirectional telemetry technology, first used to communicate with satellites, was the basis for a company's development of a pacemaker that can be programmed from outside the body. NASA requirements for miniature electronics made the technology possible. It was used in another instrument, an implantable defibrillator, which senses irregular heartbeats and automatically delivers an electrical stimulus to get the heart back on track. Visit *http://www.sti.nasa.gov/tto/spinoff1996/25.html*

Your Blood Pressure

The now-familiar device that you slip your arm into at doctors' offices and pharmacies to check your blood pressure was commercialized from various prototypes based on technology NASA developed to be able to monitor the health of astronauts while in space. This semi-automatic instrument provides a very accurate blood pressure measurement, and the results appear quickly and conveniently on a digital display.

Treating Heart Disease

Laser angioplasty offers heart patients an alternative to surgery in the treatment of clogged arteries. A laser system first used for satellite-based studies of the atmosphere has been reapplied to treat atherosclerosis, the buildup of fatty deposits in the arteries. NASA research led to the development of an excimer laser that is now routinely used to clean arteries without damage to blood vessel walls. This is particularly important because another nonsurgical treatment once often chosen by doctors, balloon angioplasty, is sometimes ruled out for females because their blood vessels are often too small for the treatment.

Diabetes Diagnostics and Treatment

NASA does not have a diabetes research program, but the agency is conducting research that has an impact on the fight against diabetes. NASA sponsors protein crystal growth, three-dimensional tissue culturing and noninvasive diagnostic technologies research that can support the development of improved treatments.

The space agency has grown human insulin crystals on two Space Shuttle missions to a quality that has not been achieved on Earth. X-ray defraction crystallization has provided a more precise structural view of insulin molecules, which could lead to new insulin therapies through improved control over the effective rate of release of insulin into the blood stream.

Clipped to a patient's clothing, the minipump delivers insulin continuously at a preprogrammed rate adjusted to the individual, allowing the insulin-dependent diabetic to lead a more normal life.

One example of NASA's new noninvasive diagnostic technology is a portable laser that can help the early detection of diabetes-related optical problems. This technology sends light waves through the eye's internal structure, which also leads to better treatment of diabetes at earlier stages of the disease. Retinopathy, or retina disease, can be caused or accelerated by diabetes, making the disease the leading cause of adult blindness in North America. The laser was developed to send light waves through the eye's internal structure as a light-scattering instrument to detect cataracts and other eye abnormalities in humans.

NASA and the Juvenile Diabetes Foundation have joined in an agreement to research the treatment and monitoring of diabetes and diabetes-related problems, using their respective strengths.

Space Crystals Provide Hope for Diabetes

Results from a 1994 insulin crystal growth experiment in space is leading to a new understanding of diabetes that may someday reduce patients' insulin injections. The largest insulin crystals ever studied were grown on the Space Shuttle. Earth-grown insulin crystals are not as large or as well ordered because they obscure the blueprint of the insulin molecules. The crystals are grown in space because the absence of gravity allows large and perfect crystalline structures to form.

The better three-dimensional view of the extremely complex insulin molecule is giving scientists a new opportunity to study in more detail the delicate balance of the insulin molecule to learn how the body regulates insulin release. In diabetes patients, insulin is not produced in sufficient quantity, nor regulated properly.

These results have the potential to improve the quality of life for diabetes patients and to significantly reduce expensive treatments by reducing a patient's number of insulin injections. Diabetes treatments account for one-seventh of the nation's health care costs.

Space Shuttle Experiment a Sweet Success

Experiments aboard the Space Shuttle may help safely satisfy the sweet tooths of diabetics and those watching their waistlines. In a control study, a team of French and American scientists found that space crystals of the sweet protein called thaumatin, a natural molecule isolated from the African serendipity berry (*Thaumatococcus daniellii*), showed a nearly 25-percent larger volume and yielded twice the crystalline order, compared to its Earth-grown counterparts.

Calorie-free thaumatin is more than 10 times sweeter than other sugar substitutes, such as saccharin or aspartame. Scientists hope to use the space-grown crystals to improve the biological understanding of how these molecules work, based on detailed knowledge of their shape and exact atomic positions.

A widespread search for noncaloric and safe natural sugar is the result of the complex and costly management of human diabetes, obesity and oral

health. Thaumatin already is being marketed as a nutritional supplement in blood sugar stabilizers for childhood behavioral problems and the more than 3.5 million sufferers from attention deficit disorder. Among soft drink consumers alone, nearly 20.6 million tons of chemicals are used around the world, nearly four kilograms per capita, with a growth rate of about 20 percent toward the end of the decade.

According to the team's report, the space crystals reinforce the conclusion of other reports that microgravity-grown thaumatin crystals compared to many Earth-grown trials were consistently and significantly larger, as well as substantially more defect free. This is the first experiment to produce space crystals by multiple methods, with both methods suggesting the same conclusion.

Balance Disorders

During and after space flight, astronauts experience difficulty in keeping their balance. A commercial company has used NASA technology for testing astronauts after space flight to produce a system to assess the extent of patients' balance problems and then retrain them for better mobility. The system, known as NeuroCom's Balance Master, assesses and then retrains patients with balance and mobility problems. NeuroCom received assistance in research and funding from NASA, and the company incorporated technology from testing mechanisms for astronauts after Space Shuttle flights.

The EquiTest and Balance Master systems are computerized posturography machines that measure patient responses to the movement of a platform on which the subject is standing or sitting. The machines then provide assessments of the patient's postural alignment and stability.

This technology is already in use in several medical centers. Many people, especially older individuals, are suffering from balance disorders, a frequent cause of falls and broken bones. NASA is working with the NIH to find ways to counteract this condition. Shuttle research on the body's balance system has resulted in new discoveries of sensory pathways and the nervous system's ability to adapt.

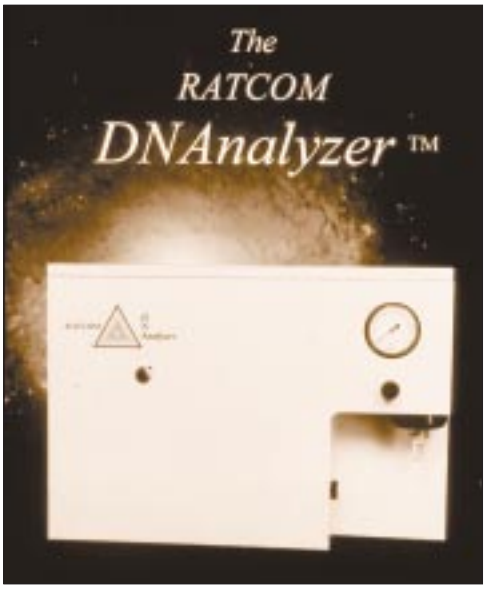
Osteoporosis

Astronauts lose bone density during space flight, which is similar to osteoporosis, the brittle bone condition affecting many older people on Earth, particularly women. Together, NASA and the NIH are studying how this condition develops and how to counteract it in space, which is important in preventing and treating this debilitating condition on Earth. NASA research has already led to the development of a fast and inexpensive tool to measure the extent of osteoporosis by analyzing the stiffness of bones. It takes measurements without exposing the patient to radiation. For more information, visit *http://weboflife.arc.nasa.gov/EXPLORATIONS/EARTH_BENES/osteo.html*

For more information, contact the NASA Commercial Technology Network by calling the National Technology Transfer Center. 800/678-6882, *www.nctn.hq.nasa.gov* Please mention you read about it in *Innovation.*

Shuttle Technology Improves Cancer Detection

A MIAMI, FLORIDA, BIOTECHNOLOGY COMPANY'S new flow cell instrument, derived from Space Shuttle technology and presently in commercialization, shows signs of improved cancer detection and treatment, as well as applications to other serious diseases. The DNAnalyzer™, a new triangular flow-cell technology from RATCOM Inc. with measuring abilities not found in other flow cytometers, is displaying great promise in separating abnormal cells from the normal cells in tumor samples. This allows for a more positive confirmation of the tumor's status.



The NASA cytometer project for the International Space Station spurred the development of this instrument—important for cancer diagnosis—that can properly classify tumors.

The prototype InFlight Cytometer, being tested at the University of Miami for use in cancer diagnosis and therapy, gives improved resolution and has three times more uniformity on a day-to-day basis than results on the same samples from older flow cytometer technology. Older technology could only suspect tumors in 20 percent of the cases in a 170-patient study, according to RATCOM President Richard A. Thomas.

Testing of the new instrument in 1997 confirmed the advancement in

flow channel design. Pioneered by RATCOM from its original compact-flow cytometer design for the Space Shuttle, it is the first commercial instrument stemming from a partnership of Kennedy Space Center and the American Cancer Society—the Space Station Inflight Cytometry Project.

The initial project undertaken by the partnership is flow cytometry. This is a process in which cells in suspension flow through a sensing region in which light signals indicating important biologic properties are generated and evaluated by photodetectors.

The cancer-fighting benefits of flow cytometry include the ability to evaluate cancer cells very early and to determine several important features, including the sensitivity of those cells to different chemotherapy drugs, the ability of the cells to grow and their capacity for spreading. Better and more timely strategies in the fight against cancer was a main objective of the research. Other potential uses of the new technology involve the early detection of leukemia, chemosensitivity studies prior to chemotherapy, antibody analysis and the detection of pathogenic organisms.

NASA sought a flight cytometer, compact enough for flight aboard the Space Shuttle and placement in the orbiting International Space Station, to separate and examine cells rapidly to learn more about the effect of microgravity on the immune system. Preliminary evidence from Space Shuttle flights suggests that immunity is depressed.

NASA and RATCOM entered into a contract for the design of an in-flight cytometer and the fabrication of a fully functional demonstration test unit. Joint research to develop this advanced flow cytometry instrument could support biomedical experiments aboard the International Space Station while advancing medical knowledge in cancer detection and treatment here on Earth.

The challenges in developing multichannel flow cytometry were addressed in a Kennedy-American Cancer Society workshop. Technical improvements needed included improved signal processing for the multichannel analysis of optical emission spectra and reductions in complexity, size and power requirements. Other improvements were simplification of sample preparation, expert system software and the numbers of optical sensors.

For more information, contact Lewis Parrish at Kennedy Space Center. 407/867-6373, *ParriLM@kscgws00.ksc.nasa.gov* Please mention you read about it in *Innovation.*

Remote Sensing Down to Earth

MEDICINE TODAY HAS A MUCH MORE BROAD range of body-scanning equipment and techniques available to create images of human interiors to aid physicians in diagnosis, treatment and surgery. Much of this technology has stemmed from the space technique known as digital image processing, developed as a means of assembling a picture of a planet or a moon from bits of sensor data sent to Earth in digital form by a distant spacecraft. Image processing technology has been more importantly or more effectively employed beyond the x-ray that shows only a bone's structure—in computer-aided tomography (CAT) scanning, diagnostic radiography, brain and cardiac angiography, sonar body scanning and monitoring surgery.

Space Telescope Looks for Cancer

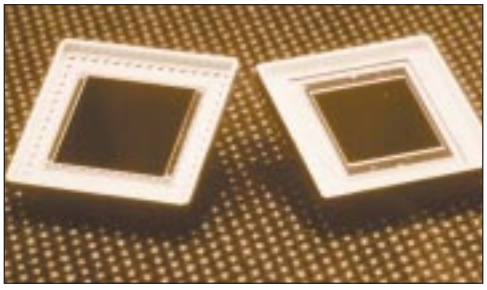
With the help of Hubble Space Telescope technology, breast biopsies to detect breast cancer can now be performed pain- and scar-free with a needle instead of a scalpel. Breast tissue is imaged more clearly than conventional x-rays, and the patient can walk out of the office and resume normal activities.

Charged coupled devices (CCDs) are high-technology silicon chips that convert light directly into electronic or digital images. Goddard Space Flight Center headed the development of the advanced, supersensitive CCD installed in the Hubble Space Telescope in 1997. The LORAD Corporation of Danbury, Connecticut, adopted the new CCD for its breast biopsy system. Through this system, the patient lies face down with one breast protruding through an opening to pinpoint the area in question. The doctor then uses the specially designed needle to extract a tiny sample.

The procedure costs about four times less than traditional biopsy surgery. The new procedure also saves the patient time and pain, and it leaves only a small needle mark rather than a large scar.

Body Imaging: MRIs and CAT Scans

In the mid-1960s, as NASA prepared for its Apollo lunar landing program, the Jet Propulsion Laboratory (JPL) developed the technology known as digital image processing to allow for the computer enhancement of Moon photographs. This technology later became the basis for the NASA Landsat satellites.



The CCD on the left is an advanced, extrasensitive device developed for NASA's Hubble Space Telescope. The virtually identical CCD on the right is a commercial derivative of the Hubble device that has contributed importantly to a new, nonsurgical and much less traumatic breast biopsy technique.

Physicians and hospitals now use digital image processing to record images of organs in the human body. Two of the most widely used body-imaging techniques are CAT scanning and magnetic resonance imaging (MRI). CAT scan image data are collected by aiming a fan-shaped x-ray beam from a number of different directions around the body. A computer then reconstructs a tomographic (slice-like) image from these multiple views. MRI uses a magnetic field and radio waves to create images, rather than x-rays.

In most cases, a CAT scan is used for bone, while MRI is used for soft tissue (such as the liver). Both methods are often used to obtain a complete diagnosis for a patient. Doctors and engineers are working to combine the best features of MRI and CAT scanning. One of their research tools is a computer program originally developed by NASA to distinguish among Earth surface features in Landsat image processing.

Infrared Thermometer: Temperature in Seconds

Here is an amazing statistic: in the United States alone, someone takes someone else's temperature about 2 billion times a year. And that is just in hospitals and doctor's offices! The 2 billion figure does not include all those anxious mothers and fathers checking on their children's fevers.

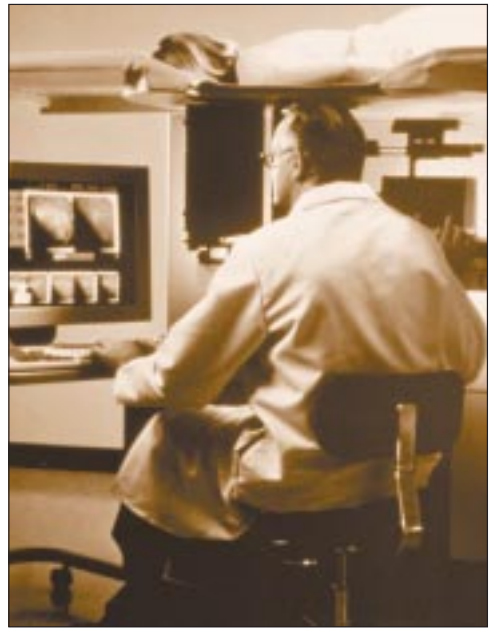
The latest in thermometer technology was made possible by NASA's ability to measure the temperatures of stars and planets—without ever leaving the ground! Taking the temperature of distant bodies is made possible through the sensing of infrared radiation given off by the star or planet.

Diatek Corporation of San Diego, California, asked NASA to help develop the sensor technology for a handheld thermometer that takes a person's temperature in less than two seconds. The thermometer has a probe that is inserted a little way into the ear. (The patient does not even have to be awake.) The probe is thrown away after use and replaced by a new one, to guard against cross-infection.

Miniaturized Transmitter

In 1999, the NASA-developed "pill transmitter" was expected to monitor mothers and their babies following corrective fetal surgery. The "pill," developed at Ames Research Center, is about one-third of an inch across and one and one-third inches long. An even smaller pill to be developed will be swallowed by astronauts so that NASA can track their vital signs during space travel.

"Nearly every time doctors operate on a fetus, the mother will later undergo pre-term labor that must be monitored," said Carsten Mundt, an electrical engineer on the Sensors 2000! team at Ames. "Pre-term labor is a serious problem that is difficult to predict and monitor with conventional equipment, and often leads to the death of the baby. But if you implant our pill, you can measure pressure changes in the uterus that result from contractions. When doctors are able to monitor the magnitude and frequency of contractions, the physicians can identify the onset of pre-term labor early enough to prevent it from becoming life threatening to the fetus."



A physician studies images acquired on the breast biopsy system.

Earlier, pediatric surgeons at the Fetal Treatment Center pioneered a cesarean surgical approach to treat fetuses suffering from various birth defects, including congenital diaphragmatic hernia. In this condition, a hole in the baby's diaphragm lets internal organs shift from inside the abdomen into the chest cavity, leaving insufficient room for lung

development. Sixty to 75 percent of babies born with this condition die. During some of these earlier surgeries, physicians implanted larger sensor-transmitters to monitor mothers and their fetuses.

Recently, Fetal Treatment Center surgeons changed their technique from cesarean to a less intrusive endoscopic method, during which they make small incisions and insert tube-like devices through the mother's abdominal wall. Normally, an endoscope is used to see into the interior of a body or hollow organ. Endoscopic instruments are now also used more frequently in surgeries requiring smaller incisions.

"This minimally invasive method represents the future of fetal surgery," said Michael Harrison, M.D., founding director of the Fetal Treatment Center, who in 1981 performed the world's first corrective surgery on a fetus before birth. "Because there are no commercially available sensor-transmitters small enough to fit through the tubes used in the new endoscopic surgery technique, scientists and engineers on our team developed the pill-shaped device so that it can pass through the tubes," said Ames team member Mike Skidmore. "Our first pill-shaped device can transmit temperatures as well as the pressure of uterine contractions."

Scientists at Ames are testing a prototype version of another pill that can measure and transmit pH, or acidity, in the fetus, according to Chris Somps, a scientist on the Sensors 2000! team. Somps explained that plans also call for even smaller pills that will measure the electrical activity of the fetal heart. These pills will transmit fetal heart data, as well as measurements of the baby's body chemicals, including ionic calcium, carbon dioxide and glucose.

"We would also like to use this technology to study what happens to astronauts during space travel," said Skidmore. "Not only could they swallow the smaller pill transmitters we plan to develop, but we have a conceptual design of small, flat transmitters that can be taped to the body like plastic bandages."

According to Mundt, there are many possible medical uses for this technology. Pills could monitor intestinal pressure changes or stomach acidity in ulcer patients. The acid-base balance in the body is a basic measure of health.

For more information on remote sensing, contact the Technology Commercialization Office at the Jet Propulsion Laboratory. 818/354-2577. Or contact the Technology Commercialization Office at Stennis Space Center. 228/688-1914. For more information on the pill transmitter technology, contact the Technology Commercialization Office at Ames Research Center. 415/604-0893. Please mention you read about it in *Innovation.*

IT'S A HOT NOVEMBER IN MIAMI

The greatest value in Miami Beach, Florida, is Tech East 99, November 1–3, three exhibits, two conference tracks and short courses. All offer the cutting edge on technology, business and ideas through advice from experts and learning from professionals in every area.

The **NASA Business Forum** conference is the first ever NASA forum on emerging commercial opportunities and issues in aerospace and aviation, including spaceports for future "spaceliners," medical breakthroughs and space-based manufacturing. Attendees also will have the opportunity to meet individually with NASA representatives to discuss business needs and capabilities.

The **Small Business Innovation Research (SBIR) Conference** is designed to help small businesses compete effectively for SBIR awards, and it offers tips on succeeding after winning. The SBIR program is the largest source of early-stage technology financing in the United States.

Registration for each track is available, as well as a passport registration for access to both. Conference registration includes access to all exhibits in Technology 2009, the Small Business Tech Expo and the Southeast Design and Manufacturing Expo, with ideas for new business, engineering solutions and the latest design and production tools, such as computer-aided design software, rapid prototyping, intellectual property, entrepreneurship, intrapreneurship and many others. **Short courses in business and technology** will give you the technical edge and sharpen your business skills in a wide variety of subjects, such as successful proposal strategies, manufacturing, intellectual property and new venture planning and development.

More information can be obtained at the Fontainebleau Hilton Resort and Towers, 4441 Collins Avenue, Miami Beach, FL 33140. 800/548-8886, 305/673-5351. Or visit *http://www.techeast.net* Please mention you read about it in *Innovation.*

Bioinformatics May Forever Change Medicine

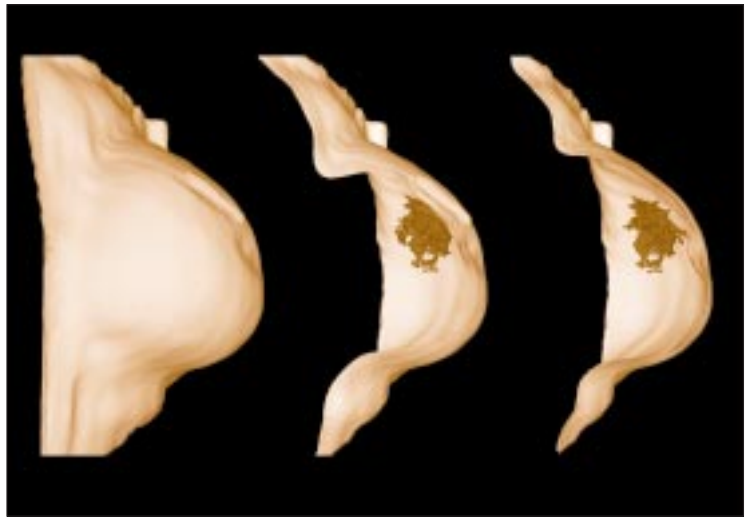
VIRTUAL REALITY—A COMPUTER-CREATED environment that simulates real-life situations—is expected to forever change medical practice and the teaching of science and medicine, revolutionizing the way surgery is done. Computer technology to improve the practice of medicine is a major goal of the Center for Bioinformatics at NASA's Ames Research Center, which is part of a larger national Biocomputation Center established by NASA and Stanford University in Palo Alto, California.

The Biocomputation Center is a national resource to further the use of virtual reality in medicine and will seek partnerships with other academic institutions, federal agencies and industry to accelerate the commonplace use of three-dimensional (3-D) and virtual environment technologies in science and medicine, as well as in space. The four areas on which the center concentrates for advanced computer technology applications in the study of biological systems are:

- Three-dimensional, serial section reconstruction (image processing)
- Advanced visualization (graphics/virtual environments)
- Modeling/simulation (finite element/neuronal networks/electrophysiology)
- Neurotechnology (from biological neuronal circuits and systems to chips, processors and computer architectures)

A virtual hospital, planned for the future, will link the best medical minds from around the country and the world to treat patients, simultaneously benefiting long-term human space presence by assisting in the emergency medical treatment of future space travelers. New medical technologies developed at the center will improve the ability of patients and surgeons to see outcomes before surgery is done. The center will also create a digital library of computerized "virtual patients" to be used to teach medical students and help physicians share information on uncommon surgeries.

Surgeons can use the big-screen workbench, special gloves, computer tracking wands and other devices to manipulate 3-D computer images of patients. "The physician can go in the night before surgery and use the computer in a virtual environment to actually walk through the operation," said Dr. Muriel Ross, director of the Center for Bioinformatics at Ames.



Above:
Clear, accurate three-dimensional images such as these are made from a series of breast and tumor MRI scans combined with reconstruction software developed at the Ames Center for Bioinformatics. A breast image from an MRI scan following a contrast medium injection to detect the tumor shows the position of the mass within the breast (middle and right cutaways). The patient only felt a portion of the mass, noted by the slender object on the left and middle cutaways, which is a tube filled with the contrast medium (gadolinium) to identify the place where the woman felt a mass.

Virtual Surgery Cutting Tool Software

Virtual reality computer tools to aid in complex facial reconstructive surgery has already been developed by the NASA-Stanford biocomputational team. Using a pair of 3-D glasses to see a patient's head from all angles on a monitor or virtual reality workbench, the surgeon uses a software scalpel and clear, accurate 3-D images to practice performing and visualizing outcomes of the surgery.

"The surgeon can work on the virtual reality image and replace the soft tissues to see what the patient may look like after facial reconstruction. If the doctor doesn't like what he or she sees, it's easy enough to start all over again," Ross explained.

Left:
A "software scalpel" used with clear, accurate three-dimensional images made from a series of scans of the human head will help doctors practice reconstructive surgery and better predict the outcome.

Reconstruction of Serial Sections (ROSS) Software

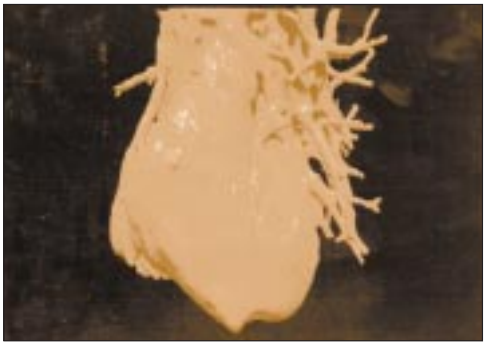
Developed by researchers at the Ames Center for Bioinformatics, this software is combined with a series of computed-aided tomography (CAT) scans to make a 3-D image of any part of the body, as part of the virtual scalpel technique. Eventually, software systems could be used in other medical specialties or surgical procedures. The Ames bioinformatics team is working on a variety of virtual reality computer tools to aid in complex reconstructive surgery and other procedures, including breast reconstruction.

Breast Tumor Enhancement Software

The development of breast tumor enhancement software at the Ames Center for Bioinformatics may make it easier, clearer and more accurate for physicians to find breast tumors. A series of magnetic resonance imaging (MRI) breast scans are also combined with the ROSS software to form a high-fidelity, 3-D computerized picture, or "reconstruction," of a breast and tumor.

"These reconstructions are highly accurate 3-D visual models of affected breasts with tumors. Once this technique is fully developed, we think physicians will be able to visualize the borders of tumors more clearly," Ross said. The method eliminates "noise," or interference, seen in the more common renderings of breast tissues done in many clinics.

"Eventually, a special version of the software will be developed for MRI. In the meantime, we have demonstrated that high-fidelity, 3-D reconstructions can be made from typical MRI breast scans," explained Ross. "Later, we intend to work with sonograms," she said, which uses sound to visualize objects inside bodies. "We want to reduce noise that comes from multiple, echo-like reflections of sound coming from tissues. Borders of objects can be difficult to define because echoes bounce and can interfere with one another."



Three-dimensional human heart reconstruction images could be part of a virtual environment workbench that NASA and other organizations are working together to develop as part of a virtual hospital. Combining MRI scan images and NASA technology software in a virtual hospital setting, physicians will be able to collaborate, share information, plan complex surgical procedures and visualize the potential results of reconstructive surgery in a three-dimensional virtual environment simulator.

NASA has a number of activities in virtual collaboration at several of its field centers. Visit *http://www.hq.nasa.gov/office/olmsa/aeromed/telemed/welcome.html* or *http://www.hq.nasa.gov/office/olmsa/aeromed/telemed/centers.html* Or call NASA's Telemedicine Technology Gateway at 1-800/678-6882.

Ames Partners to Implement a Virtual Hospital

In an agreement with Salinas Valley Memorial Healthcare System that may revolutionize modern health care and develop a entirely new way of looking at the doctor-patient interface, cybersurgeons will be making house calls to patients miles and continents away. Work on the virtual hospital—a health care facility without walls but with technology to electronically transmit and manipulate 3D high-fidelity resolute images in real time—began in 1999 with hospital physicians providing feedback to NASA regarding image quality and network efficiency.

The virtual hospital project will give physicians at geographically dispersed locations the capability to share true-fidelity patient data (such as x-rays, MRIs and other 3-D images and data sets) on-line. Doctors will be able to collaborate with their colleagues around the corner or around the world, in the areas of consultation and diagnosis and in the performance of actual, although "virtual," surgeries.

Under the terms of this Space Act Agreement, Ames Research Center uses its expertise in bioinformatics and high-speed, high-bandwidth networks in establishing a workstation at Salinas Valley capable of transmitting data and receiving 3-D images of the human body over NASA's Next Generation Research and Education Network (NG/NREN). The hospital is comparable to UCLA, Stanford and other leading national medical facilities in terms of the number of heart catheterizations, angioplasties and bypass surgeries conducted on an annual basis, according to Salinas Valley officials.

Virtual Collaborative Clinic

This cooperative demonstration project, among five distant U.S. sites connected over a high-performance computer wide area network, was conducted in May 1999 to demonstrate how to use NASA telemedicine to diagnose patients, practice operations and train over a computer network. The demonstration was conducted to support remote collaborations, to plan surgeries and to make diagnoses—and eventually to operate from a remote site.

The sites linked were the Cleveland Clinic from NASA's Glenn Research Center in Ohio, the Northern Navajo Medical Service Center in New Mexico, Stanford University in California, Salinas Valley Memorial Healthcare System from the University of California at Santa Cruz and NASA's Ames Research Center, a major contributor to research on the Next Generation Internet. Physicians and technical staff at the five remote sites interacted with 3-D visualizations of patient specific data using the next-generation high-bandwidth networks, CalRen2 and Abilene, and Engineering Animation's World2World software.

The medical visualizations were a stereo reconstruction of a heart with a graft reconstructed from a CAT scan, stereo dynamic reconstructions (heart shown beating) of echocardiograms with Doppler effects and a 3-D virtual jaw surgery demonstration using the CyberScalpel, developed by the Ames, Center for Bioinformatics, for irregular-shaped or round bones and organs. The interactions were carried out in real time. Computer screens at the five sites allowed each physician to view every procedure in stereo 3-D as the images of the virtual patient were manipulated. The specialists used high-fidelity, NASA-developed 3-D imaging software to analyze and discuss patients.

"We're looking at methods to bring the clinic to the patient, rather than the patient to the clinic," said Ross, who head's NASA's effort at Ames to develop patient care from a distance. "We're supporting remote collaborations of doctors at different locations on Earth. This will prepare us to use the technology for spacecraft crews traveling to the International Space Station, Mars or other planets, where specialists may not be available."

Specialists could guide a general practitioner or a robot operator on a spacecraft from a great distance, Ross explained. Specialists collaborating from different places on Earth could plan a medical procedure, then send it to an astronaut physician to perform. An operation could be performed in virtual reality a number of times, storing the procedure in computer memory, and then the approach that is best could be used during the actual operation. There have also been discussions of projecting a computer image onto a patient. The projected images could then guide doctors during operations.

The event demonstrated the potential for improving health care at the far corners of Earth through high-performance computing by linking remote sites with the best medical minds and facilities. The Virtual Collaborative Clinic is part of future plans that call for Ames and the Salinas hospital to work with Stanford University Medical Center and the Cleveland Clinic to explore implementing the virtual hospital technology to remote areas around the world. The three hospitals and all major cardiac centers will use high-speed Internet links to exchange images and information.

For more information, contact the Center for Bioinformatics at Ames Research Center. 650/604-4804, *http://biocomp.arc.nasa.gov* Please mention you read about it in *Innovation.*

A Technology-Based New Product and Company

ONE DOCTOR'S DREAM OF A MEDICAL VERSION of the HAL computer from the movie *2001: A Space Odyssey* has culminated in a successful commercial product, the MDX© Clinical Decision Support Technology. NASA's need was to have a system to help astronauts diagnose their own illnesses during long space voyages.

In 1987, Ralph Grams, M.D., a medical systems specialist at the University of Florida's College of Medicine, started working with Kennedy Space Center's Biomedical Office to develop a computer-based medical information and diagnostic support system known as the Clinical Practice Library of Medicine (CPLM). Now, 12 years later, Dr. Grams has formed a new company, Martek Research, Inc., of Gainesville, Florida, to market MDX© and Smart Charts©, Martek's two initial and copyrighted products.

Potential market sources range from health maintenance organizations (HMOs) and large clinical groups to the primary care physician in solo practice. "We also see a role for our product with existing electronic medical record (EMR) vendors who want the best decision support system (DSS) and chart creation tools in the industry," Grams said.

The MDX innovation, contained in one PC-based CD–ROM, is described as a computer-based physician decision support tool that provides a comprehensive differential diagnosis based on patient signs, symptoms and findings, using the traditional medical diagnostic strategy of pattern recognition. This is the customary method by which a physician compares the known with

the unknown to see the degree of fit and conformation. The CD–ROM contains a database of textbooks and journals containing the industry standard patterns, and this allows the MDX program to quickly search all known clinical factoids for fit and conformation.

The use of intelligent medical records, or Smart Charts, could potentially effect any patient who visits a physician or goes to a hospital for treatment, Grams said. The MDX portion of the project provides diagnostic support for tough clinical problems and would be used in situations in which doubt or clinical questions are encountered in the care plan. Both of these technologies can improve physician productivity, enhance outcomes and reduce costs by providing reliable primary care clinical decision support tools. The economic benefits are evident when a doctor has legible, letter-perfect charts that teach as well as document the patient care process in the exam room.

The competitive advantage of the MDX and Smart Charts innovations rests with the databases, which are totally unique and very difficult to duplicate. The size and scope of these medical files allow Martek Research to provide superior clinical data during the patient care examination and to direct and control the entire process. This is a total change in style from the blank page and brain-dead systems used in the past. The computer now knows more medicine than any human could memorize in one's lifetime. The system has no limits as to the size of this knowledge base and can grow and change with the company's professional medical updates. The system supports the simple, routine cases and is totally capable of handling the most complex problems.

The MDX CD–ROM contains the largest structured medical database in the world, according to Grams, and is capable of constant updates. Reference texts and journals are the foundation for all these databases so that the files are fully supported for any legal challenge. The data do not represent any small groups' personal opinions, but display the consensus finding of large clinical peer review panels that publish their disease profiles in major referenced documents.

Martek has a publishing joint venture partner with Facts & Comparisons, a St. Louis company that is a leading provider of authoritative drug information to professionals and students in the health professions. It is part of the Wolters Kluwer International Publishing Division, which also includes Lippincott Williams and Wilkins of Philadelphia, Adis Press of New Zealand and Ovid Technologies of New York, together forming one of the leading international information providers to health care professionals.

For more information, contact Lewis Parrish at Kennedy Space Center. 407/867-6373, *ParriLM@kscgws00.ksc.nasa.gov* Please mention you read about it in *Innovation.*

WEATHER SATELLITES TRACK, CONTROL DISEASE

Using weather satellites to spot the early signs of rising sea temperatures in the eastern Pacific Ocean, the phenomenon called El Niño, scientists may be able to help save East Africans and their livestock from Rift Valley Fever. This mosquito-borne disease can cause death in livestock populations and flu-like symptoms that can be fatal to humans.

In the July 16 issue of the journal *Science,* researchers from NASA's Goddard Space Flight Center, Greenbelt, Maryland, and the Department of Defense's Global Disease Infections System, Walter Reed Army Institute of Research, Washington, D.C., reported studying nearly five decades of satellite data. They determined that rising sea-surface temperatures in the western equatorial Indian Ocean, combined with an El Niño in the Pacific, can lead to abnormally heavy rains in East Africa. This favorable habitat for the mosquitoes carrying the Rift Valley Fever virus can be predicted up to six months in advance so pesticides can stem the mosquito season before it starts.

Researchers found that an El Niño episode alone does not ensure an outbreak. According to the report, the decisive factor is the warming of the Indian Ocean along with the Pacific, which occurred in two of five El Niños over the last 17 years.

Satellites help determine areas receiving the most rain and being greener than normal. Aedes mosquitoes lay their eggs in moist soil when floodwaters recede. The area refloods, and the young insects hatch and feed on local livestock. The Culex, a second mosquito prevalent during excessive rains, contracts the virus from infected livestock and spreads it to humans.

For more information, contact Lynn Chandler at Goddard Space Flight Center. 301/286-5662. Please mention you read about it in *Innovation.*

The Future of Medical Research: The ISS and Biotechnology

IMAGINE BEING A SCIENTIST, BUT ONLY BEING able to go into your best laboratory for 10 days every year or so. The Space Shuttle is an excellent platform for biotechnology research, but it has to return to Earth after two weeks in space, along with the spaceborne laboratory and its outstanding and unique features for performing research. Even if we could fly six Space Shuttle flights per year, each successfully producing crystals to reveal the structure of 1,000 different proteins per flight, it would still take 35 years to learn the structure of all human proteins.

Based on the experience aboard the Russian space station *Mir*, access to the International Space Station (ISS) promises to increase the rate of advancement in this field by a factor of ten. The Shuttle-*Mir* program provided the United States with the opportunity to conduct experiments in microgravity for periods of time far exceeding the two-week maximum of Space Shuttle flights. The flight of seven American astronauts and more than 140 experiments on *Mir* were an important step in preparing for ISS assembly and research.

Microgravity science used cutting-edge technology to increase dramatically the number of protein crystals grown, to allow significant expansion of in-flight tissue culture experiments from weeks to months and to benefit medical research on Earth with knowledge gained. With the ISS, a permanent laboratory will be established in a realm in which gravity, temperature and pressure can be manipulated to achieve a variety of scientific and engineering pursuits that are impossible in ground-based laboratories.

On the ISS, NASA will examine in depth the fundamental effects of microgravity on human health during long-duration space flights, not only for space travelers, but to use the knowledge of the human body at its most basic level to further research here on Earth. A greater understanding of gravity's effects has the potential to bring about a boom in commercial medical products on Earth.

What Is Biotechnology?

Biotechnology is an applied biological science that involves the research, manipulation and manufacturing of biological molecules, tissues and living organisms. It is expected to dominate the 21st century's economy and have a significant impact on our lives.

NASA's dynamic microgravity research in three principal areas—protein crystal growth, mammalian cell and tissue culture, and fundamental biotechnology—will continue aboard the ISS. New opportunities, some just now being explored, will open up in biotechnology on the ISS. Investigators will look into the use of biologically inspired materials and the role that gravity plays in genetic expression.

Marshall Space Flight Center in Huntsville, Alabama, is NASA's Microgravity Center of Excellence for biotechnology. It is supported by the biotechnology program office at Johnson Space Center in Houston, Texas.

Why Conduct Biotechnology Research in Microgravity?

Research on the Space Shuttle and the Russian space station *Mir* has indicated that protein crystals grown in microgravity can yield substantially better structural information, and disease-treating drugs are designed from protein structure data. Determining protein structure is the key to the design and development of effective drugs for the more than 100,000 different proteins important to the human body's everyday functions and the fighting of disease.

By understanding how a protein's structure affects its function, a drug can be created to "fit" into a protein's active site—similar to inserting a key into a lock—to disable the protein's function. This approach promises to help produce superior drugs for a wide range of conditions, and the ISS could become one of the world's premier sources for critical data on the protein structures needed for this new method of drug development.

ISS facilities will enable investigators to analyze crystals on orbit, decreasing the cost and increasing the quality of research. In addition, the station will be used to study and understand the physics involved in protein crystal growth, helping overcome the difficulties that currently limit much of this research on Earth.

Pure, precisely ordered insulin crystals of sufficient size and uniformity are in high demand by drug developers. Insulin crystals grown on the ground do not grow as large or as ordered as researchers desire.

Biotechnology Research Tools and Areas

Protein Crystal Growth

Microgravity experimentation has shown scientists that low-gravity conditions allow for better and larger crystal production in which cells cluster together in three dimensions, often

closely resembling the shape such tissue takes in the human body. Earth's gravity interferes with protein crystal growth on the ground, resulting in cell cultures that are more two-dimensional, which prevents precise definition of the molecules and fine structure and limits the sample's usefulness as a research tool.

In gravity conditions, sedimentation (the separation of materials of different densities) causes the crystals to sink to the bottom of their growth container, but in microgravity, convective flows (flows caused by temperature-driven density differences in a fluid) are greatly reduced, and crystals grow in a much more stable environment. This may be responsible for the improved structural order of space-grown crystals, allowing for precise definition of the molecules and fine structure. Knowledge gained from studying the process of protein crystal growth in microgravity conditions will have implications for protein crystal growth experiments on Earth.

The Bioreactor

By using space-based experiments as a model, researchers have developed a "bioreactor," a mechanism for terrestrial applications that uses horizontal rotation to mimic the microgravity environment. It is successfully being used to culture tissue samples as diverse as liver, muscle, cartilage and bone.

Traditional and conventional static tissue culture methods form flat sheets of growing cells that differ in appearance and function from their three-dimensional counterparts growing in a living body. However, the rotating wall bioreactor, developed to further enhance three-dimensional tissue formation, cultures cells in a horizontal cylinder, which continuously and slowly rotates, allowing for a suspension of tissue samples in growth fluid (to escape much of gravity's influence) and a reduction of damaging shear forces.

Perhaps most significantly, tissue cultures grown in this type of bioreactor, from just a few cancer cells, possess structures and functions similar to those found in the human body. This allows for tests and the study of new treatments on patient cell cultures rather than on patients themselves, and it avoids the risk of harmful side effects to a patient.

The low-turbulence culture environment provided by the NASA Bioreactor promotes the formation of large, three-dimensional cell clusters and has been instrumental in helping scientists better understand normal and cancerous tissue development.

Scientists at NASA's Johnson Space Center are modifying the bioreactor to monitor and control nutrients in the tissue's solution. In the future, this technology will enable quicker, more thorough testing of larger numbers of drugs and treatments. Ultimately, the bioreactor is expected to produce even better results in the microgravity environment achieved in orbit.

Mammalian Cell and Tissue Culture

The study of normal and cancerous mammalian cell and tissue growth holds enormous promise for applications in medicine. Culture tissues have already been grown in the bioreactor aboard the Space Shuttle and on the Russian space station *Mir,* where even greater reduction in stresses on growing tissue samples have allowed larger tissue masses to develop.

Bioreactors are being designed and modified for the ISS so that the bioreactor's continued and expanded use can improve our knowledge of normal and cancerous tissue development. In cooperation with the medical community, the rotating bioreactor design is being used to prepare better models of human colon, prostate, breast and ovarian tumors. In the bioreactor, these tumors grow into specimens that resemble the original tumor.

Similar results have been observed with normal human tissues as well. Cartilage, bone marrow, heart muscle, skeletal muscle, pancreatic islet cells, liver cells and kidney cells are examples of the normal tissues currently being grown in rotating bioreactors by investigators. In addition, laboratory models of heart and kidney diseases and viral infections (including those from the Norwalk virus, a major cause of epidemic gastroenteritis, and the human immunodeficiency virus, or HIV) are in development for further study using this technology.

Because space research sheds light on the fundamental effects of gravity on tissue formation and development, continued cell culture research aboard the ISS will allow scientists to refine Earth-based biomedical techniques. Ultimately, tissues cultured outside the body may be used to replace damaged tissues, treat diseases or eventually replace entire organs.

Telemedicine

Telemedicine, the practice of medicine from a distance through the use of advanced information and communications systems, will ensure that our crews receive the best medical care we can deliver. As our astronauts spend longer periods in space at greater distances from Earth, it will not always be practical to return a sick or injured crew member to our planet's surface for care. Neither will it be possible to fly a full

complement of trained medical personnel with each mission. General paramedic-level knowledge among the crew will be the norm. With this in mind, NASA and its partners are working to integrate the latest in telecommunications, computers and medical technologies in health care to provide our astronauts the best medical care possible.

The ISS will serve as a testbed for new remote medical and life-support technologies to provide high-quality health care and environmental conditions to next-generation space travelers. NASA is currently conducting ground research on an automated portable intensive care unit. Emerging technologies, such as virtual reality and wireless medical monitoring, are being incorporated into advanced remote health care systems. Work in cybersurgery, surgery using digital models and virtual reality is also ongoing. As our knowledge in these areas matures, we will incorporate these technologies into the ISS medical support systems.

At the same time, we can use these technologies to improve our system of health care delivery on Earth. NASA-developed telemedicine systems have been used to provide high-quality medical advice, instruction and education to parts of our nation and the world where advanced medical care or access to health care is not always available—and where it can mean the difference between life and death in acute medical cases. The highly successfully Spacebridge to Russia program, a joint effort between NASA and the Russian Space Agency, is an Internet-based telemedicine testbed that links academic and clinical sites in the United States and Russia for clinical consultations and medical education. A predecessor project, Spacebridge to Armenia, was used to provide medical consultation services during the recovery from the Armenian earthquake in 1988.

Advanced technologies such as telemedicine will enable specialized medical knowledge to serve more people than ever before. Only a permanently crewed ISS with substantial laboratory capabilities will allow research in these directions to proceed productively.

As we work to advance the state of medical care technology, space clinical practices will incorporate the knowledge gained from ISS research on the effects of microgravity on the human body. The classical medical triad of prevention, diagnosis and treatment will be refined to reflect the effects of space travel. Therefore, facilities for basic biomedical research will be used in conjunction with the ISS crew health care system to advance our state of knowledge and care for our astronauts. ✸

For more information about telemedicine, call the NASA Telemedicine Gateway. 800/678-6882, *http://www.nttc.edu/telemed.html* For more information on biotechnology, call the Technology Commercialization Office at Marshall Space Flight Center. 205/544-4266, *http://microgravity.msfc.nasa.gov/MICROGRAVITY/Biot.html* Please mention you read about it in *Innovation.*

X-33 TECHNOLOGY HELPS NEWBORN DELIVERIES

Fiber optic sensing technology originally developed for the X-33, NASA's new single-stage-to-orbit system, and composite materials are being applied to redesigned obstetrical forceps to reduce the risk to infants delivered by forceps. NASA's Marshall Space Flight Center partnered with Dr. Jason Collins of the Pregnancy Institute in Slidell, Louisiana, and with Prism, a San Antonio medical products manufacturer. Obstetric forceps are used by physicians to position an infant in the mother's womb prior to delivery and, in some cases, to assist with the delivery.

Fiber optic sensing technology originally developed for the X-33 is imbedded into obstetric forceps to provide immediate, exact readings during delivery for reduced fetal injury.

Hydrogen and oxygen tanks aboard the X-33 have fiber optic sensors embedded along the edge to monitor the health of the entire system, detecting problems before they arise. In the forceps, the fiber optic smart sensors are embedded inside the handles, sensing deflation and pulling forces. The monitor provides the physician with exact readings immediately.

Obstetrical forceps have been in use for more than 300 years with more than 700 variations of the design; however, none of these allowed the physician to assess the force the instrument placed on the infant. An improvement was definitely needed that would minimize the risk to newborns delivered by forceps. NASA's solution is forceps made of a polymeric material that flexes under pressure. During the manufacturing process, fiber optic sensors are embedded in the material; these sensors are from space program instrumentation technology and indicate strain.

Optical fibers lead from the strain indicators to a unit that allows the obstetrician to monitor forces on the infant throughout delivery. The forceps have a fail-safe mechanism to ensure that no more than five pounds of pressure is exerted on the infant's head, with a pull force limit of approximately 20 pounds.

The forceps will benefit medical students as well. At present, obstetricians must acquire a feel for their instruments during actual infant delivery situations to ascertain how much force is safe. The fiber optic forceps will allow obstetrical students to learn how to use forceps within safe limits before entering practice. Also, Dr. Collins predicts that the fiber optic forceps will reduce the number of cesarean section deliveries, reduce the risk of injury to the mother and significantly lower the occurrence of fetal injury caused by ordinary forceps, thus reducing overall health care costs. ✸

For more information, contact Seth Lawson at Marshall Space Flight Center. 256/544-8545. Please mention you read about it in *Innovation.*

Successes Borne of SBIR

NASA'S SMALL BUSINESS INNOVATION Research (SBIR) program focuses on small business research and commercialization. It increases opportunities for small businesses to participate in federal research and development, to foster and encourage socially and economically disadvantaged persons to participate in technological innovation, to increase employment, to improve overall U.S. competitiveness and to stimulate U.S. technological innovation.

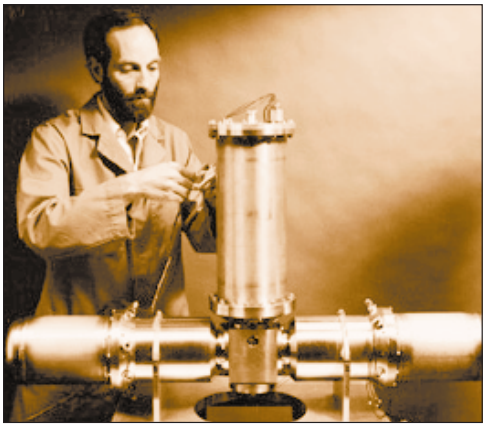
Beating Back Bacteria

SBIR-supported technology from a company that makes the only space-certified and approved-for-flight water purification system flown on all Shuttle missions since 1990 has been applied to develop a commercially available bacteria-beating dental unit. MRLB International Incorporated of River Falls, Wisconsin, has designed DentaPure®, a dental waterline purification cartridge developed using NASA water purification technology. MRLB's unit can clean and decontaminate water as a link between filter and dental instruments.

The purification cartridge can be installed in seconds and changed, not daily, but once a week. For use on high-speed dental tools and other instruments, the cartridge is easily installed on all modern dental unit water lines.

This cartridge for dental use incorporates a resin technology developed by Umpqua Research of Myrtle Creek, Oregon. Umpqua has been awarded a number of SBIR contracts by NASA's Johnson Space Center. As an answer to contaminated dental unit water, the product furnishes disinfected water, maintaining water purity even with suckback. Complete with a tiny membrane, the cartridge is crafted to remove or destroy bacteria to levels that meet or exceed American Dental Association recommendations for dental unit water quality.

The DentaPure® cartridge eliminates contaminated water by using a NASA water purification technology developed through the SBIR program.



NASA requirements called for low-temperature equipment to run sensors to achieve refrigeration levels for a space-rated freezer. The result is the BeCOOL™ line of low-temperature refrigeration equipment that makes the newest cryocooler hardware attractive for a variety of commercial applications, such as controlling computer temperature and for laboratory experiments.

A Stirling Idea

Low-temperature refrigerators, medical diagnostic equipment and sophisticated electronics—all these are benefiting from cryocooling technology. Stirling Technology Company (STC) of Kennewick, Washington, designed a line of cryocoolers under SBIR contracts with NASA's Goddard Space Flight Center and Marshall Space Flight Center.

STC has advanced Stirling engine technology from the 1800s into the space age. Unparalleled in energy efficiency and versatile in performance, Stirling engines can be converted to make refrigerators and to chill to cryogenic temperatures. Commercialization of the product was initially marketed to laboratories that require cryogenic refrigeration and for medical applications.

A new linear motor, invented by Dr. Syed Nasar from the University of Kentucky, accommodated low-cost mass production assembly and fabrication tech-

By encapsulating the end of the Light Emitting Diode (LED) with a balloon, light is diffused over a larger area of the brain. This allows the surgeon a better view and to destroy the tumor without damaging the delicate brain tissue around it.

Pictured is a mock-up of brain surgery being performed. An attempt to develop a light that would allow for the growth of plants in space has been developed into an innovative brain cancer treatment called Photodynamic Therapy, which destroys the tumor without damaging the delicate brain tissue around it.

niques. STC's tests and refinement resulted in a line of low-temperature refrigeration equipment that sports long life, low maintenance and high reliability and attains high safety characteristics.

STC believes that niche markets are likely to evolve for power generators that are highly efficient, reliable, maintenance-free and multi-fuel compatible and produce ultra-low emissions. Supported by company research funds, 10-watt and 350-watt power generators have been built. Multiple units have been sold to government and commercial customers for evaluation purposes. STC's forecast is a demand for turn-of-the-century generators that offer a capacity in the three-kilowatt range. Since its incorporation in 1985, STC has received more than $22 million in research and development contracts from both government and commercial clients.

Space Age Probes Shine a Light on Tumors to Save Lives

Surgeons have used a special lighting technology, developed by a Wisconsin company to conduct plant research in space, in two successful operations to treat brain cancer on Earth. Before the surgeries, Dr. Harry Whelan, a pediatric neurologist and professor at the Medical College of Wisconsin in Milwaukee, and his colleagues performed experiments whose results indicate that when special tumor-fighting drugs are illuminated with Light Emitting Diodes (LEDs), the tumors are more effectively destroyed than with conventional surgery.

"A young woman operated on in May has fully recovered with no complications and no evidence of the tumor coming back," Whelan said. The woman turned to NASA technology after exhausting all other options. "A young man who underwent surgery in August is still recovering, but everything looks great, and thus far there is no evidence of the tumor reoccurring."

The treatment technique called Photodynamic Therapy uses tiny pinhead-size LEDs developed through SBIR contracts to activate light-sensitive, tumor-treating drugs. The program is managed by the Technology Transfer Office at Marshall Space Flight Center in Huntsville, Alabama. To ensure that other promising LED medical applications are investigated, NASA recently selected a Phase II SBIR proposal for negotiation with Quantum Devices Inc. of Barneveld, Wisconsin, the company that initially developed LEDs for commercial plant-growth investigations on the Space Shuttle.

The light source, consisting of 144 tiny diodes, is compact—the size of a small human finger about a half inch in diameter—and mechanically more reliable than lasers and other light sources used to treat cancer. The entire light source and cooling system is only the size of a medium suitcase.

The LED probe can be used for hours at a time and remains cool to the touch. The entire LED unit can be purchased for a fraction of the cost of a laser. Whelan has used the probe on a trial basis

Cedaron Medical's Dexter Outcomes workstation provides a friendly data collection system for the occupational therapy, physical therapy, orthopedic surgery and plastic surgery fields. The system is based on an SBIR contract to develop a system to monitor upper extremity function of astronauts during space flight.

with Food and Drug Administration approval for the removal of children's brain tumors and anticipates this operating technique to be the tool of the future. His technique involves injecting a drug called Photofrin II into the patient's bloodstream. The drug attaches to unwanted tissues and permeates them, without affecting the surrounding tissues. The solid-state LED probe is placed near this permeated tissue, illuminating the tumor and activating the drug to destroy the tumor cells and leaving tender brain stem tissues virtually untouched. Visit Dr. Whelan's web site at *http://www.mcw.edu/whelan*

"This technology has been successfully used to further commercial research in crop growth," said Mark Nall, manager of NASA's Space Product Development Program, part of the Microgravity Research Program Office at Marshall. "Now, a small business has taken the technology and adapted it for an entirely different role to help people here on Earth. With the help of NASA's Small Business Innovative Research program, Quantum Devices and the Medical College of Wisconsin have turned commercial space technology into a new medical device."

LEDs, as a low-energy light source, were used on NASA's second United States Microgravity Laboratory Spacelab mission in October 1995, as part of the Astroculture Plant Growth Facility. The experiment was led by Dr. Raymond J. Bula of the Wisconsin Center for Space Automation and Robotics in Madison, a NASA Commercial Space Center. Commercial Space Centers, supported by NASA, pursue opportunities for continued growth of U.S. industry through the use of space.

Medical Practice Makes Perfect

Health care providers strive to provide more efficient service in a competitive and cost-conscious world. The pressures of managed care can put a tremendous strain on physicians, staff and certainly the patients themselves. Paperwork can overwhelm all concerned, just in monitoring treatment effectiveness and reimbursement.

Cedaron Medical, Inc., of Davis, California, manufactures a range of products to increase clinical productivity, thereby enhancing patient care. Its Dexter Outcomes workstation provides a friendly data collection system for the occupational therapy, physical therapy, orthopedic surgery and plastic surgery fields. The system, based on an SBIR contract, is crafted to minimize paperwork shuffle and to establish a more cost-effective and efficient medical care facility. Outcomes analysis measures a hospital's performance in several ways:

- Patient response to the care provided
- Costs and average length of stay against a comparable treatment
- Strength and range of motion in orthopedic and other treatments

As a result of earlier work with NASA, today Cedaron has computer systems installed in Asia, Europe, South America and across the United States.

For more information, contact Carl Ray of NASA's SBIR program at NASA Headquarters. 202/358-4652, 202/ 358-3878, *cray@hq.nasa.gov* For more information about LEDs, contact Steve Roy at Marshall Space Flight Center. 205/544-0034. Please mention you read about it in *Innovation.*

New Improved Robots for the Operating Room

AN AUTOMATED ENDOSCOPIC SYSTEM FOR Optimal Positioning (AESOP), a robotic arm that assists in surgical procedures, has been augmented under a second Small Business Innovation Research (SBIR) program contract, administered by the Jet Propulsion Laboratory. ZEUS, the improved advanced computer-enhanced robotic system version of AESOP, is currently under a U.S. Food and Drug Administration–approved Phase I Investigational Device Exemption (IDE) study.

Clinical trials currently under way in the United States include delicate heart bypass surgery. ZEUS is marked for commercial sale in the European Community. The original AESOP, also developed under an SBIR contract, helps surgeons in surgical procedures such as gall bladder operations, hernia repair and gynecological and urological operations. It received Food and Drug Administration approval in 1995.

Computer-enhanced robotic systems have been developed successfully by Computer Motion Inc., to assist surgeons in the approximately 1 million endoscopic surgical procedures performed each year in the United States. Endoscopic procedures use a laparoscope, a thin probe with a miniature camera attached, which is surgically placed inside the patient. The surgeon views an image of the surgical field on a television monitor.

The role of AESOP is to hold the laparoscope in the desired position for the surgeon, replacing the unsteady hand of a surgical nurse and giving the surgeon direct control of the laparoscope's position. Possible miscommunications between the surgeon and the surgical nurse are avoided, and the surgical nurse is free to perform other tasks. Also, the surgeon has a jitter-free image to view the operating scene.

AESOP received a number of important enhancements. These include additional robotic manipulators or arms under the surgeon's control, the use of voice commands to control the position of the laparoscope and finer controls of the robotic arms, including the filtering out of tremors to the levels required in microsurgical suturing.

The time needed for endoscopic procedures has been significantly reduced with the aid of AESOP, based on actual operating room experience. The advancing capabilities of robotic systems are opening the door for new and safer endoscopic procedures. Potentially limiting the number of surgical nurses required to assist in these procedures represents significant cost savings.

Patients also benefit whenever endoscopic procedures are elected. Minimally invasive endoscopic procedures result in less patient trauma and discomfort, as well as much faster recovery times. For example, conventional open-heart surgery, which now requires a lengthy incision and splitting open the patient's breast bone to give surgeons access to the heart, will only necessitate a few small incisions with endoscopic technology.

For more information, contact Patricia McGuire at the Jet Propulsion Laboratory. 818/354-1258, 818/354-2385, *Patricia.A.McGuire@jpl.nasa.gov*
Please mention you read about it in *Innovation.*

TWO-CHEMICAL CARCINOGEN DETECTOR

Through Small Business Innovative Research (SBIR) Phase I and II contracts, a Pittsburgh, Pennsylvania, chemical detector company has developed a two-chemistry badge for monitoring exposure and risk analysis of toxic vapors. NASA's Kennedy Space Center needed a reliable way to monitor employees in its hypergolic operations for exposure to carcinogens hydrazine (Hz) and monomethyl hydrazine (MMH). Both hydrazines have an eight-hour time-weighted average threshold limit value of 10 parts per billion for personnel exposure.

GMD Systems of Bacharach, Inc., developed for Kennedy a two-chemistry colorimetric monitoring dosimeter badge that detects Hz and MMH vapors. The lightweight, easy-to-use, sensitive and reliable disposable badges will help minimize the risks associated with the exposure of personnel to toxic vapors. GMD's commercial version can be used in chemical manufacturing, industrial cleaning applications and other areas where Hz is used. The inexpensive badges are individually sealed and dated to provide actual exposure doses. Stain stability and retention are excellent, with low and maximum dose detection. The dosimeter badges have been used by major chemical companies worldwide.

The badge has two exposed, separate paper tape chemistries that change colors when exposed to Hz or MMH, which can immediately be seen in the badge's pair of circular windows. By using a dose estimator, the user can match the stain density to available dose information and determine the approximate exposure level.

A 1980s dosimeter badge prototype was not effective, and a NASA contractor working with the Naval Research Laboratory found a reaction of colorless aqueous vanillin solution with Hz and MMH to form a yellow solution. Risk areas where exposure monitoring is required include facilities in which workers are engaged in the assembly and operational handling of spacecraft, missiles and aircraft auxiliary power units in which fuels are used.

For more information, contact Lewis Parrish at Kennedy Space Center. 407/867-6373, *ParriLM@kscgws00.ksc.nasa.gov* Please mention you read about it in *Innovation.*

TECHNOLOGY OPPORTUNITY SHOWCASE

Technology Opportunity Showcase *highlights some unique technologies that NASA has developed and which we believe have strong potential for commercial application. While the descriptions provided here are brief, they should provide enough information to communicate the potential applications of the technology. For more detailed information, contact the person listed. Please mention that you read about it in* Innovation.

A Program to Measure Carotid-Wall Thickness

The Jet Propulsion Laboratory (JPL) seeks to transfer the carotid-wall ultrasound measurement technique it developed as a measurement method that uses an automated edge-finding technique to locate the wall boundaries. This method has 5 to 10 times less variability than the manual method. Until recently, measurement of the wall thickness from ultrasound images was accomplished by manually identifying the boundaries of the wall on displayed images using a computer mouse. The thickness of the carotid artery wall has been found to be a highly sensitive indicator of various cardiovascular disorders, such as atherosclerosis and hypertension. Measurement of the wall thickness from ultrasound images is being widely used in epidemiology studies related to these disorders and in clinical tests of various drugs and other therapies. A personal computer operator identifies the approximate location of the arterial wall's boundary. The edge-finding, maximum gradient detection algorithm locates the exact boundary. The tracking method tests the edge "strength" of each detected boundary point and logic to reject poor quality or questionable boundary points. Low measurement variability allows testing the efficacy of drugs and other therapies with fewer subjects in a shorter time, which in turn reduces the testing cost. This new version of PROSOUND, being developed at JPL with funding from the National Institutes of Health (NIH), is an updated version of the first, built in 1988 and 1992 by Robert Selzer in collaboration with the University of Southern California, which holds a copyright and sells the program.

For more information, contact the Technology Transfer Office at the Jet Propulsion Laboratory. 818/354-2577. Please mention you read about it in *Innovation.*

Early Diagnosis of Eye Diseases

Glenn Research Center is seeking industry partners for developing and commercializing a technology for the early detection of various eye diseases. A patent application has been filed. A new fiber-optic probe based on dynamic light scattering has been developed for early detection, which can yield such benefits as screening for anti-cataract drugs, offering better control of diabetes, providing valuable insight into ocular and systemic effects of hyperglycemia, identifying people with undiagnosed disease and better controlling glycemia and diabetes mellitus. A low-power laser beam is aimed into the eye, and the backscattered light is collected and processed to determine the average size and distribution of submicroscopic particles in the eye, such as cholesterol deposits in the anterior chamber, protein crystallines in the lens, and hyaluronon acid molecules and collagen fibers in the vitreous humor. By monitoring the change in the particle size, medical personnel can detect diseases such as cataracts, diabetic retinopathy and asteroid hyalosis in their early stages. Blood sugar and cholesterol levels also could be monitored by such eye measurements without extracting blood. The probe is compact and easy to use. There is no physical contact with the eye, the laser radiation level is extremely low and the measurement duration is very short, ensuring safety. The probe can be easily attached to an existing ophthalmoscope by means of a Hruby lens holder. An optional video imaging system can be added to provide visual monitoring of the eye as the measurements are under way. In collaboration with the National Eye Institute of NIH, experiments are being conducted on congenital and drug-induced cataracts in Philly and transgenic mice. Also, clinical trials on human patients are planned.

For more information, contact Dr. Rafat R. Ansari at Glenn Research Center. 216/433-5008, 216/977-7138, *ransari@lerc.nasa.gov* Please mention you read about it in *Innovation.*

Millimeter Wave/Microwave Ablation

Johnson Space Center is seeking industrial partnerships to continue the testing of the millimeter wave/microwave ablation and to license this technology for nonaerospace applications. The technology is for the nonsurgical repair of diseased coronary arteries by intervention cardiologists during coronary catheterization. Potentially safer than balloon angioplasty and other prior forms, the device delivers millimeter/microwave energy by way of a catheter to precise locations of the coronary arteries. The device selectively targets and heats atherosclerotic lesions. It can be used to melt away fatty deposits of atherosclerosis and does not scar the blood vessel, thus preventing restenosis (a condition in which platelets and white blood cells go where the blood vessel was damaged). It is very nonintrusive and can be used as a preventive measure. It can precede the implantation of a stint and allow multiple tasks to be performed in one catheterization. The device consists of a millimeter/microwave power source, a catheter transmission line in the form of a waveguide or coaxial cable and an antenna/radiator located at the distal end of the catheter. The potential commercial use, with a forecasted multibillion-dollar market worldwide, is noninvasive treatment for atherosclerosis.

For more information, contact the Technology Transfer and Commercialization Office at Johnson Space Center. 281/483-1749, 281/244-8452, *commercialization@jsc.nasa.gov* Please mention you read about it in *Innovation.*

NCTN DIRECTORY

Moving Forward

NASA Field Centers

Ames Research Center
Selected technological strengths are Information Technologies, Aerospace Systems, Autonomous Systems for Space Flight, Computational Fluid Dynamics and Aviation Operations.

Carolina Blake
Ames Research Center
Moffett Field, California 94035-1000
650/604-1754
cblake@mail.arc.nasa.gov

Dryden Flight Research Center
Selected technological strengths are Aerodynamics, Aeronautics Flight Testing, Aeropropulsion, Flight Systems, Thermal Testing and Integrated Systems Test and Validation.

Eugene (Lee) Duke
Dryden Flight Research Center
Edwards, California 93523-0273
805/258-3802
lee.duke@dfrc.nasa.gov

Glenn Research Center
Selected technological strengths are Aeropropulsion, Communications, Energy Technology and High Temperature Materials Research, Microgravity Science and Technology and Instrumentation Control Systems.

Larry Viterna
Glenn Research Center
Cleveland, Ohio 44135
216/433-3484
Larry.A.Viterna@grc.nasa.gov

Goddard Space Flight Center
Selected technological strengths are Earth and Planetary Science Missions, LIDAR, Cryogenic Systems, Tracking, Telemetry, Command, Optics and Sensors/Detectors.

George Alcorn
Goddard Space Flight Center
Greenbelt, Maryland 20771
301/286-5810
george.e.alcorn.1@gsfc.nasa.gov

Jet Propulsion Laboratory
Selected technological strengths are Deep and Near Space Mission Engineering and Operations, Microspacecraft, Space Communications, Remote and In-Situ Sensing, Microdevices, Robotics, and Autonomous Systems.

Merle McKenzie
Jet Propulsion Laboratory
Pasadena, California 91109
818/354-2577
merle.mckenzie@jpl.nasa.gov

Johnson Space Center
Selected technological strengths are Life Sciences/Biomedical, Spacecraft Systems, Information Systems, Robotic and Human Space Flight Operations

Henry (Hank) Davis
Johnson Space Center
Houston, Texas 77058
281/483-0474
henry.l.davis@jsc.nasa.gov

Kennedy Space Center
Selected technological strengths are Emissions and Contamination Monitoring, Sensors, Corrosion Protection and Biosciences.

Gale Allen
Kennedy Space Center
Kennedy Space Center,
Florida 32899
407/867-6226
gale.allen-1@kmail.ksc.nasa.gov

Langley Research Center
Selected technological strengths are Aerodynamics, Flight Systems, Materials, Structures, Sensors, Measurements and Information Sciences.

Sam Morello
Langley Research Center
Hampton, Virginia 23681-0001
757/864-6005
s.a.morello@larc.nasa.gov

Marshall Space Flight Center
Selected technological strengths are Materials, Manufacturing, Non-destructive Evaluation, Biotechnology, Space Propulsion, Controls and Dynamics, Structures and Microgravity Processing.

Sally Little
Marshall Space Flight Center
Huntsville, Alabama 35812
256/544-4266
sally.little@msfc.nasa.gov

Stennis Space Center
Selected technological strengths are Propulsion Systems, Test/Monitoring, Remote Sensing and Nonintrusive Instrumentation.

Kirk Sharp
Stennis Space Center
Stennis Space Center, Mississippi
39529-6000
228/688-1914
kirk.sharp@ssc.nasa.gov

NASA ON-LINE

Go to the **NASA Commercial Technology Network (NCTN)** on the World Wide Web at ***http://nctn.hq.nasa.gov*** to search NASA technology resources, find commercialization opportunities, and learn about NASA's national network of programs, organizations, and services dedicated to technology transfer and commercialization.

NASA's Business Facilitators

NASA has established several organizations whose objectives are to establish joint sponsored research agreements and incubate small start-up companies with significant business promise.

Joseph C. Boeddeker
Ames Technology Commercialization Center
San Jose, CA
408/557-6789

Greg Hinkebein
Mississippi Enterprise for Technology
Stennis Space Center, MS
228/688-3144

Wayne P. Zeman
Lewis Incubator for Technology
Cleveland, OH
216/586-3888, 216/433-5300

Thomas G. Rainey
Florida/NASA Business Incubation Center
Titusville, FL
407/383-5200

Judy Johncox
University of Houston/NASA Technology Center
Houston, TX
713/743-0451

Joanne Randolph
Business Technology Development Center
Huntsville, AL
256/704-6000, ext. 202

Richard C. (Michael) Lewin
Maryland Economic Development Corp.
Greenbelt, MD
800/541-8549

Van Garner
California State Polytechnic University–Pomona
Pomona, CA
909/869-2276

Martin Kaszubowski
Hampton Roads Technology Incubator
Hampton, VA
757/865-2140

Small Business Programs

Carl Ray
NASA Headquarters
Small Business Innovation Research Program (SBIR/STTR)
202/358-4652
cray@hq. nasa.gov

Paul Mexcur
Goddard Space Flight Center
Small Business Technology Transfer (SBIR/STTR)
301/286-8888
paul.mexcur@pop700.gsfc.nasa.gov

NASA-Sponsored Commercial Technology Organizations

These organizations were established to provide rapid access to NASA and other federal R&D and foster collaboration between public and private sector organizations. They also can direct you to the appropriate point of contact within the Federal Laboratory Consortium. To reach the RTTC nearest you, call 800/642-2872.

Ken Dozier
Far West Technology Transfer Center
University of Southern California
213/743-2353

Dr. William Gasko
Center for Technology Commercialization
508/870-0042

J. Ronald Thornton
Southern Technology Applications Center
University of Florida
352/294-7822

Gary F. Sera
Mid-Continent Technology Transfer Center
Texas A&M University
409/845-8762

Lani S. Hummel
Mid-Atlantic Technology Applications Center
University of Pittsburgh
412/383-2500

Christopher Coburn
Great Lakes Industrial Technology Center
Battelle Memorial Institute
440/734-0094

Joseph P. Allen
National Technology Transfer Center
Wheeling Jesuit University
800/678-6882

Doris Rouse
Research Triangle Institute Technology Applications Team
Research Triangle Park, NC
919/541-6980

Events/Multimedia

New Business Incubator Launched in Montana

Big Sky Economic Development Authority of Billings, Montana, has launched the Montana Incubator for NASA Technology (MINT). James F. Ouldhouse is appointed to manage the organization's planning and services. The NASA-sponsored incubator is focused on fostering the start-up and growth of technology-based businesses through the commercialization of NASA and related technology. MINT, an "incubator without walls," is teamed with the NASA-Montana State University TechLink Center and will leverage existing business assistance services of the Big Sky Economic Development Authority to provide business development and technology/capital sourcing services for selected clients. For more information, contact James Ouldhouse at 222 North 32nd Street, Billings, Montana, 59101-1911. 406/256.6871, 406/256.6877, *ouldhouse@bigskyeda.org*

Classroom of the Future's BioBLAST® Available

BioBLAST® (Better Learning Through Adventure, Simulations and Telecommunications) is now available as a multimedia curriculum supplement for high school biology classes to encourage students to conduct real scientific research in an interactive adventure/simulation framework. Hands-on laboratory investigations, computer simulations and Internet-based tools and telecommunications resources may be accessed via the BioBLAST virtual reality interface, which depicts a futuristic, moon-based research outpost. Incorporating data from NASA's Advanced Life Support Research program, BioBLAST draws students into a futuristic, problem-solving scenario in which teams of students use simulation models to develop and test their own designs for a bioregenerative system to support human life outside the safety of Earth's atmosphere. Produced and developed by NASA's Classroom of the Future (COTF), this project was jointly funded by NASA's Educational Technology program and the Life Sciences Division of NASA's Office of Life and Microgravity Sciences and Applications. For more information or to order BioBLAST, contact the COTF at 304/243-4416 or *getBioBLAST@cet.edu*, or go to its web site at *http://www.cotf.edu/BioBLAST/*

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