

Spinoff 2001

SPECIAL MILLENNIUM FEATURE



National Aeronautics and Space Administration

Spinoff 2001

National Aeronautics and Space Administration
Office of Aerospace Technology
Commercial Technology Division

On the Cover:

The montage represents images of NASA's advancements in space exploration and the transfer of NASA technology to the private sector. Representations include the Space Shuttle, which is NASA's most reliable and versatile launch system; a manned mission to deep space; and the International Space Station that brings knowledge and insights about the far reaches of space down to Earth. The remaining images depict spinoffs in the areas of satellite imagery, noise control, air traffic management, cameras for night vision surveillance, and computer technology.

Developed by
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NASA Center for AeroSpace Information (CASI)



FOREWORD

As NASA Administrator, I take exceptional pride in the manner in which innovative entrepreneurs take NASA's revolutionary technologies, which are developed for space and aeronautics programs, and adapt them to the benefit of everyone on Earth. I am proud of this aspect of NASA's work because it shows just how connected we all are on this small planet. This publication summarizes just some of the application of NASA's expertise, bringing the fruits of investment in NASA to everyone's doorstep.

This year we moved into a new era in human space exploration. We now have the International Space Station well underway with the second of our permanent crews aboard. As our full-time habitation of the space environment grows, the products and technologies needed to keep our crews healthy grows too. That is why research on the effect of space travel on living things—cells, tissues, plants, animals, and people—is so important. Just as important, is the application of that knowledge to all of us here on Earth. Few people are fortunate enough to go into space, but many of us benefit from what we learn by putting those few into that most extreme of environments.

NASA's research and development programs, carried out under the guidance of our strategic plan, are carefully crafted to point NASA's efforts toward scientific and technical advances needed for our missions in space and aeronautics. Through programs such as the Hubble Space Telescope and the Chandra X-ray Telescope, we make breakthrough advances in our knowledge of this universe. Through programs that look back at the Earth from space, we increase our knowledge of this fragile planet. We invest in research related to aircraft, spacecraft, and their propulsion systems. We study and develop new materials and processes to manufacture them to the high tolerances required for extreme environments. We advance the field of robotics and applied physics. We also examine the effect of space travel on machines and on the most amazing machine of all—the human body.

A technology developed to monitor the cardiac output of astronauts in space has been adapted so that physicians on Earth can measure the ability of their patients' hearts to deliver blood to the body. What was once an intrusive procedure requiring a hospital stay can now be replaced with readings from an external monitor.

Workers who once labored in the very dangerous job of inspecting petroleum tanks can do so from the safety of the controls of a robotic inspector. The emotional and financial heartbreak of fire can be reduced or eliminated altogether, with a coating developed first for NASA heatshields, and modified for use in building materials such as wood, plasterboard, steel, plastics, fiberglass, and ceramics.

This publication is full of examples of the innovation of our private sector. It is this innovation that keeps America at the forefront of scientific and technical leadership. Many of the examples in this publication are surprising, many are inspiring; all are interesting and indicative of the wealth and breadth of our collective genius.

When I am asked what relevance NASA's research and programs have to everyday life, I refer people to *Spinoff*—the stories behind the connection between NASA technology and a better life for all.



Daniel S. Goldin
Administrator

National Aeronautics and Space Administration



Daniel S. Goldin
Administrator

INTRODUCTION

For the past 43 years, NASA has devoted its facilities, labor force, and expertise to sharing the abundance of technology developments used for its missions with the nation's industries. These countless technologies have not only successfully contributed to the growth of the U.S. economy, but also to the quality of life on Earth. For the past 25 years, NASA's *Spinoff* publication has brought attention to thousands of technologies, products, and services that were developed as a direct result of commercial partnerships between NASA and the private business sector. Many of these exciting technologies included advances in ceramics, computer technology, fiber optics, and remote sensing.

New and ongoing research at the NASA field centers covers a full spectrum of technologies that will provide numerous advantages for the future, many of which have made significant strides in the commercial market. The NASA Commercial Technology Network plays a large role in transferring this progress. By applying NASA technologies such as data communication, aircraft de-icing technologies, and innovative materials to everyday functions, American consumers and the national economy benefit.

Moving forward into the new millennium, these new technologies will further advance our country's position as the world leader in scientific and technical innovation. These cutting-edge innovations represent the investment of the U.S. citizen in the Space Program. Some of these technologies are highlighted in *Spinoff 2001*, an example of NASA's commitment to technology transfer and commercialization assistance.

This year's issue spotlights the commercial technology efforts of NASA's John F. Kennedy Space Center. Kennedy's extensive network of commercial technology opportunities has enabled them to become a leader in technology transfer outreach. This kind of leadership is exemplified through Kennedy's recent partnership with the State of Florida, working toward the development of the Space Experiment Research and Processing Laboratory. The new laboratory is the first step toward the development of a proposed 400-acre Space Commerce Park, located at Kennedy Space Center.

Spinoff, once again, successfully showcases the variety of commercial successes and benefits resulting from the transfer of NASA technology to private industry.

It is with great pride and pleasure that we present *Spinoff 2001* with a Special Millennium Feature. With help from U.S. industry and commercial technology programs, NASA will continue to assist in the presentation of innovative new products to our nation.



Dr. Robert L. Norwood
Director, Commercial Technology Division
National Aeronautics and Space Administration

Spinoff developments highlighted in this publication are based on information provided by secondary users of aerospace technology, individuals, and manufacturing concerns who acknowledge that aerospace technology contributed wholly or in part to development of the product or process described. Publication herein does not constitute NASA endorsement of the product or process, nor confirmation of manufacturers' performance claims related to the particular spinoff development.

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KENNEDY

NASA vigorously pursues partnerships with the commercial sector that benefit both the national economy and the quality of our everyday lives. Each NASA field center invests a great deal of effort in technology transfer activities, resulting in new and innovative products and developments.

This section highlights the technology transfer programs implemented at the John F. Kennedy Space Center. Kennedy's Technology Programs and Commercialization Office supports the commercial development of space-age technologies through licensing agreements, partnerships, and Small Business Innovation Research and Small Business Technology Transfer programs. As we enter the 21st century, Kennedy's cutting-edge facilities, engineering know-how, and research initiatives, coupled with their numerous commercial partnerships, ensures a continuance of trailblazing technologies to lead us into the new millennium.

SPOTLIGHT ON KENNEDY SPACE CENTER

The Technology Programs and Commercialization Office at the NASA John F. Kennedy Space Center, in Florida, is vigorously implementing Administrator Daniel S. Goldin's Agenda for Change by striving to increase its number of partnerships with the commercial sector. To facilitate this, a staff of seven permanent NASA technology transfer professionals, two NASA rotational assignment employees, and eight on-site support specialists work within the framework of the office that encompasses technology evaluation, intellectual property, commercialization, patent licensing, joint development partnerships, SBIR/STTR programs, grants, and Space Act Awards. Kennedy Space Center's patent counsel and a paralegal also support the office. In an effort to more closely align Kennedy's way of doing business with that of the private sector, the Center is supporting the development and transfer of technology leading to commercial products and services through a mix of business practices and specific plans to leverage NASA resources.

Licensing

Several Kennedy-developed technologies have resulted in exclusive licenses during the past year, including:

- Conducting Compositions of Matter, a technique that uses template guided polymerization to increase the solubility and processibility of electrically conducting polymers;
- Gas-Liquid Supersonic Cleaning and Cleaning Verification Spray System, a spraying system for cleaning mechanical components, which uses less liquid and operates at significantly lower pressures;
- Process and Equipment for Nitrogen Oxide Waste Conversion to Fertilizer, a control element within a nitrogen oxide wet scrubber used to reduce emissions of rocket fuel oxidizer;

- Non-Intrusive Cable Tester, for detecting a short or open circuit in a shielded cable that requires low frequency input;
- Internet Display of PC GOAL Real-Time Data Using Java (JView), a personal computer-based software for distributed multiple Space Shuttle subsystem status displays;
- Corrosion Resistant Coating, electrically conductive polymer coatings developed as corrosion-protecting coatings for metal surfaces; and
- Multipurpose Inspection Software, a customized software system that automates the scheduling, reporting, and tracking of the fire inspection (prevention) process.

Other technologies such as the Remote Monitor Alarm System, an electronic central monitoring system used to monitor malfunction alarms and power supplies on remotely located equipment modules of transmitting and receiving equipment in fiber-optic communications network; and Accurate Location of Lightning Strikes, a system that determines the locality of a lightning strike within the perimeter of a launch pad, were licensed non-exclusively.

Under a Dual Use Cooperative Agreement, The Aerospace Engineering Group of IDEA (Beltsville, Maryland) was competitively selected to jointly complete development of the Automatic Particle Fallout Monitor (APFM) with NASA, fulfilling an immediate demand as part of International Space Station processing. The APFM measures the size and number of particles, as small as 5 micrometers in diameter, that are collected on a witness surface and provides multiple cleanliness measurements that conform to Military (MIL) Standard 1246. IDEA is commercializing the patented Kennedy invention through an exclusive license and has targeted several markets, including aerospace, semiconductors, medicine, and electronics fabrication.

Representatives from various companies attend an industry briefing on the Cabin Pressure Monitor at Kennedy Space Center.



Industry briefings are a mechanism used increasingly at Kennedy Space Center to market technologies that have commercial application. Two such briefings were held at the Center this year, with representatives from 20 companies benefiting from a general session, which included a technical briefing by the inventors, followed by breakout sessions which addressed intellectual property issues and licensing specifics. These briefings resulted in multiple license applications, from which two licenses were negotiated, providing future royalties to NASA.

Partnerships

Key to the success of the technology transfer function are the partnerships that the Center has established. Recently, the Georgia Institute of Technology was chosen to operate and manage the Southeast Regional Technical Transfer Center (SERTTC) under a five-year, \$7 million contract, with Kennedy acting as the regional NASA sponsor. The SERTTC contract supports three NASA field centers: Marshall Space Flight Center, Stennis Space Center, and Kennedy Space Center. The SERTTC serves the southern states of Alabama, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee, and is one of six regional technology transfer centers (RTTCs) around the country. In addition to the licensing of technologies, the SERTTC assists applicants for NASA's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) initiatives. Specialists at the SERTTC also help connect businesses that have specialized research needs with available research and development (R&D) facilities within NASA.

Kennedy benefits from a highly successful and long-standing relationship with Research Triangle Institute (RTI). RTI has worked with NASA for over 30 years on its technology assets, providing a range of services including: technology

assessment, valuation, and marketing; market analysis; commercialization planning; and the development of partnerships. During the past five years, the group evaluated more than 1,000 NASA technologies, helped develop 55 licensing agreements, and brought 27 products to market.

Kennedy Space Center has entered into a two-year agreement with the Technological Research and Development Authority (TRDA) to help the Center promote a newly restructured, dual-use technology program. The partnership is designed to support the identification of promising new technology within NASA that has commercial applications. This will result in more viable dual-use technology projects and the accomplishment of multiple technology transfers and commercialization on a continuing basis. Under the new agreement, the TRDA will be responsible for providing awareness to Florida companies. The program will be marketed to universities, regional economic development organizations, small business development centers, and others who can help the TRDA search for commercial companies, especially small businesses, focused in the high-tech, defense, and aerospace industries.

Another resource that Kennedy uses to transfer technology to the commercial market is the Florida/NASA Business Incubation Center (FNBIC). FNBIC was created to assist entrepreneurs and small technology-based businesses by offering share office resources at a reduced cost, enhanced access to state and local business assistance programs, and enhanced access to NASA technologies. To date, three royalty-bearing license agreements have been signed between NASA and FNBIC clients to commercialize Kennedy-developed technologies.

In addition to partnerships sponsored directly by the Technology Programs and Commercialization Office, Kennedy Space Center sponsors other business-related

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An artist's conception of the proposed Space Experiment Research and Processing Laboratory (SERPL) facility. Construction is projected to begin in October 2001.

SPOTLIGHT ON KENNEDY SPACE CENTER

(Continued)

partnerships. In partnership with the State of Florida, the Center is developing the Space Experiment Research and Processing Laboratory (SERPL). It will be a world-class laboratory with all the capability and systems necessary to host International Space Station experiment processing, as well as associated biological and life sciences research, including biotechnology; microgravity; space agriculture; biomedicine, conservation biology; and microbial ecology. This unique laboratory will be the magnet facility in the initial phase of a proposed 400-acre Space Commerce Park at Kennedy Space Center. The park will provide an ideal location for businesses and research groups with a need for close proximity to the Space Center's launch and landing facilities, and technical capabilities. This project represents a significant opportunity to enhance commercial and academic access to the spaceport and the International Space Station. Research will be jointly conducted by NASA and a university-led consortium open to public and private institutions. Each partner's scientific research and intellectual resources will enhance the total knowledge base and expertise, and provide a solid foundation for a new science, research, and technology development community in the area.

The Cryogenics Testbed Facility, a new venture in technology and research collaboration, is just one more example of the partnerships being forged with Kennedy Space Center. Cryogenics and high vacuum techniques and technology are being used all around the world. Kennedy created this facility to better apply cryogenics to our lives in the fields of medicine, biology, food, computers, industry, rocket propulsion, and the spaceports of the future. The special facility is operated under a jointly funded agreement between Dynacs Engineering Co., Inc., the Florida Department of Community Affairs, the Technological Research and Development Authority, and NASA. The facility has already paid dividends in applying technology solutions to operational needs at the Space Shuttle launch pad. Several commercial cryogenic projects have already been completed with the number of businesses seeking services steadily starting to climb. The testbed demonstrates the win-win philosophy and the innovative initiatives in technology transfer for which Kennedy has become known. This testbed will be the pathfinder for making other Kennedy testbeds commercially available as well.

SBIR/STTR Programs

The Technology Programs and Commercialization Office is a major contributor to the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs at Kennedy Space Center. Congress established the SBIR Program in 1982 to provide increased opportunities for small businesses to participate in research and development (R&D), to increase employment, and to

increase private-sector commercialization of innovations derived from Federal R&D. Legislation enacted in December 2000 extended and strengthened the SBIR program and increased its emphasis on pursuing commercial applications for innovations developed with SBIR funding. Kennedy has been very successful in granting six Phase III contracts totaling over \$3 million on SBIR innovations. Kennedy's SBIR program has also generated 18 NASA Success Stories, where a small business concern has successfully commercialized an innovation developed through a SBIR contract.

The STTR program is very similar to the SBIR program but requires that the small business concern enter into a cooperative agreement with a non-profit research institution to jointly propose technology developments. The STTR program requires that at least 30 percent of the contract work be performed by the research institution. The STTR program has proven to be extremely successful in increasing the number of Florida companies and research institutions involved in the program and receiving awards.

The SBIR/STTR programs support technologies such as: fluid system technologies, spaceport structures and materials, process engineering, command control and monitoring technologies, range technologies, and biological sciences. The combined SBIR/STTR programs at Kennedy in the past year have funded close to \$5 million for research and development contracts.

Marketing

The marketing program in the Technology Programs and Commercialization Office at Kennedy Space Center is specific to technologies developed in support of the Space Shuttle, Space Station, and Payload Processing missions. The marketing effort supports Agency-wide initiatives, such as sensors, medical devices, and materials. The sensors industry initiative is particularly relevant to Kennedy, since many of our technologies involve detection devices capable of performing under rigorous conditions of launch and the harsh conditions of space. Throughout the launch process, from pre-launch testing through the final seconds of countdown, more than 300 sensors are critical in the launch decision. These sensors with high-performance criteria are of great interest to industry applications ranging from medical and environmental, to manufacturing and instrumentation. For instance, the UV-IR Hydrogen Flame Detector, used to detect hydrogen fires on the Shuttle pad, has applications in the petrol chemistry industry.

Since Kennedy technologies are developed for use at the Center, they are in a higher state of readiness for transfer to applicable industries. The Transient Voltage Recorder that helps detect surges that could damage high-tech equipment on Shuttle systems also has applications in sensitive environments such as computer rooms, communications systems,

and control operations. The Conversion of Nitrogen Oxide Waste conversion technology, developed to reduce hazardous rocket fuel waste, also has applications in the power plant industry. The Wireless Universal Interface Adapter provides push-to-talk signals to a communications system as if the user were directly wired to the system. Used at in Kennedy ground support equipment operations, this technology is applicable to call centers, emergency response, and law enforcement. These and other technologies are readily available for licensing and transfer for commercial application through Kennedy's Technology Programs and Commercialization Office.

Awards

Several Kennedy technologies earned awards this past year, both inside and outside of NASA. Nitrogen Oxide Waste Conversion won the NASA Commercial Invention of the Year, Gas-Liquid Supersonic Cleaning and Cleaning Verification Spray System was honored by the Federal Laboratory Consortium Southeast Region for Excellence in Technology Transfer, while Advanced Lubricants, a success story from a previous year, was inducted into the U.S. Space Foundation Space Technology Hall of Fame in April 2000. Additionally, with concerted efforts through the Space Act Awards program, Kennedy Space Center increased recognition for inventors through technical awards in the amount of \$175,000. Award recipients attend an annual luncheon,

which serves not only to bring recognition to inventors, but also promotes awareness of the requirement and benefits of reporting new technologies to the Center.

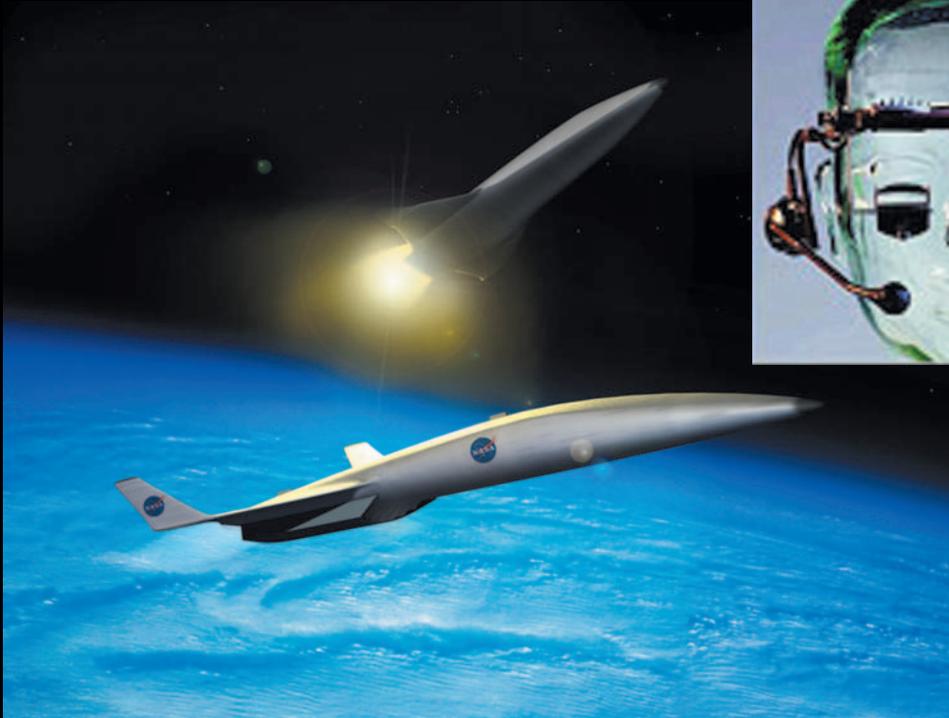
Inreach

Kennedy's inreach efforts include an annual Technology Transfer Week, during which office representatives staff an exhibit in the several facilities at the Center, answering questions and dispensing program literature. Center director, Roy Bridges, sponsored a Center-wide initiative to increase the number of new technology reports. Toward this effort, the Technology Programs and Commercialization Office partnered with contractor representatives to promote an understanding of technology transfer objectives and contract requirements to report technologies developed at the Center in support of the Shuttle program. The results showed a marked increase in the numbers of new technology reports filed by contractors.

Many challenges lie ahead, and the role of the Technology Programs and Commercialization Office will continue to be refined. The office is an integral part of the NASA commercial technology mission and a mainstream function of Kennedy Space Center. As we enter the 21st century, Kennedy Space Center will continue to review and improve the process of enabling commercial development, supporting development of dual-use technology, and transferring technology. ❖



Space Act Award recipients are honored at an annual luncheon.



AEROSPACE RESEARCH

An essential aspect of NASA's Strategic Plan incorporates research and development efforts that will further the ongoing success and leadership of NASA in the area of scientific and technical advances. Benefits resulting from these advances are seen not only by the scientific and engineering community, but also by all citizens of the United States.

A network of ten NASA field centers is armed with the necessary resources for creating innovative technologies and scientific advances—advances that allow NASA to further expand our understanding of our planet and the universe. Ongoing efforts to create new technologies such as next-generation aircraft, robotics, new remote sensing technologies, performance coatings, propulsion technologies, and many others will help us to achieve maximum benefits from space and expand our existence beyond Earth.

NASA is developing the technology of tomorrow, today. These forward-thinking technological advances provide private industry with commercial products and services that offer benefits to all. NASA's enthusiastic efforts and activities serve to maintain our economy's global leadership and better the lives of people across the United States and the globe.

NASA HEADQUARTERS

NASA Headquarters oversees the Agency's multifaceted mission of ongoing scientific research, investigating the reaches of outer space, and developing new and innovative technology. NASA has developed five Strategic Enterprises, as outlined in the Agency's Strategic Plan, to coordinate these activities in pursuit of its mission. Each Enterprise covers a key area of NASA's research and development efforts. The five Strategic Enterprises are: Aerospace Technology, Biological and Physical Research, Earth Science, Human Exploration and Development of Space, and Space Science.

Aerospace Technology

NASA's charter is to pioneer advanced technologies that will meet the challenges facing air and space transportation, to maintain U.S. national security and preeminence in aerospace technology, and to extend the benefit of its innovations throughout society.

A modern air and space transportation system is fundamental to the national economy, quality of life, and security of the United States. For 75 years, a strong base of aerospace technology research and development has provided enormous contributions to this system—contributions that have fostered the economic growth of the Nation and provided unprecedented mobility for U.S. citizens. In the past 30 years, aircraft noise was reduced by a factor of 10, fuel consumption was cut in half, and a notably low accident rate was maintained despite a threefold increase in flight operations. Although major technical advances have made the Nation's air and space transportation system the largest and best of its kind, the future holds critical challenges to its continued growth and performance.

Because the U.S. air and space transportation system serves both critical national security needs and the public good, ensuring the continued health and preeminence of that system is a key issue for the future of this Nation. NASA is the Nation's leading government agency for providing technological leadership and advancements for the aerospace industry and the traveling public.

In addition to its role in advancing air and space transportation, the Enterprise has a role in developing basic technology for a broad range of space applications, such as aerospace communications, power and propulsion systems, microdevices and instruments, information technology, nanotechnology, and biotechnology. These advances will expand our knowledge of the Earth and the universe through space missions.

Historically, transportation and communication have always been integrally linked. Today, tourism, e-commerce, and other factors such as economic growth and changing demographics are fueling demand for access to high-speed, highly distributed transportation systems.

For the U.S. commercial space launch industry, however, 1998 and 1999 were disappointing years, due to a string of

failures that restricted the launch rate and slowed the development of new vehicles. A number of entrepreneurs have announced plans for commercial launch vehicles in hopes of capturing some of the strong market for launch services of commercial satellites.

As the 21st century begins, NASA seeks to forge a "Highway to Space" that will enable citizens to travel, work, and live in space as a matter of routine. Because of NASA research, it will be possible for the private sector to make space transportation economical. This, in turn, will create enormous opportunities for commercial endeavors, new services, scientific and medical research, and other uses not yet imagined.

The space industry is changing dramatically as it transitions from government-driven needs to market-driven growth. However, this industry is less mature than the aviation industry and the technologies are more complex.

Technology has a significant role in meeting these challenges. Advanced physics-based modeling, simulation, new materials and structural concepts, and other technologies will enable quieter, more efficient aircraft and more robust and affordable spacecraft. As the space transportation system grows, it will be, in the future, linked increasingly with the aviation system.

The main challenges for the space industry continue to be reliability and cost. New technologies that enable simplified space transportation operations, robust design and operating margins, and near complete reuse of hardware have the potential to reduce costs dramatically. Safe, low-cost space transportation will make space commercially accessible for both passenger and cargo operations. Equally important are new propulsion technologies that will enable new in-space operations, such as economical travel between low Earth orbit and geo-stationary orbits, faster travel to other planets, and ultimately, the stars. It will also allow the continued expansion of human and robotic exploration throughout our solar system.

Biological and Physical Research

Space Shuttle flight has been synonymous with science research in biology, physics, chemistry, and engineering since the Shuttle program's inception. In the year 2000, NASA's Biological and Physical Research Enterprise began focusing its scientific research on biological sciences in preparation for full scientific utilization of the International Space Station in the coming decade. This focus adds cutting-edge interdisciplinary sciences of the 21st century to the space program, such as space genomics, biomolecular physics, macromolecular biotechnology, and nanotechnology.

Continual research on Earth and in space provides fascinating opportunities to improve life on Earth. For example, industry has planned to invest over \$6 million to develop a bone replacement ceramic-metal composite that is

highly porous, allowing blood vessels, nerves, and even bone to grow through and around it. By optimizing the pore size, distribution, and strength of a composite material, industry hopes to perfect materials for more durable bone replacements. Eventually research could lead to products that could dissolve into the body as natural bone cells grow into an implant.

In addition, conducting scientific research in space, where gravity is one-millionth that of Earth, allows researchers to observe properties of solids, liquids, and gases that could potentially change industrial practices and products in ways that are unimaginable today.

While perfecting research that will enable humans to exist off the planet, ground research and flight opportunities on the Space Shuttle and International Space Station will use the unique characteristics of space for research to improve most facets of life on Earth in the coming decade—your health, home, environment, transportation, and commerce.

Earth Science

NASA's Earth Science Enterprise (ESE) is dedicated to understanding the total Earth system and the effects of natural and human-induced changes on the global environment. NASA's commitment to share the benefits of Earth Science discoveries with the broad public is evidenced in the Enterprise's commitment to translate NASA-funded Earth Science and technology research results to the development of remote sensing applications for practical, everyday use.

NASA spearheaded efforts to share Earth Science discoveries and applications through a federation of Earth Science Information Partners (ESIPs). The federation is comprised of partners from government agencies, national laboratories, universities, nonprofit organizations, and commercial providers of data and information services. The partners work together to ensure that quality scientific data and information are made available to a wide community of scientists and non-scientists alike.

Under ESIP, NASA's Earth Science Enterprise partnered with the National Broadcasting Company (NBC) and General Electric Corporate Research & Development to utilize ESE data in operational weather forecasting. By integrating NASA's remotely sensed

data into daily weathercasts, NBC became the first television network to offer high-resolution imagery to the public on a routine basis. The public benefited by receiving better information and an increased awareness of the practicality of NASA's remote sensing applications.

Dave Jones, a meteorologist and President-CEO of StormCenter.com, LLC, first piloted the television weathercasts on NBC4 in Washington, D.C., on January 1, 2001. Through StormCenter.com, the partnership with NBC continues and allows each of the 13 NBC-owned and operated television stations to use advanced remote sensing imagery in their local newscasts.

"This capability translates into a much better product for viewers of local NBC newscasts in major markets nationwide," says Jones. "Utilizing more advanced visuals and graphics developed from high-tech satellites will engage the public to learn more about their environment and how their behavior affects our weather and climate. People really do want to understand what is happening with our planet and what they can do to make sure the Earth remains healthy for future generations. Providing this type of information on network news will allow for greater local awareness for communities and individuals to participate in this high-interest area."

StormCenter.com will be expanding its reach into other types of media by attracting media partners across the nation. These partners will use StormCenter.com content for newspapers, radio and television web sites, and wireless applications.

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Using NASA-gathered imagery, StormWatch viewers receive a side-by-side comparison of the Pamlico River at various points during the summer of 1999.

NASA HEADQUARTERS

(Continued)

This partnership serves as a successful model for translating NASA's Earth science into new and innovative information products that extend the social and economic benefits of NASA's Earth science research to a broad user community.

Human Exploration and Development of Space

NASA's Human Exploration and Development of Space (HEDS) Enterprise includes the International Space Station (ISS), Space Shuttle, Space Communications, and Space Access offices. The mission of HEDS is to open the space frontier by exploring, using, and enabling space development, and to expand the human experience into the far reaches of the universe.

The ISS, a key HEDS program, is capable of performing unique, long duration, space-based research in a variety of disciplines, while providing a unique platform for observations of the Earth, Sun, and other astronomical objects. The ISS is crucial to fulfilling NASA's mission to explore, use, and enable the development of space for human enterprise.

The past year has seen a tremendous surge of program activity, as the ISS grew from the Unity and Zarya modules to become a permanently inhabited and premier research laboratory in space. Since May 2000, NASA and its partners at the Russian Aviation and Space Agency executed 11 successful launches and dockings to the space station. Among the elements now on orbit are the Zvezda Service Module, Russia's keystone contribution, and the U.S. laboratory, Destiny.

Permanent human habitation began aboard the space station in November 2000. The ISS commercialization efforts include opportunities for investors to develop new capabilities for the station through submission of Entrepreneurial Offers. These are private investment proposals to NASA.

In addition, HEDS Technology and Commercialization Initiative advances several strategic goals and objectives that enable the commercial development of space. Activities include 1) systems analysis, concepts and modeling, 2) enabling research and technology, and 3) technology flight demonstrations. In fiscal year 2001, a competitive cooperative agreement notice was released to solicit proposals, and it is anticipated that initial awards will be announced as early as May 2001.

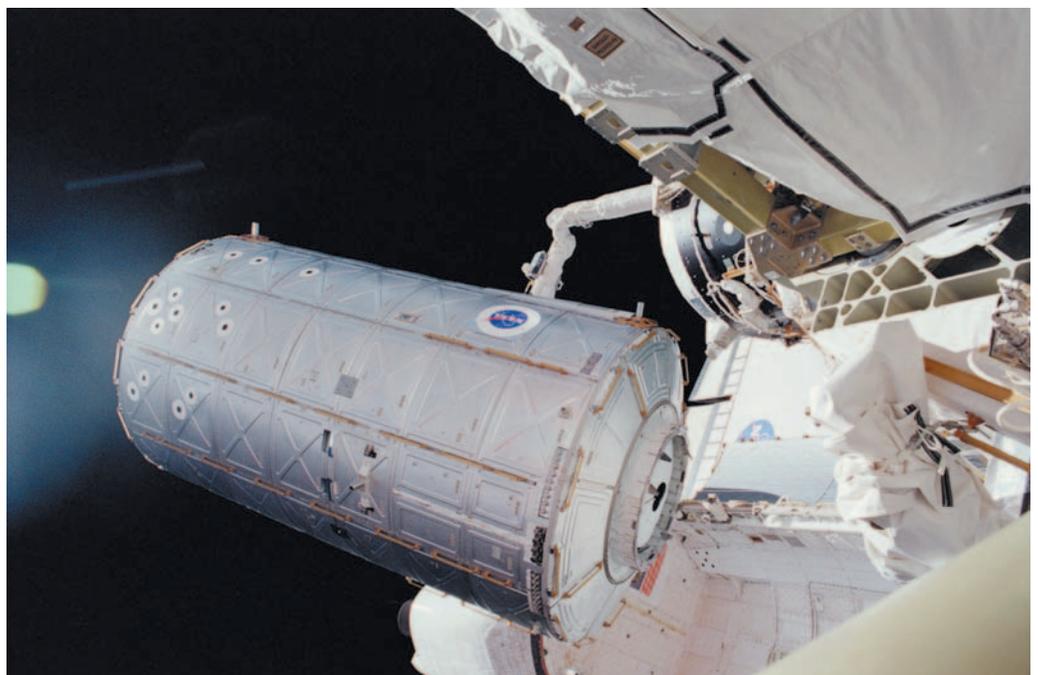
The HEDS Enterprise also provides support for Space Shuttle payload buildup, test and checkout, integration, servicing, transportation and installation, as well as support for NASA missions launched on Expendable Launch Vehicles. HEDS also provides command, tracking, and telemetry data services between ground facilities and flight mission vehicles.

Space Science

The Space Science Enterprise is poised to enter the new millennium with a solid foundation upon which to build, as well as expand new capabilities to explore the farthest reaches of the universe and the solar system.

The Office of Space Science is looking for answers to questions such as: How did the universe, galaxies, stars, and planets form and evolve? How can exploration of the universe and our solar system revolutionize our understanding of physics, chemistry, and biology? Are there Earth-like planets beyond our solar system? Does life in any form, however simple or complex, carbon-based or other, exist elsewhere than on planet Earth?

Long-term goals of the Space Science Enterprise are to establish a virtual presence throughout the solar system and



In the grasp of the Shuttle's remote manipulator system robot arm, the Destiny laboratory was moved from the cargo bay of the Space Shuttle and attached to the International Space Station in February 2001. Destiny is the first of six international research laboratories.



Backdropped against the blue and white Earth and sporting a readily visible new addition in the form of the Canadarm2 or Space Station robotic arm, the International Space Station was photographed following separation from the Space Shuttle Endeavour.

probe deeper into the mysteries of the universe and life on Earth and beyond; to pursue space science programs that enable future human exploration beyond low Earth orbit; to develop and utilize revolutionary technologies for missions impossible in prior decades; and to contribute measurably to achieving the science, mathematics, and technology education goals of our nation.

To better study solar variability and understand its effects on humanity, NASA is starting a program called "Living With A Star," a set of missions and enhancements to current programs which will eventually encompass a number of

spacecraft and systems. "Living With A Star" will also pursue partnerships with other Federal agencies that are concerned with the effects of the Sun on the Earth. The goal is to provide an exciting new capability for understanding, and ultimately predicting "solar weather," which affects Earth.

The "Living with A Star" initiative will: 1) observe the entire Sun simultaneously using a few well-positioned spacecraft, including Solar Sentinel spacecraft, which will observe the side of the Sun away from the Earth, the first spacecraft capable of doing so; 2) track solar storm regions both above and below the solar surface for the first time, using an advanced spacecraft called the Solar Dynamic Observatory (SDO), which will also probe the interior of the Sun to help us understand the source of solar variability; 3) use the Sentinels, the SDO, and dozens of low cost microsattellites in critical regions around Earth to track Earth-directed solar mass ejections and their impact on the Earth's space environment; 4) use one of the most intriguing and far-reaching technologies currently under development, the large Solar sails, which will use the energy in sunlight to reach their stationary positions above the poles of the Earth and in polar orbit about the Sun; 5) miniaturize spacecraft and instruments in order to orbit numerous "space buoys" similar to ocean buoys, which will probe the Earth's upper atmosphere and space environment, and their response to solar storms.

NASA's Space Science Enterprise has experienced a number of tremendous successes. Some of the top highlights include Hubble scientists' measurements of how fast the universe is expanding, and astronomers' searches of the galaxy that led to the discovery of six new planets, bringing the total to 28 of known planets outside the solar system. The Mars Global Surveyor provided the first global 3-D map of Mars, which includes an impact basin deep enough to swallow Mount Everest. NASA's Compton Gamma Ray Observatory alerted astronomers of one of the most powerful explosions in the universe, enabling them to take the first optical images of the gamma ray burst explosion that occurred on January 23, 1999. The deployment of the Chandra X-ray Observatory into orbit provided a stunning image of the Crab Nebula. Several NASA spacecraft observed that the solar wind and auroral display at the North Pole virtually disappeared from May 10-12, 1999, the most drastic and longest-lasting decrease ever seen. The crew of the Space Shuttle Discovery replaced Hubble's gyros, made numerous improvements to battery power and guidance systems, and replaced the outer layers of thermal protection, making it better than new. ❖

AMES RESEARCH CENTER

NASA's predecessor, the National Advisory Committee for Aeronautics (NACA), established Ames Research Center over 60 years ago on December 20, 1939, as an aircraft research laboratory. Located on 2,000 acres, Ames sits in the heart of California's Silicon Valley in the San Francisco-San José Bay area. With world-renowned researchers, scientists, and an array of state-of-the-art facilities, Ames is responsible for the performance of a tightly coupled, multidisciplinary research base directed toward NASA's missions. Ames achieves scientific and technical excellence through its first-rate management team, critical mass of top-tier scientists, "excellence-driven" research environment, and collaboration with distinguished academic, corporate, and non-profit organizations.

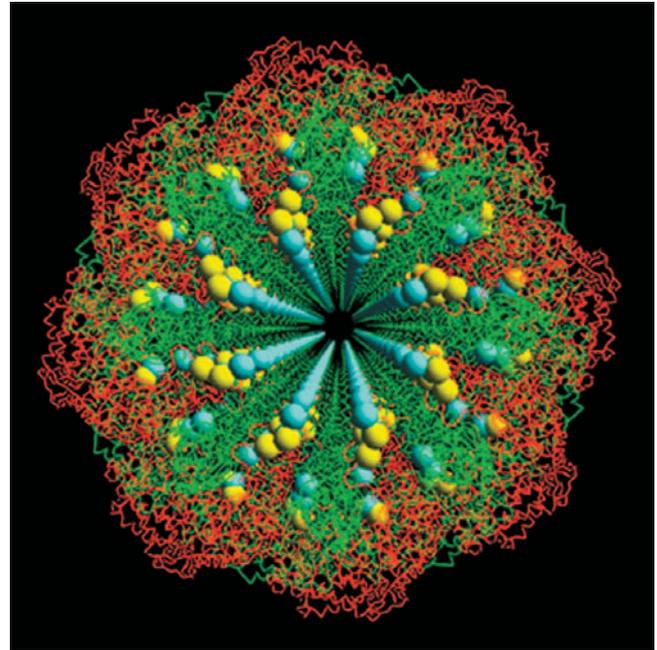
Ames' budget for fiscal year 2001 is \$720 million. The Center has nearly 1,500 civil servants and over 3,000 on-site contractors in its work force. Ames is NASA's Center of Excellence for information technology and has additional core technology competencies in biotechnology and nanotechnology. Ames pursues NASA missions in aerospace operations systems and astrobiology. The Center has core scientific competencies in fundamental space biology and all disciplines of the Agency's multifaceted astrobiology thrust. The Center also performs key work in support of NASA missions in computational systems, aviation capacity, air traffic management, thermal protection systems, and a host of other areas.

The grand challenge of NASA's mission to explore space and study the origin and role of life in the universe is driving the Agency's focus on the technology triad of information technology, biotechnology, and nanotechnology. These arenas are widely accepted as the most likely sources of breakthrough technologies in the next decade. Ames is unique within NASA in its ability to provide the integrated research environment required to exploit the crossover potential, as well as the individual fields of the technology triad, to meet the Agency's mission needs.

Fundamental research and technology development is performed in the areas of nano-scale assembly, computational nanotechnology, nano-scale computing and sensing elements, and nano-scale architecture, and systems integration. The Center is pursuing the development of protein-based nanotubes, a crossover technology potentially capable of self-organization and replication.

Ames conducts research and develops technologies biologically-inspired and employed within basic biological processes, including biomimetics, bioinformatics, and space genomic/protonomic systems (analytical and sensing systems that enable in situ character studies of genetic materials and proteins in space and extraterrestrial environments).

The Center specializes in the research and development of methods, technologies, and processes in autonomous reasoning, human-centered computing, and intelligent data under-



Ames Research Center conducts innovative research regarding nano-scale assembly, computational nanotechnology, nano-scale computing and sensing elements, and nano-scale architecture and systems integration. The Center is pursuing the development of protein-based nanotubes, potentially capable of self-organization and replication.

standing for broad application to NASA's mission requirements. Ames is NASA's pathfinder in single-system image parallel computers, quantum computing, distributed heterogeneous computing, revolutionary computing, and high performance networks.

As the NASA lead for astrobiology, the Center studies the origin, evolution, distribution, and destiny of life in the universe. Astrobiology represents the synthesis of disciplines from astronomy to zoology, from ecology to molecular biology, and from geology to genomics. Ames hosts the NASA Astrobiology Institute, which conducts and integrates groundbreaking astrobiology science with the assistance of its 11 founding member institutions and numerous affiliated consortiums.

Life in the unique environments of space, including microgravity, high radiation and temperature extremes, and planetary protection, are key themes of Ames' space biology science base. The convergence of space biology with the technology triad provides fundamental enabling knowledge for human exploration. Ames exploits the potential knowledge transfer to Earth-based health issues through the establishment of partnerships with the medical community, including the National Cancer Institute.

The complexity of and performance demands on aerospace operational environments are increasing significantly. The national response to this rise in requirements is the increased application of automation and autonomous reasoning methodologies. Ames is at the forefront of the development of

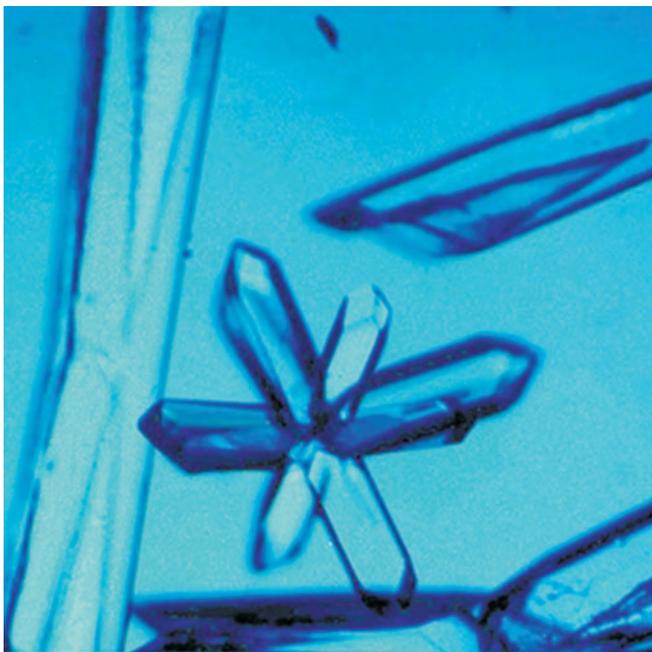
automated aerospace operation for applications from decision tools for air traffic management deployed by the Federal Aviation Administration (FAA), to autonomous reasoning control of spacecraft in unpredictable environments.

Ames works with the FAA and the aircraft operations industry to meet the nation's expanding air transportation demands by developing and demonstrating pioneering concepts and technologies to improve safety, increase efficiency, and enhance environmental protection. In particular, Ames is striving to provide the research and technology products needed to achieve the President's challenge to improve aviation safety.

The Ames base program develops advanced research and technology to enable revolutionary advances in understanding concepts, methods, and procedures of aviation operation systems.

Ames' Future Flight Central (FFC) is the world's premier technical design studio for 21st century airport operations and planning. The facility is able to replicate a 360-degree high-fidelity visual simulation of any airport in the world. FFC can provide a functionally accurate, physical and software replication of any airport's current or future tower or operations center. Airport research and operations staff can work with NASA experts using the FFC to: plan new runway configurations, test new ground traffic and tower communication procedures, and validate air traffic planning simulations based on airport and airline planning tools.

The Surface Movement Advisor (SMA) project is a joint FAA and NASA undertaking to help current airport facilities operate more efficiently. The SMA system integrates airline schedules, gate information, flight plans, radar feeds, and runway configuration (departure split and landing direction).



This integrated information is then re-transmitted over the network and shared between the key players at an airport.

The Center also plays a major role in efforts to enable major increases in the capacity and productivity of the national airspace system through the development of revolutionary operations systems and vehicle concepts. Terminal Area Productivity will increase the capacity of existing major U.S. airports that experience delays in non-visual or instrument meteorological conditions. This Ames project will increase capacity and reduce delays by decreasing spacing requirements between aircraft approaching an airport and by expediting ground operations while meeting FAA safety guidelines.

Ames' scientists conduct advanced research in a unique flight simulation complex. Ames provides researchers with exceptional tools to explore, define, and solve issues in both aircraft and spacecraft design. Ames' vertical motion simulator offers fast and cost-effective solutions using real-time, piloted simulations, realistic sensory cues, and the greatest motion range of any flight simulator in the world.

Ames is the lead center for Aviation Systems Technology Advanced Research (AvSTAR). AvSTAR will accelerate the development of selected NASA air traffic management technologies that have been identified by industry and the FAA to improve the capacity and reliability of the current system. It will also provide the foundational research and long-term exploratory investigations for the air transportation system of the future.

Mission success starts with safety, and Ames is leading the NASA Design for Safety (DFS) development effort with a vision of achieving ultra-high levels of safety and mission success through the infusion of advanced technologies. To that end, DFS will develop advanced technology methods for: reasoning, model-based, risk-advised system engineering to provide continuous, systematic, quantified assessment of risk and high-assurance systems; continuous lifecycle knowledge capture, evaluation, and utilization; and highly adaptive, resilient systems to provide intelligent responses to both known and unanticipated hazards.

The DFS project will ensure that the techniques developed are applied throughout the lifecycle of NASA systems and programs. Further, it will seek to tailor, mature, and infuse the technologies developed into all NASA enterprise missions.

DFS will incorporate a number of elements and thrusts, including intelligent system risk management, model-based reasoning and architecture, knowledge engineering and development of resilient, self-monitoring systems based on advanced sensor research, and artificial intelligence. ❖

Ames Research Center performs research and development of biologically-inspired technologies employed within basic biological processes. These include biomimetics, bioinformatics, and space genomic/protonomic systems (analytical and sensing systems that enable in situ studies of the character of genetic materials and proteins found within space environments).

Dryden Flight Research Center

NASA's Dryden Flight Research Center is a national gateway to the skies—and beyond. Dryden's responsibility for flight research includes everything from airplanes that use solar power to fly higher than ever before, to a future "space lifeboat" that could safely return crews to Earth in an emergency.

Present ongoing projects at Dryden, located in California's Mojave Desert include: aerospace research that bridges speeds ranging from 25 miles an hour to 10 times the speed of sound; using computers and satellite positioning technology to guide aircraft in bird-like tight formations for greater efficiency and better, safer use of crowded airspace; and twisting a high-speed jet aircraft's wings to give it better maneuverability.

Just as formations of migratory birds use their relative positions to take advantage of reduced drag, thereby increasing their range, so too can aircraft performance benefit from specific tight formation flight. One of Dryden's many projects focuses on Autonomous Formation Flight (AFF), which looks for ways to apply this advantage to aircraft.

With that premise, Dryden engineers, in cooperation with NASA's Ames Research Center, the Boeing Company, and the University of California (UCLA), are collaborating on a sophisticated blend of global positioning system (GPS) technology and inertial navigation gear that promises to give measurements of the relative positions of aircraft in formation with accuracies within six inches. The Dryden-led team believes this accuracy can be used to autonomously guide aircraft and keep them in tight formations, allowing them to reap the benefits of vortex energy caused by the lead aircraft.

Gerard Schkolnik, AFF project manager, explains: "The goal of the AFF project is to demonstrate a sustained ten percent fuel savings of the trailing aircraft during cruise flight." Air cargo companies are already looking on with

interest to see if they might one day achieve such economies by dispatching their aircraft in formations using follow-on evolutions of the AFF suite being tested in the skies over Dryden. Another benefit of a mature AFF technology could be the ability to safely handle higher volumes of air traffic by treating formations of aircraft as individual units. And in space, AFF technology might enable a swarm of small satellites to congregate, creating a virtual large satellite for a specific mission.

In cooperation with the U.S. Air Force Research Laboratory and Boeing's Phantom Works, Dryden is researching the use of lighter-weight flexible wings for improved maneuverability of high-performance military aircraft in the Active Aeroelastic Wing (AAW) project.

The AAW project goal is to demonstrate improved aircraft roll control through aerodynamically induced wing twist on a full-scale aircraft. The test aircraft—an F/A-18A obtained from the U.S. Navy—has been modified with additional actuators, a split leading edge flap, and thinner wing skins that will allow the outer wing panels to twist up to five degrees. The traditional wing control surfaces—trailing edge ailerons and the outboard leading edge flaps—are used to provide the aerodynamic force needed to twist or "warp" the wing. Project engineers hope to obtain equivalent roll performance of the production F/A-18 at transonic and supersonic speeds without using the stabilators and with smaller control surface deflections. Removing the stabilators' roll control function will eliminate the "corkscrew" effect common to the F/A-18, which limits the number of rolls performed.

AAW research could also enable thinner, higher aspect ratio wings on future aircraft. This could result in reduced aerodynamic drag, allowing for greater range or payload and improved fuel efficiency. Data obtained from flight tests at

Dryden will provide benchmark design criteria as guidance for future aircraft designs.

AAW technicians have completed installation and checkout of research instrumentation and avionics wiring on the modified F/A-18, along with a full-up systems checkout of the flight control software developed by Boeing's Phantom Works in the AAW flight control computer.

Structural loads testing in Dryden's Flight Loads Laboratory began in mid-March 2001. Wing twist testing occurred in early April, followed by more extensive loads calibration testing. The structural loads testing on the



The X-38 "lifeboat" flies free from its B-52 mothership.

F/A-18's modified wings will take almost six months, followed by painting of the aircraft, a traditional rollout, and extensive systems tests and simulation before flights begin. According to Dryden AAW project manager Denis Bessette, the loads applied to the aircraft will be up to 70 percent of the design limit load, with load distribution over the wings a particularly critical item.

The two-phase AAW flight tests will begin with parameter identification flights in late 2001. Data obtained from the first phase flight series will be used to refine the AAW flight control laws, and after further software development, the second phase of research flights should take place in 2003.

The solar-powered Helios Prototype was readied for a summertime 2001 attempt at a never-before-achieved milestone in the annals of flight—sustaining horizontal flight at 100,000 feet above the Earth. Technicians for AeroVironment, Inc., the giant flying wing's manufacturer, completed installation of high-efficiency solar cell arrays on all six of the Helios Prototype's wing sections early this year. They also completed upgrades to the ground control station, the tracking antennas, and updated operational procedures.

The Helios Prototype was shipped to Hawaii in the spring of 2001, where AeroVironment engineers and technicians began reassembly and checkout of the craft at the Navy's Pacific Missile Range Facility. The first flight under solar power, covering functional checkout and flight envelope expansion, was targeted for early August.

The 247-foot-span ultralight flying wing, whose development is being funded and managed under NASA's Environmental Research Aircraft and Sensor Technology (ERAST) project, flew six low-altitude airworthiness validation flights on battery power at Dryden in the fall of 1999.

The 100,000-foot altitude flight is one of two major flight milestones set for the craft by NASA, the other being a four-day non-stop endurance demonstration flight above 50,000 feet planned for 2003. Development of a regenerative hydrogen-oxygen energy storage system which would make the multi-day continuous flight possible is progressing at AeroVironment. The system uses excess power generated by the solar arrays during the daytime to run an electrolyzer that separates water into its component parts, hydrogen and oxygen, which are then stored under pressure in specially-designed tanks. At night, the hydrogen and oxygen are recombined by the fuel cells, with electricity produced as a by-product providing power to Helios' motors.

Two subcontractors, Giner and Lynntech, have developed prototype "short-stack" fuel cells and electrolyzers, which have undergone rigorous testing. Lynntech is building full-size units that will be installed in a prototype energy storage system at AeroVironment. The completed system will then be



Two F/A-18B aircraft fly in tight formation using the autonomous flight functions developed at Dryden.

subject to both sea level and high-altitude testing in an altitude chamber. NASA's Glenn Research Center will conduct further testing of Giner's intermediate and full-size fuel cell and electrolyzer components. Additionally, another subcontractor, Kaiser Compositex, is developing and testing composite pressure tanks for storing the hydrogen and oxygen.

The X-38 is a possible prototype "lifeboat," designed to carry up to seven passengers home from orbit in an evacuation or medical emergency. The project combines proven technology—the lifting body essential for aerodynamic lift, designed and tested in the 1960s and 1970s—to some of the most cutting-edge aerospace technology available today, such as the most powerful electric motors ever used to drive a spacecraft's aerodynamic control surfaces. The X-38 has tested the largest parafoil parachute in history, with a span of 143 feet. Data from the aerodynamic studies of the lifting body contributed to the design and operational profile of the Space Shuttles and is reemerging to help develop a crew return vehicle.

On loan from the Air Force, the X-40A is an 85 percent scale version of NASA's X-37, a flight technology demonstrator testing future launch technologies in orbit and reentry from the harsh environment of space through Earth's atmosphere. The X-40A is performing a series of flights and autonomous landings as part of the X-37 program, intending to reduce the risk of flight testing the X-37, not from 15,000 feet like the X-40A, but from low Earth orbit. With such a wide range of aircraft and aerospace research advancements, Dryden Flight Research Center will continue to be a leading developer of innovative technologies with aviation applications. ❖

GLENN RESEARCH CENTER

Glenn Research Center, located on the outskirts of Cleveland, Ohio, is dedicated to creating technologies that will propel us into the new millennium. Perhaps it is this, as well as a dedication to innovation and excellence, that has positioned Glenn a NASA's Center of Excellence in turbomachinery. This attitude and sense of pride is exemplified in the ongoing, cutting-edge activities being conducted at the Center.

The Glenn-managed Ultra-Efficient Engine Technology (UEET) Program includes participation from Ames Research Center, Langley Research Center, and Goddard Space Flight Center, as well as five engine and two airplane manufacturers. The six-year, nearly \$300 million program's goal is to demonstrate new engine technologies that reduce aircraft emissions, reduce noise, and increase performance. Much of the success will come from improved materials, new propulsion controls, advanced combustors, and turbomachinery concepts. This technology is in the works, with the integration of technologies in a working engine, while integrating the engine into an aircraft airframe is still to come. The UEET Program will enable future-generation aircraft to travel a wide range of flight speeds, farther, cleaner, and safer than ever before.

In 2000, Glenn completed the hardware development of its Physics of Colloids in Space experiment. The experiment is one of a series of Glenn-managed microgravity science

experiments scheduled to be conducted on the International Space Station (ISS). A colloid consists of fine, insoluble particles suspended in a fluid. Everyday examples of colloids are paint, milk, salad dressings, and aerosols. The Physics of Colloids in Space experiment will allow scientists to study the basic physical properties of colloids without the influence of gravity. The long-term goal of this investigation is to learn how to steer the growth of colloids to create new materials and structures.

Glenn is the co-lead for ISS's electrical power system with Johnson Space Center. Glenn is responsible for the technical design and development of all the individual pieces of the electrical power system on ISS, and is the proud major provider of the electrical power equipment for the ISS. Glenn technologies were carried to the ISS aboard two Shuttle missions in 2000. STS-92, launched in October 2000, carried the Integrated Truss Structure Z1, which includes four pieces of the ISS's electrical power equipment, all of which Glenn developed: the plasma contactor, a high-tech grounding rod for ISS; converter units, which provide grounding and voltage regulation; the remote power control modules, which are multichannel high-power circuit breakers for both switching and protection in case of a short circuit during ISS construction activities; and circuit isolation devices, which are manually-activated switches that provide manual shut-off of high power.



Glenn Research Center's sapphire refractive secondary concentrator will be used with primary collector-concentrators to focus solar energy. The solar energy can be used in power conversion systems, thermal propulsion systems, and solar furnaces.

On STS-97 station assembly flight 4A in November 2000, the first U.S. photovoltaic (PV) module was carried to the ISS and installed. The module supplies the ISS with solar power via solar arrays, batteries, and other power system electronics. Glenn had a significant role in the design and development of the PV module and managed the hardware development of the flight hardware. Also installed on that mission were two radiators, which remove waste heat from ISS. One of these radiator panels was tested in the Space Power Facility, the world's largest space environment simulation chamber at Glenn's Plum Brook Station in Sandusky, Ohio.

Common to many of the space applications that use solar thermal energy—such as electric power conversion, thermal propulsion, and furnaces—is a need for highly efficient, solar concentration systems. An effort is underway at Glenn to develop a refractive secondary concentrator, which uses refraction and total internal reflection to efficiently concentrate and direct solar energy. When used in combination with advanced lightweight primary concentrators, the refractive secondary concentrator will produce very high system concentration ratios (10,000 to 1) and, of more practical interest, very high temperatures (>2000 °K).

The innovative refractive secondary concentrator has significant advantages over all other types of secondary concentrators. It is very efficient, requires no active cooling, relaxes the pointing and tracking requirements of the primary concentrator, and enables very high system concentration

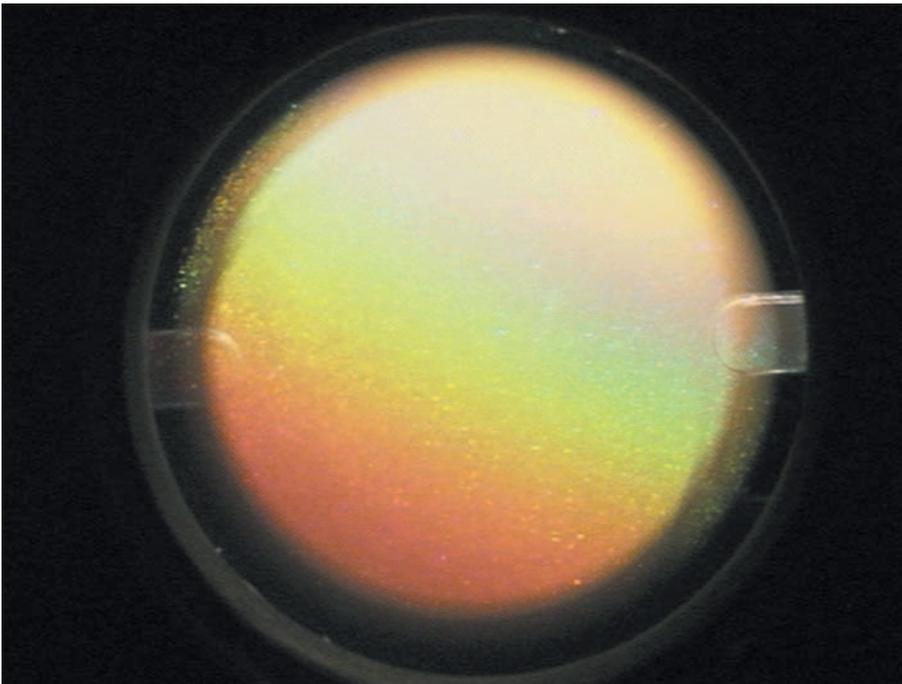
ratios. This technology can be used in any system that requires the conversion of solar energy to heat, for example, materials research furnaces on ISS and thermal propulsion systems.

Continuing in its heritage of innovation, Glenn researchers have developed a new alloy for use in regeneratively cooled rocket engines. The GRCop-84 alloy has an excellent combination of conductivity, thermal expansion, strength, creep resistance, ductility, and low-cycle fatigue life. Its use is expected to enable significant gains in engine performance and reliability. The ultimate test was to actually use the new alloy as a liner and test it in a rocket engine. Two 6-inch-long liners with inner diameters of approximately 2 inches were fabricated at Marshall using a vacuum plasma spraying technique, and then tested at Glenn. Twenty-seven hot fire tests were conducted, after which the liners showed no signs of degradation.

As part of NASA's Aviation Safety Program goals to reduce aviation accidents due to icing, Glenn is leading a flight simulator development activity to improve pilot training for adverse flying characteristics due to icing. Flight simulators that include the aerodynamic effects of icing will give pilots realistic exposure to the effects of icing-induced hazards, such as ice-contaminated roll upset, tailplane stall, or other loss-of-control events that may result from ice on the airframe.

In order to achieve a high fidelity flight simulation, wind tunnel tests were conducted on a 6.5-percent-scale model of a Twin Otter aircraft. These tests resulted in databases containing aerodynamic forces and moments, as functions of angle of attack; sideslip; control surface deflections; forced oscillations in the pitch, roll, and yaw axes; and various rotational speeds. Some wing and tail surface pressure data were also recorded. The databases are the foundation for a PC-based Icing Flight Simulator delivered to Glenn in fiscal year 2001.

The continued activities at Glenn make the Center a shining example of the vast array of NASA's benefits. Work conducted at Glenn Research Center helps to open windows to new worlds of opportunity both in space and on Earth. ❖



The Physics of Colloids in Space hardware is now flying on the ISS and producing pictures like the one above of the colloid with polymers experiment. Scientists varied the amount of polymer in each mixture to cause the suspension to act like fluid, glass, crystals, or gels.

GODDARD SPACE FLIGHT CENTER

Goddard Space Flight Center, located in Greenbelt, Maryland, is dedicated to furthering our knowledge of the Earth and its environment, the solar system, and the universe, through space observations. By developing new technologies to advance this mission, the Center strives to expand our understanding of our planet and beyond.

To support NASA's Space Science Enterprise, Goddard leads missions in space-based physics and astronomy that foster research programs through a broad variety of flight opportunities. The Center also promotes the development of advanced technology designed to enhance scientific capabilities at an affordable cost. Goddard space scientists seek answers about the composition and variability of stellar objects like black holes and exploding stars, and how the universe formed and evolved. The Center also contributes to the quest to learn how planetary systems are born and evolve. Goddard missions help researchers study the nature of the Sun's interaction with its surroundings and Earth, and determine the physical properties of the planets and interplanetary space.

NASA's Hubble Space Telescope is managed by and operated from Goddard Space Flight Center. In its first 10 years, the 12.5-ton Earth-orbiting observatory has studied 13,670 celestial objects, made 271,000 individual observations, and returned 3.5 terabytes of scientific data. Hubble's scientific hall of fame includes the current deepest view of the universe in visible light; images of the majestic birth of stars in spectacular stellar clouds; observations of extraordinary arcs, shells, and ribbons of glowing gas sculpted by the deaths of stars much like our Sun; unique records of mega-megaton blasts produced by comet fragments falling into the cloud tops of Jupiter; a map of the surface of distant Pluto; and evidence that galaxies may have been built up from smaller objects early in the history of the universe.

Goddard-operated space observatories continue to make discoveries about the Sun and advance our ability to predict the effects of solar storms on the Earth. Among the important observatory contributors are the Solar and Heliospheric Observatory (SOHO), a cooperative project being carried out by the European Space Agency and NASA; and Goddard's WIND and Transition Region and Coronal Explorer (TRACE) satellites.

From the local weather to the larger environment, our home planet changes every day. These changes affect our quality of life, our health, and our economy. Since the first days of observing Earth from space in the early 1960s, NASA and Goddard Space Flight Center have been pioneers in helping scientists, policymakers, and the general public gain a better understanding of how and why these changes occur. This research, and the new technology that pushes it forward, has matured to a point where we can begin to understand the details of how Earth's land, atmosphere, oceans, ice, and life interact with each other, both in local communities and across vast regions of the globe.

Goddard scientists and engineers contribute daily to NASA's Earth Science Enterprise, which consists of research studies, satellites and aircraft missions, and advanced computer networks



Fountains of multimillion-degree, electrified gas in the Sun's atmosphere revealed the location where the solar atmosphere is heated to temperatures 300 times greater than the Sun's visible surface. This was discovered while observing the gas fountains with NASA's Transition Region and Coronal Explorer (TRACE) spacecraft.

that transmit data and resulting information to a variety of users across the world.

A new generation of Earth science—one that studies the Earth's land, oceans, air, ice, and life as a total global system—began with a picture perfect launch of the Terra spacecraft from Vandenberg Air Force Base, California. Terra is the “flagship” for the Earth Observing System (EOS) series of satellites, a precedent-setting program in the emerging field of Earth System Science.

Goddard facilities, especially Wallops Flight Facility, Virginia, play a large role in many upcoming NASA projects. The High Energy Solar Spectroscopic Imager (HESSI) will explore the basic physics of particle acceleration and energy release in solar flares. The Thermosphere, Ionosphere, Mesosphere, Energetics, and Dynamics (TIMED) spacecraft will conduct a global study of a critical region in Earth's atmosphere. The mission will study the influences of the Sun and humans on the least explored and understood region of Earth's atmosphere. The QuikTOMS (Total Ozone Mapping Spectrometer) mission is designed to continue daily mapping of the global distribution of total column atmospheric ozone. Continuous observation of global ozone is critical in order to monitor the expected recovery of ozone as levels of chlorofluorocarbons decrease from their current maximum as a result of the Montreal Protocol limits.

The Big Bang theory is based on Albert Einstein's general theory of relativity and the 1929 discovery that the universe is expanding. This expansion implies the universe was denser and hotter in the distant past, and was able to produce the lightest chemical elements such as hydrogen and helium. The Big Bang

theory correctly predicts the relative amounts of these light elements. It also predicts that the universe should be bathed in a faint afterglow of radiation. The Cosmic Background Radiation appears as a glow that is remarkably uniform in all directions in the sky (“isotropic”), though the Cosmic Background Explorer (COBE) discovered very faint non-uniformities (“anisotropy”) in this glow in 1992. The Microwave Anisotropy Probe (MAP) satellite will produce a much more detailed picture of the early universe than COBE did. This information, which is recorded in the Cosmic Background Radiation, will allow astronomers to address these key cosmological questions.

Formerly called Earth Observing Spacecraft PM-1, Aqua will observe changes in the Earth’s radiation energy budget, together with measurements of changes in land/ocean surface and interactions with the atmosphere through the exchanges of energy, carbon, and water.

NASA’s Tracking and Data Relay Satellite-I (TDRS) is next in a series of communications satellites that will serve as the sole means of continuous, high-data-rate communications with the Space Shuttle, the International Space Station, and with dozens of scientific satellites in low-Earth orbit. TDRS-I is the second of three satellites that will help replenish NASA’s aging TDRS fleet.

The Ice, Cloud, and land Elevation Satellite, or ICESAT, will accurately measure the elevations of the Earth’s ice sheets, clouds, and land, as well as answer fundamental questions about the growth or shrinkage of the Earth’s polar ice sheets and the future rise or fall of global sea levels.

Goddard will continue to provide us with innovative research with some of their future initiatives. NASA’s Ultra Long Duration Balloon (ULDB) program is developing a revolutionary research balloon that could open a new era in scientific research. The full-scale ULDB is the largest single-cell, super-pressure (fully sealed), balloon ever flown. The Solar Radiation and Climate Experiment (SORCE) will continue the precise measurement of total solar irradiance.

The EOS Aura mission will help answer vital science questions. Is the Earth’s ozone layer recovering? Is air quality getting worse? How is Earth’s climate changing? The EOS Aura instruments have the unique and complementary abilities to provide data about the Earth’s atmosphere on a global scale. EOS Aura is the third in a series of Earth Observing Satellites to study atmospheric chemistry. Through its Earth Observing System efforts, Goddard is generating new remote sensing and spacecraft technologies to be used for a joint effort involving NASA, the National Oceanic and Atmospheric Administration (NOAA), and the Department of Defense. The National Polar-orbiting Operational Environmental Satellite System Preparatory Project (NPP) could potentially improve the capabilities of future polar-orbiting weather satellites to satisfy both civil and national security requirements for meteorological, oceanographic, climatic, and space environmental data. The Global Precipitation Mission (GPM) is a follow-up to the Tropical Rainfall Measuring Mission (TRMM). GPM is expected to lead to significant improvements in the forecasting of extratropical and tropical cyclones.

Goddard is leading the development of the Next Generation Space Telescope (NGST); a new type of observatory with capabilities that will surpass those currently available in existing ground-based or space telescopes. NGST will employ some of the most advanced optical systems ever placed into space to observe the first stars and galaxies in the universe.

The Solar Terrestrial Probe Program science objectives are directly tied to the quests in the Sun Earth Connection theme. They describe the system behavior of the magnetic variable star, our Sun, and its interaction with the entire solar system. Living with a Star (LWS) is a NASA initiative that addresses the effects of solar variability on life and society, including human technology, humans-in-space, and terrestrial climate.

The Gamma-ray Large Area Space Telescope, or GLAST, is a future high-energy gamma-ray mission, which promises to be a significantly advanced tool for answering these questions and

others. Constellation-X is a team of powerful x-ray telescopes that will orbit closely to each other, like a constellation of tiny stars, and work in unison to simultaneously observe the same distant objects. The Laser Interferometer Space Antenna (LISA) consists of three spacecraft flying 5 million kilometers apart in the shape of an equilateral triangle, to observe gravitational waves from galactic and extra-galactic binary systems. Swift is a three-telescope space observatory for studying gamma ray bursts. Swift will have the unique ability to rotate in orbit and point its gamma ray telescope, x-ray telescope, and ultraviolet/optical telescope at gamma ray bursts within minutes of the burst’s first appearance. ❖



An artist's concept of NASA's Ultra Long Duration Balloon (ULDB), a revolutionary new balloon capable of supporting scientific observations above 99 percent of the Earth's atmosphere for durations approaching 100 days.

JET PROPULSION LABORATORY

NASA returned to Mars on April 7 with the 2001 Mars Odyssey Orbiter, which roared into space onboard a Delta II rocket. The spacecraft carries a suite of scientific instruments designed to tell us what makes up the Martian surface and provide vital information about potential radiation hazards for future human explorers.

The 2001 Mars Odyssey mission is managed by the Jet Propulsion Laboratory (JPL)—NASA's lead center for robotic space exploration of the solar system. Nestled in the foothills of the San Gabriel Mountains above Pasadena, California, JPL also manages the worldwide Deep Space Network, which communicates with spacecraft and conducts scientific investigations from its complexes in California's Mojave Desert, Spain, and Australia.

Mid-year, JPL's director of 10 years, Dr. Edward Stone, announced his retirement, and Dr. Charles Elachi stepped into his position. Dr. Elachi's vision for the laboratory is to continue to do what has never been done before. JPL and NASA exist to envision and then create for the future.

Engineers sharing Dr. Elachi's vision are already creating the technologies of the future, today. Emergency vehicle warning systems, software to help farmers, networks of small sensors to help preserve the environment, wearable personal communications systems, robotic arms to assist with rehabilitation therapies, and lightning-speed computer chips are all in development. Some of these developments will bring about new discoveries and lead in the search for life on other planets,

while also providing breakthrough advances in communications, the environment, and even in saving lives.

On the local front, a city just 10 minutes from JPL is pilot testing a technology developed at JPL that will alert motorists of rapidly approaching emergency vehicles. The Emergency Vehicle Early Warning Safety System, developed with the assistance of the Technology Affiliates Program, equips emergency vehicles with transponders that communicate via microwave with receivers on large visual displays deployed on the mast arms above intersections. As an emergency vehicle approaches an intersection, a police officer or firefighter activates the transponder by pressing a switch on the dashboard, which automatically turns the traffic light to yellow, then red, for cross traffic. The visual display board uses icons to show the emergency vehicle approaching or leaving the intersection and the direction it is traveling.

Some of the people closest to the land, farmers, will be the first to benefit from a new global positioning technology developed to make NASA satellites more efficient and cost-effective. Farmers worldwide are putting the new system to the test through a partnership between JPL and NavCom, a division of the John Deere Company. NavCom licensed the technology from JPL and will be equipping tractors with receivers that will provide location information instantly—a vital tool for precision farming. The technology will allow farmers to navigate fields at night and when visibility is poor. More importantly, with soil sensors and other monitors, it will let them calculate and map out precisely where the field may need more water, fertilizer, or weed control, saving both time and money.

In Alaska, tiny sensor pods that resemble a child's toy form a sensor web that will help monitor the environment along the Alaskan pipeline. Alyeska, Inc., is currently working with JPL engineers to adapt their sensor web technology to monitor for oil leaks and preserve the natural habitat along the 800-mile (1288-kilometer) stretch of pipe. The pods communicate with each other, creating a virtual presence allowing large areas to be monitored continuously. Unlike remote operations, sensor webs are placed inside the environment, thus making them capable of sensitive, on-site measurements not possible from satellites. Last year, a prototype sensor web was tested and "planted" in gardens here

on Earth in preparation for missions to help monitor potential biological activity on planets.

In space, a wearable computer system with audio and video capability may someday be available to astronauts. The Wireless Augmented Reality Prototype (WARP) system will



This small device, called a pod, can be collected in groups together to form a new type of instrument called a Sensor Web. Each pod contains sensors that collect information from the surrounding environment and communication chips that transmit the data to other pods. Hopping from pod to pod, the data eventually arrives at a primary uplink where it can then be sent to an orbiting satellite for transmission back to Earth.

include a lightweight headpiece equipped with a miniature display, two-way real-time audio, and video capability. Finally, just what every astronaut needs, a wearable communicator unit. This system will allow crewmembers onboard the Space Shuttle and the International Space Station to communicate via video and audio transmission. The system will allow astronauts to get instant data from remote computers through an eyepiece, freeing their hands for other jobs. On Earth, the potential uses are endless. Imagine owning your own wearable personal communications system.

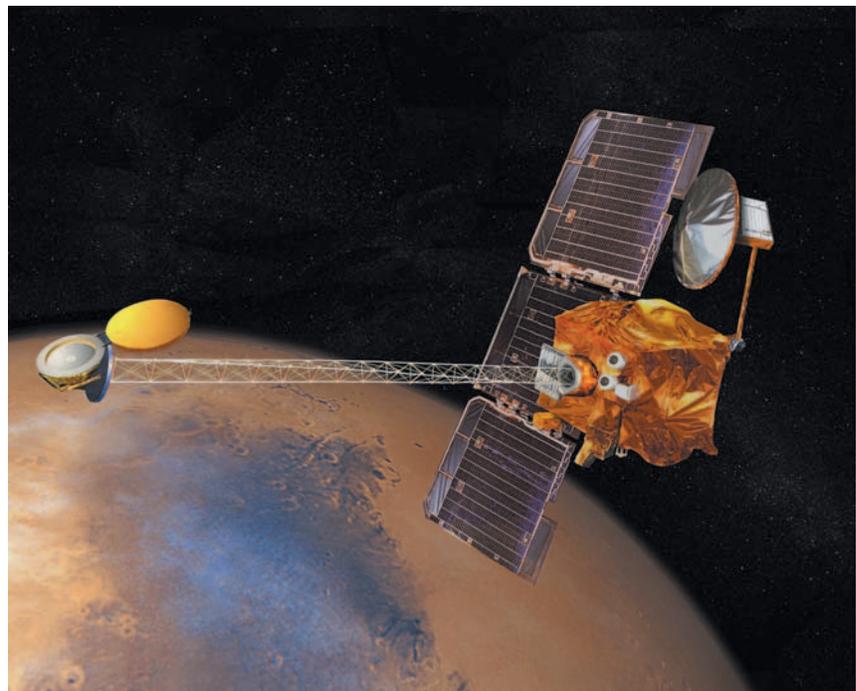
Earlier this year, JPL engineers and UCLA neurophysiologists teamed up to create a prototype, robot-like device that, when complete, will be used in a rehabilitation program that could potentially help wheelchair-bound people take their first steps. The device, still in the developmental phase, could be part of clinical trials in about three years. This same device could also be useful to astronauts in maintaining their ability to walk safely following prolonged periods in micro-gravity, such as extended missions on the International Space Station.

Defying traditional laws of physics, researchers may have found a way to blast through roadblocks on the highway to faster and smaller computers. Using modern quantum physics, researchers discovered that entangled pairs of light particles, called photons, can act as a single unit, but perform with twice the efficiency. This research could enable us to continue upgrading computers even after traditional manufacturing procedures have been exhausted.

New JPL technology developments hold promise for the coming year. A hopping robot on wheels, an artificial ear made of nanotubes, machines with human-like vision, and computers that think for themselves are just a few. Many of the technologies currently under research and development will have non-space related benefits. A hand-held device to measure a patient's eye to get a blood glucose reading; a laser that could perform a spinal tap; and a nicotine patch that measures calcium loss, which could be a useful tool in the prevention and mitigation of osteoporosis, are all being considered and may be possible in the years to come. ❖



The Wireless Augmented Reality Prototype, or WARP, is a personal communications system that will one day be used aboard the Space Shuttle and the International Space Station. The system not only allows for ease of communication between crewmembers, but also includes a wearable monitor that can be used to view documents.



The 2001 Mars Odyssey Orbiter was launched on April 7, 2001, arriving at Mars on October 20, 2001. The Orbiter carries three instruments: the Thermal Emission Imaging System (THEMIS), the Gamma Ray Spectrometer (GRS), and the Mars Radiation Environment Experiment (MARIE).

JOHNSON SPACE CENTER

Lyndon B. Johnson Space Center, established in 1961, is NASA's primary center for: design, development and testing of spacecraft and associated systems for human flight; selection and training of astronauts; planning and conducting of human space flight missions; and participation in medical and engineering experiments carried aboard space flights. Located just outside of Houston, Texas, the Johnson Space Center houses NASA Mission Control and is responsible for all on-orbit Space Shuttle operations.

The International Space Station (ISS) program involves 16 partner nations, 5 space agencies, as well as several languages and cultures. ISS operations require attention—all day, every day, all year long—from Mission Control Centers at Johnson, in Russia, and also from the flight control centers of our international partners. During the past year, the ISS has grown to 105 tons—about the mass of a Space Shuttle—and measures 240 feet wide. In August 2000, the new Johnson ISS flight control training facility opened. Named the “Red Flight Control Room,” it is used alone or in concert with the “Blue” shuttle flight control room and the “White” ISS control room, to train teams for future assignments. Near the year's end, on November 2, 2000, the Expedition One crew arrived in a Russian Soyuz capsule to begin a new era of continuous international cooperation in space.

Because Mission Control is a major provider of communications, Johnson Space Center personnel took pride when Softphone was installed aboard ISS. Softphone makes calling someone from orbit as easy as placing a call from any desk at Johnson. Donning a headset plugged into their laptops, the astronauts can reach anyone with a Johnson extension by dialing a five-digit number. Should an astronaut wish to place a local, long-distance, or international call, they simply dial nine first.

Softphone, though not critical to keeping the outpost in orbit, has already become a much-appreciated luxury. “We're really enjoying it and getting a lot of use out of the Softphone,” said Jim Voss in a voicemail message left for Brett Parrish, a Johnson engineer who worked on the project. “Thanks a lot... It's great to have it on board.”

For decades, the only way to communicate with astronauts was via radio, which had several limitations and relatively low signal quality. During those years, only the privileged Capsule Communicator (CAPCOM) sat in ready contact with astronauts. Limita-

tions existed as to where and when the astronauts could talk with their families over the old radio system. “In the past the CAPCOM was the one that talked to the astronauts and that was it—period,” Parrish said. “There were a few exceptions like flight surgeons, the President, or the family in a protected room. Now it's as comfortable as calling from the office, which is something we take for granted. But if you're in a tin can for six months, it's a long time to go without talking to your kids or your spouse.”

Softphone is a dream come true for many people. Johnson and Cisco Systems updated the phone system for communications operations on the ground like those in the Mission Control Center and between certain directorates. Cisco reengineered its Softphone program, because the design was not able to survive the NASA satellite network. The network sometimes requires signals to be bounced around for tens of thousands of miles before reaching their target—in this case the ISS. But, technical problems arose involving signal delay and the inability of the Shuttle and ISS communication systems to carry Internet Protocol “packets” of information. Cisco engineers revamped the program until it could handle all of the difficulties.

The Softphone, as well as other advanced communication capabilities, could not exist without the help of the Orbiter Communication Adapter (OCA). The little computer card and routing equipment have revolutionized data transfer, networking, and communications with vehicles in orbit. The OCA “tricks” old NASA satellite links into thinking they are a modern Ethernet network. It can be built into almost any communication system, and can serve as a relatively inexpensive basis for communication systems that used to cost millions.



Astronaut Jim Voss using the Softphone.

Another NASA project uses Johnson-developed technology to help in the search for “heavenly coffee.” The mission will use an unpowered aircraft, known as an “Uninhabited Aerial Vehicle” or “UAV,” to aid Hawaiian coffee growers by providing the growers with color images of their crops. From this information the growers will know, down to the day, the best time for harvesting the beans, thus bringing the best flavor to consumers.

Part of NASA’s UAV-based science demonstration program, these flights will show the ability of this aircraft to carry Earth-viewing scientific payloads in long-duration missions at altitudes exceeding the endurance of a pilot in a traditional aircraft.

The research team will use the Pathfinder-Plus aircraft; a high-flying solar-powered UAV built by AeroVironment, Inc., Monrovia, California. The craft will loiter over crop fields for long periods during the harvest season. After the flights, the Kauai Coffee Company plantation and a research team led by Clark University, Worcester, Massachusetts, will brief coffee industry officials on its findings.

The mission will allow NASA to provide the benefits of aerospace research to the multi-billion dollar coffee industry, while exhibiting capabilities that will benefit both scientific and commercial objectives well into the new millennium. “This mission is both scientifically exciting and commercially appealing. While validating this new breed of aircraft we’re also providing sound science with real-world, practical applications to the American people,” said Dr. Ghassem Asrar, Associate Administrator for Earth Sciences, NASA Headquarters, Washington, D.C.

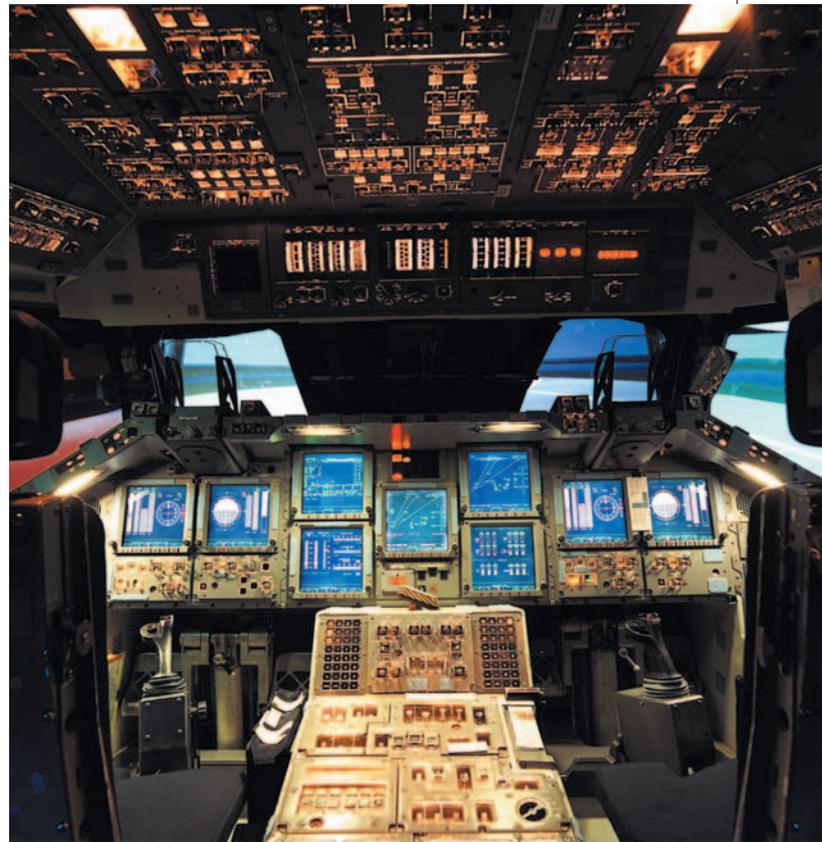
One particular Johnson triumph was the successful test flight of the X-38 prototype “lifeboat,” assembled at Johnson Space Center. The X-38 floated to a successful touchdown under the world’s largest parafoil at NASA’s Dryden Flight Research Center at Edwards Air Force Base, completing the seventh large-scale free flight test for the X-38 project.

The landing test began at an altitude of about 37,500 feet, when the X-38 was released from NASA’s B-52 aircraft. The test verified recent enhancements made to the X-38’s flight control software and also checked advances in the two-stage repositioning deployment of a drogue parachute that initially slows the vehicle from 600 miles an hour to about 60 miles an hour. The parachute also sets the stage for deployment of the 7,500-square-foot-parafoil wing. After a 13-minute gliding descent, the unmanned X-38 touched down at a speed of less than 40 miles an hour.

The X-38 Crew Return Vehicle program not only conducted the first successful test flight of the world’s largest parafoil, but also reached several other X-38 milestones in 2000. These include the testing aboard shuttles of the X-38 navigation system and the test flight of the X-38’s final body shape configuration.

Johnson made significant progress during 2000 in critical research and development areas. The new “glass cockpit” on Space Shuttle Atlantis gives pilots more information in a more capable display. Congress provided additional funding for key safety upgrades designed to reduce the risks during ascent, orbit and re-entry, and to increase the “situational awareness” of Shuttle crews during flight.

In the area of space operations, Johnson’s Space Operations Management Office worked to consolidate human spaceflight communications and data services. The launch of the latest Tracking and Data Relay Satellite marked a major achievement in this area. Through the ongoing efforts of Johnson researchers and engineers, the Center will continue to place a strong emphasis on the development and commercialization of key NASA assets and capabilities—helping U.S. businesses to “do business” in low Earth orbit as the commercial space industry rapidly expands. ❖



The Multifunction Electronic Display Subsystem (MEDS), otherwise known as the “glass cockpit,” is shown in the fixed base Space Shuttle mission simulator at Johnson Space Center’s Mission Simulation and Training Facility. MEDS is installed on the Space Shuttle Atlantis.

KENNEDY SPACE CENTER

Three, two, one, and we have liftoff...as the Space Shuttle heads for Earth orbit from the John F. Kennedy Space Center, America's premier spaceport. On April 19, 2001, Kennedy celebrated the 20th anniversary of the first Shuttle launch with the launch of STS-100 on Endeavour. During the past 20 years, the Shuttle has transported approximately three million pounds of cargo, and hundreds of astronauts have had the unique privilege of traveling aboard this unrivaled space vehicle. At the same time, more than 100 modifications have been made to make the Shuttle safer and more efficient and reliable, as well as to expand its capabilities. Shuttle upgrades include a "glass cockpit," composed of 11 new, full-color, flat-panel displays on the flight deck; a relocated airlock to prepare for International Space Station (ISS) assembly flights; an updated communications system; and better protection elements for the orbiter's cooling system.

Weather is very important to the Shuttle program. Because Florida is known as "the lightning capital of the U.S.," lightning detection systems play an important role at Kennedy. A technology that determines the ground strike point of lightning in the immediate vicinity of the shuttle launch pads is valuable in determining which electronic equipment or system needs to be retested following a lightning strike. The lightning detector technology has commercial potential in sensitive manufacturing facilities, missile storage facilities, or hazardous chemical storage bunkers.

As NASA's designated Center of Excellence in launch and payload processing systems, Kennedy's primary responsibilities include Space Shuttle processing, the acquisition and management of Expendable Launch Vehicle launch services, payload carriers, payload processing, and support. Kennedy's Spaceport Technology Center (STC) initiative is an evolving component of Kennedy's dual mission in Space Launch Operations and Spaceport and Range Technologies. The STC is designed to align and enhance existing Kennedy technology development product lines with the needs of current and future reusable and expendable space transportation systems and their payloads. Kennedy has established unique development capabilities (personnel and laboratory/test bed facilities) for collaborative technology development efforts in several technology thrust areas called spaceport technology development initiatives (STDIs). The STDIs are: fluid system technologies, spaceport structures and materials, process engineering, range technologies, and command, control, and monitoring technologies. Kennedy also has product lines for "spaceport design and systems development," which test and integrate an array of component technologies in order to build and deploy an operational spaceport system. Kennedy's complementary advanced spaceport technologies and systems will benefit current and future spaceports on Earth and beyond.

An ongoing project at Kennedy is a study of the extent to which electrostatic charge can be generated and how it can

Testing of the personal cabin pressure monitor is conducted in the altitude chamber at Tyndall Air Force Base, Florida.





The Nitrogen Oxide Waste Conversion Scrubber installed at the oxidizer farm on Launch Complex 39A at Kennedy Space Center.

accumulate on lunar soil and dust particles. The findings of this research will provide critical information and techniques for the successful operation of an extraterrestrial spaceport by eliminating potential hazards relating to dust accumulation on equipment surfaces, astronaut suits, solar panels, habitat filters, thermal radiators, and other equipment. Dust accumulation could lead to a loss in performance, or even render equipment unusable. Commercial applications may be found in the antistatic, paint, and grain industries.

As the quest continues to construct an orbiting research facility, Kennedy endeavors to help ensure safe and successful ground operations for the ISS flight hardware. Kennedy successfully completed Phase I of Multi Element Integrated Testing (MEIT), involving the U.S. Laboratory Destiny, electrical power, control and communication modules, a docking port, and the Canadian-built robot arm. Kennedy teams focused their efforts on MEIT Phase II test planning and completed the first MEIT II test configuration involving a Kennedy-developed ground support U.S. Lab Emulator, additional power modules, and the Mobile Transporter. One of the first payloads to reside on the Station, the Protein Crystal Growth-Enhanced Gaseous Nitrogen Dewar, was processed at Kennedy Space Center for flight STS-106. It was returned from orbit on flight STS-92, demonstrating the full cycle for ISS hardware performing research in space.

A technology has been developed at Kennedy that may be beneficial to ISS and other Low-Earth Orbit (LEO) vehicles such as the Space Shuttle, as well as long-duration interplanetary vehicles and future planetary habitats. The personal

cabin pressure monitor warns, by means of audio, vibratory, and visual alarms, of the impending danger of hypoxia when cabin pressure has fallen to pre-programmed threshold levels. This device can also be used in a variety of aviation, aerospace, and non-aerospace applications where knowledge of one's exposure to low partial pressure of oxygen is important.

Due to its location on the Merritt Island National Wildlife Refuge and its biological diversity, Kennedy Space Center has developed a biological sciences capability that includes spaceport ecosystem assessment. Under the Endangered Species Act and the National Environmental Policy Act, launch operations require evaluation and impact minimization. Approximately 100 wildlife species found at Kennedy are the subject of conservation concerns. Monitoring focuses on combining field and remote sensing data with predictive/interpretive models on marine turtles, gopher tortoises, indigo snakes, wading birds, shorebirds, scrub jays, beach mice, and manatees. A technology developed to reduce hazardous rocket-fuel waste has also resulted in positive effects to the environment at Kennedy. The Nitrogen Oxide Waste Conversion Scrubber converts hazardous waste to a high-grade fertilizer, while reducing air pollution. Its commercial applications include possible use in power plants.

As we move into the 21st century, Kennedy Space Center faces many challenges. The strategic goals, vision, and guiding principles developed at Kennedy mirror the dedication, excellence, and integrity of investing in America's future through continued space exploration. ❖

LANGLEY RESEARCH CENTER

From Hampton, Virginia, Langley Research Center contributes to a broad range of aerospace technologies, from making space access a routine venture, to developing down-to-Earth ideas about aircraft safety and on-time operations. Langley is also adding to our knowledge of atmospheric science, providing scientific data for informed national decision-making about our environment.

NASA's Space Launch Initiative (SLI) has been established to find a more affordable and reliable highway into space. Whether it is doing business in Earth orbit or exploring distant worlds, the toughest part of the journey is the first few hundred miles up through the atmosphere to space. Consequently, it is critical that the airframe of any future vehicle be optimized for maximum performance while incorporating minimum weight—the classic aerospace dilemma.

Langley, world renowned for its research into the performance of winged vehicles and space vehicles, will lead the development and demonstration of airframe technologies for SLI: lightweight temperature-resistant structures and materials, aerodynamics, systems engineering and analysis to help define needed technologies, and advanced cockpit technologies to improve safety and reliability. Langley is working with Marshall Space Flight Center in the development of cryogenic tanks to hold super-cold liquid hydrogen fuel, with Ames Research Center on thermal protection systems, and with Johnson Space Center on cockpit technologies.

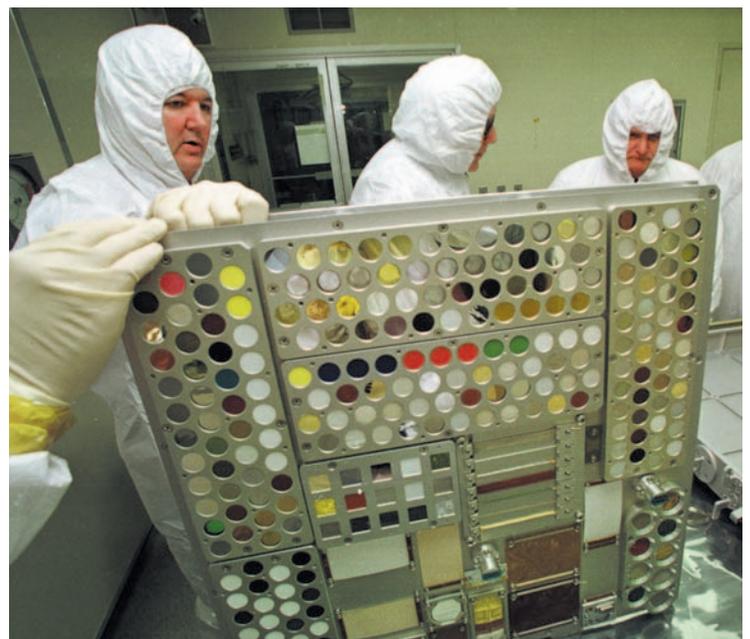
The first experiment to be performed on the International Space Station (ISS) was contributed by Langley. The Materials International Space Station Experiment (MISSE) is designed to evaluate the performance, stability, and long-term survivability of more than 700 materials and components planned for use by NASA, the Department of Defense, and commercial spacecraft manufacturers. "Space is a hostile environment, destructive to many materials," said William Kinard, program scientist for MISSE. "New, affordable materials are the enablers for advanced spacecraft. In-situ space testing, as provided by MISSE on the ISS, is an essential part of the development process for these new space materials."

For the next two decades, a series of robotic missions made up of orbiters, landers, and rovers will explore Mars looking for evidence of past or present life. Langley will contribute aerodynamics, aerothermodynamics, atmospheric flight simulation, guidance and control research—everything required to make a successful flight through the atmosphere of Mars. Langley performed a 70-day simulation of aerobraking around Mars for the Mars Odyssey Orbiter, launched in April 2001. One of the Center's jobs is to figure out how deep the orbiter should go on each pass. If the passes are too deep, the solar panels could burn up; if the

passes are too shallow, the mission could end up in a useless orbit. For the 2003 Mars Exploration Rovers, Langley is developing the end-to-end flight simulation and aerodynamic database for flight from atmospheric interface all the way to touchdown on the surface of Mars.

Another group of researchers are exploring revolutionary aircraft technologies in a program called 21st Century Aerospace Vehicle. These researchers believe that aircraft of the future will benefit by taking on some of the form and function of birds. The aircraft will have "smart" materials with embedded sensors and actuators. Sensors, like the "nerves" of a bird, will measure the pressure over the entire surface of the wing and direct the response of the actuators—the "muscles." These actuators will change the shape of the wing for optimal flying conditions. Intelligent systems made of these smart sensors, micro processors, and adaptive control systems will enable vehicles to monitor their own performance, their environment, and their operators in order to avoid crashes, mishaps, and incidents. Distributed as a network throughout the structure, they will provide the means for imbedding a "nervous system" in the structure and stimulating it to change shape. They will also serve as the means for sensing any damage or impending failure long before it becomes a problem.

In the near term, aircraft will be safer thanks to NASA contributions to the national Aviation Safety Program. For example, close calls between aircraft and ground vehicles or other planes have grown steadily in recent years, with 320 incidents reported in 1999 alone. Reducing runway incursions has become the Federal Aviation Administration's number one safety priority. In one research project, an advanced cockpit display system, developed by engineers at NASA Langley, could help prevent runway incursion incidents and near accidents on airport



Clean room personnel place material samples into trays to be installed in the Passive Experiment Containers (PEC) for the Materials International Space Station Experiment (MISSE); a project that will characterize the performance of over 700 materials.



Langley researchers and engineers are currently working on a concept aircraft which will incorporate “smart” materials that will allow the wings of a craft to change shape for optimal flying conditions.

runways, taxiways, and ramps. The system combines a head-down display of an electronic moving map of airport runways and taxiways with a head-up screen that gives the pilot real-time guidance. The system shows and sounds an alert if another plane or vehicle is about to encroach onto the runway. The system would improve aviation safety and efficiency several ways, including allowing more aircraft to land on time in bad weather.

Airline passengers frustrated with delays at U.S. airports may be able to reach their destinations faster in the future because of advances in predicting aircraft wake turbulence on final approach. With this new technology, called Aircraft Vortex Spacing System (AVOSS), Langley developments will help airliners achieve optimal spacing and efficiency. The system determines how winds and other atmospheric conditions affect the wake vortex patterns of different types of aircraft. AVOSS uses a laser radar or lidar technology to confirm the accuracy of those forecasts. The information is processed by computers, which can then provide safe spacing criteria automatically. All aircraft produce wake vortices that act like two small, horizontal tornadoes trailing behind the wing tips that can be felt as mild-to-severe turbulence by following aircraft. Lack of an accurate prediction system forces air traffic controllers to use rigidly fixed distances to separate different classes of aircraft, especially during bad weather, causing air traffic delays that disrupt flight schedules and increase costs. AVOSS is expected to provide the information needed for safe, efficient separation, from approach to landing. AVOSS is a part of the NASA Aviation Systems Capacity Program, headquartered at Ames Research Center, Moffett Field, California.

This is a pivotal time for NASA’s general aviation efforts. The Advanced General Aviation Transport Experiments (AGATE) program, based at Langley, has concluded its seven-year research agenda, boasting of many successes in its efforts to revitalize

general aviation. The government-industry-university consortium is a model for how to work together to make the most of tax dollars on behalf of the nation. Successes include the development of airborne technologies like near real-time weather and synthetic vision for safety and efficiency, and highway-in-the-sky displays to aid in navigation. The FAA worked as an AGATE member to streamline certification processes for new aircraft, helping make aircraft of the future more affordable. Embry-Riddle Aeronautical University, another AGATE member, worked to create simplified piloting curricula to encourage more people to become pilots.

A new NASA-led program, housed at Langley, called the Small Aircraft Transportation System (SATS), will demonstrate how single-engine aircraft can offer an attractive alternative to existing transportation systems for trips from about 150 to 1,000 miles. SATS is seen as freeing people and products from existing transportation system delays, by creating access to more communities in less time. The SATS concept of operations uses small aircraft for business and personal transportation, for on-demand, point-to-point travel between smaller regional, reliever, general aviation, and other landing facilities, including heliports. The five-year SATS program will culminate in a joint NASA/FAA/industry demonstration of selected operational capabilities at designated “SATSLab” airports. The results will establish the basis for future decisions by local, state, and federal policy makers regarding SATS and air transportation.

Langley is making use of measurements from aircraft and satellites to better understand natural and man-made changes to our atmosphere. Long-term, global studies include the tracing of seasonal airflow from Asia across the Pacific in the Transport and Chemical Evolution over the Pacific (TRACE-P) experiment. Emissions are expected to increase in this part of the world as East Asia continues to industrialize. This is an opportunity for researchers to study how chemical reactions and movement affect the air as it moves at a sun-filled tropical latitude. TRACE-P is the latest in a long series of NASA-led Global Tropospheric Experiments (GTE) aimed at a better understanding of worldwide chemistry of the troposphere—the part of the atmosphere closest to the Earth’s surface.

In another study, Langley researchers are helping to document the important role of polar stratospheric clouds in the destruction of protective ozone over the Arctic. Ozone in the upper atmosphere protects plants and animals on the surface of the Earth from harmful ultraviolet radiation. The Sage III Ozone Loss and Validation Experiment (SOLVE) revealed large-scale characteristics of polar stratospheric clouds, including their extent and chemical properties. In sunlight, these high-altitude clouds help release ozone-destroying chlorine from otherwise non-harmful gases. Once details of this process are incorporated into chemistry and climate models, scientists will have a better idea of the extent of future ozone destruction in the Arctic and the possibility of an eventual “ozone hole” over the Arctic. ❖

MARSHALL SPACE FLIGHT CENTER

As NASA's lead center for space transportation systems and development, and the Center of Excellence for space propulsion, the George C. Marshall Space Flight Center in Huntsville, Alabama, leads NASA's mission to develop safe, reliable, and affordable space transportation systems. The Center also maintains propulsion systems for America's current space fleet.

Marshall leads NASA's efforts in microgravity research—experiments conducted in the low gravity inside orbiting spacecraft—as well as in the development of space optics manufacturing technologies. The Center also delivers practical applications of NASA space research and technologies here on Earth.

Marshall is managing the Space Launch Initiative, NASA's comprehensive research and technology development effort to dramatically increase the safety, reliability, and affordability of space transportation systems. The initiative calls for a focused investment of \$4.8 billion through fiscal year 2006 to develop concepts and technologies needed to create a second generation reusable launch vehicle—one that is expected to be 10 times cheaper and 100 times safer than today's space launch systems.

The Advanced Space Transportation Program at Marshall looks beyond second generation systems, keying on flying third and fourth generation reusable launch vehicles. These programs are tackling the difficult task of lowering the current \$10,000-per-pound cost of putting payloads into space—first to \$1,000 per pound, then to as low as \$100 per pound.

NASA's Marshall Space Flight Center manages the Agency's Space Launch Initiative, a comprehensive research and technology development effort intended to increase safety, reliability, and affordability of space transportation systems. This artist's rendering of a futuristic two-stage flight vehicle is just one concept of such a system.

To reach these goals requires revolutionary aerospace technologies—from magnetic, chemical, and propellantless propulsion systems to new energy sources such as space solar power or antimatter propulsion. These and other advances are now being studied, developed, and tested at Marshall.

The Center leads NASA's government team in development and testing of the X-37 space plane, which is expected to make history as the first reusable demonstrator to fly in both orbital and reentry environments. Designed to demonstrate dozens of advanced airframe, avionics, and operations technologies that can support various launch vehicle and spacecraft designs, the X-37 will travel up to 25 times the speed of sound, remain in orbit up to 21 days, and land on a conventional runway.

Today and continuing well into the future, the Space Shuttle remains unmatched by any other launch system. Marshall manages all Space Shuttle propulsion elements, including the Main Engine, External Tank, and Solid Rocket Boosters. In 2001, a redesigned Shuttle Main Engine makes its debut flight. The updated Block II engine includes a new high-pressure fuel turbopump designed to increase the number of flights between required overhauls. Additional upgrades to the Shuttle's propulsion systems are planned for completion by 2005.

Marshall scientists and engineers routinely contribute to new processes and technology innovations in areas as diverse as manufacturing, communications, and electronics. Microgravity research conducted in Earth orbit furthers our



understanding of critical biological, chemical, and physical processes—opening doors to the commercial development of space.

Until recently, microgravity research was limited to relatively short-duration Space Shuttle flights. This changed with the addition of the Destiny Laboratory Module to the International Space Station in 2001. One of numerous Space Station elements built and tested at Marshall, Destiny allows for long-duration microgravity experiments and is the premier laboratory for this research.

As Space Station construction continues in orbit, the Center maintains a key role in hardware development and science operations for the orbiting research outpost. Marshall is overseeing development of Station Nodes 2 and 3—modules that serve as hubs for distribution of water, electrical power, and thermal controls for the Space Station—as well as the Station's Environmental Control and Life Support System, a water recycling and oxygen generation system.

Marshall also oversees development and operation of the Space Station's Multipurpose Logistics Modules, Italian-built modules that will carry laboratory racks filled with equipment, experiments, and supplies to and from the Station.

The Payload Operations Center at Marshall is NASA's primary Space Station science command post, coordinating all science aboard the Station and communications between researchers on Earth and their on-board experiments. Marshall is also responsible for coordinating and managing all Station microgravity science and commercial research payloads.

With more than 30 years' experience developing optical systems for space exploration, Marshall leads NASA's space optics manufacturing technology development, including optics design, fabrication, testing, and analysis.

The Space Optics Manufacturing Technology Center at Marshall is spearheading NASA's development of advanced, ultra-lightweight optics materials, fabrication technologies, precise measurement standards, and state-of-the-art test facilities. The Center currently supports NASA's Goddard Space Flight Center by leading optics technology development for the Next Generation Space Telescope, the successor to the Hubble Space Telescope. The Center is also developing ultra-lightweight optics for the Constellation X-ray mission, the successor to the Chandra X-ray Observatory, which was designed and developed at Marshall and launched with spectacular results in 1999.



Team members in the Payload Operations Center at Marshall—NASA's primary Space Station science command post—coordinate all science on the International Space Station and communications between researchers on Earth and their on-board experiments.

Marshall partners with Alabama universities, industry, and other federal agencies in the new National Space Science and Technology Center. Opened in Huntsville, Alabama, in 2001, the center is a collaborative effort that enables scientists and educators to partner on cutting-edge advances in space science, materials science, biotechnology, Earth sciences, propulsion, information technology, optics, and other areas that support NASA's mission.

In collaboration with Stanford University researchers, Marshall scientists are developing a sophisticated experiment called Gravity Probe B, designed to prove or disprove portions of Albert Einstein's general theory of relativity. The Gravity Probe B mission is scheduled to launch in late 2002.

Marshall's aggressive reach for the stars is intended to do more than advance humanity's drive to explore. Technologies derived from America's space program—offering a wealth of benefits such as new medicines, manufacturing processes, and electronics—are available to private industry, universities, and government agencies through the Center's Technology Transfer Department. The technology transfer program encourages a broad use of Marshall innovations and expertise by American private enterprise. ❖

STENNIS SPACE CENTER

Situated near Mississippi's Gulf Coast, just 45 minutes from New Orleans, John C. Stennis Space Center is a unique federal city that continues to feel the positive results from increased construction, expansion, and collaboration. The Center is seeing tremendous growth by its existing tenants and the addition of new agencies, companies, and groups to the facility.

NASA's mission at Stennis includes managing NASA's rocket propulsion test programs and facilities for current and future space vehicles, and providing test services for government and commercial customers, while another mission includes Earth science applications. Scientists at Stennis conduct a broad range of remote sensing applications projects with a focus on developing systems and tools to better monitor and manage the health and productivity of our nation's land and coastal resources.



A TRW 650K Low Cost Pintle Engine undergoes hot fire testing at Stennis' E-1 test stand. The test article achieves a high level of power without a high cost because of the simplicity of its design. Physically, the TRW 650K is the second largest engine ever tested in the United States.

Stennis Space Center is NASA's lead center for rocket propulsion testing and manages the Agency's rocket propulsion test assets, including facilities at the Marshall Space Flight Center in Alabama, the White Sands Test Facility in New Mexico, and the Glenn Research Center Plum Brook Station in Ohio.

Building on a role in engine and vehicle testing that spans 30 years, Stennis is the Center of Excellence for propulsion testing. Every Space Shuttle Main Engine (SSME) undergoes acceptance testing at Stennis. The engine is installed vertically in one of two large test stands where a series of test firings are

performed. Once proven flight worthy, the engine is transported to the Kennedy Space Center in Florida where it is installed on an orbiter.

Safe and affordable space transportation is the highest priority for NASA's Space Launch Initiative. This priority provides commercial industry with the opportunity to meet NASA's future launch needs. By conducting testing on engines for the X-33 and X-34, Stennis researchers gained a wealth of technology that can be used for future vehicles. This is vital since Stennis will continue to play an integral role as the lead center for propulsion testing in testing future component and propulsion systems.

Commercial test programs are also conducted at Stennis Space Center. For example, the Center has been selected to assemble and test the RS-68 engine and the common booster core for the Boeing Company's Delta IV rocket. The RS-68 is the world's largest liquid-hydrogen, liquid-oxygen engine. Boeing has leased the B-1 test stand from NASA for these tests.

Stennis' E-Complex test facility serves as a developmental rocket engine component test facility for future generation rocket engines. The flexible three-stand complex can carry out rocket engine testing and other types of testing involving ultra high-pressure gases and high-pressure, super-cold fluids. One of its first uses was to ground test rocket engine components for the Reusable Launch Vehicle (RLV) program.

Stennis research engineers also use the E-Complex facility to advance knowledge in test technology areas, such as instrumentation, the study of exhaust plumes, test facility design and capability, and data acquisition.

Stennis Space Center is also NASA's lead center for Earth science applications. Its mission is to "extend the benefits of Earth Science Enterprise's (ESE) discoveries, knowledge, technology, and data beyond the traditional science community—to turn Earth science results and capabilities into practical tools for solving practical problems."

In support of NASA's ESE, the Geospace Applications and Development Directorate (GADD) at Stennis conducts a broad range of remote sensing applications projects. Remote sensing is a way to gather information about the Earth using aircraft or satellites. By using digital images, interpreting photographs, and comparing results to ground truth data, the GADD provides information that has real-world applications. These applications have the potential to enhance our quality of life and to create new products, services, and industries based on NASA-developed technology. Some of these applications include land-use mapping, flood plain management, crop condition monitoring, forest management, environmental monitoring, and natural hazard assessments. This emerging multibillion-dollar industry has the potential to increase U.S. economic competitiveness in world markets while providing NASA with a reliable commercial source for scientific data.

Scientists at Stennis also conduct coastal aquatic research using remote sensing technologies. Remote sensing instruments, both airborne and satellite, are integrated with scientific disciplines such as biology and geochemistry to study the role of coastal environments in marine biochemical cycles. This research is important in understanding how light is transmitted and reflected through water, and how this may be applied through the use of remote sensing in coastal environments.

NASA personnel are also involved in seatruthing, which involves going out to an area of the ocean and taking measurements of phytoplankton, sediment, and other constituents of the sea. Seatruthing, used to verify and calibrate data acquired by remote sensing satellites such as the Sea-viewing Wide Field-of-view Sensor (SeaWiFS), is expected to play a major role in global climate change research.

The advancement and application of new technologies in government and commercial products and services has always been important to the well-being of the United States. Since its inception in 1958, NASA has been an important source of much of the nation's new technology. The Office of Technology Transfer at Stennis works to identify technology development opportunities and make these available to domestic companies as commercial products. It does so by making technologies available through public licenses and partnerships, providing technical advice, and acting as a clearinghouse for technology needs. NASA's Commercial Technology Program provides a variety of opportunities for the American public to work with NASA in the transfer of technology, including licensing opportunities, dual-use projects, Small Business Innovation Research and Small Business Technology Transfer (SBIR/STTR), and technology assistance.

An integral part of the Stennis community is its education programs. The Office of Education is dedicated to fostering a continued growth in student participation and success in the areas of science, mathematics, geography, and technology. The Office is also responsible for the design and implementation of other educational programs aimed at improving America's schools and supporting the nation's education goals. Programs developed at Stennis are supported or implemented at the local, state, and national levels.

NASA's Educator Resource Center (ERC) offers a vast collection of material for educators, including hundreds of videotapes, computer software, printed materials, and lesson plans that reflect the most recent scientific discoveries about space, oceans, and the Earth. The ERC also provides professional development opportunities for educators through workshops and seminars. A computer center and the Missis-



Dr. Richard Miller, left, chief of NASA's Earth System Science Office (ESSO) at Stennis Space Center, works with post-doctoral student Yuan Jinchun, right, and a crew member in preparing a bio-optics package for underwater data collection.

issippi Interactive Video Network help teachers integrate state-of-the-art technology into their classrooms.

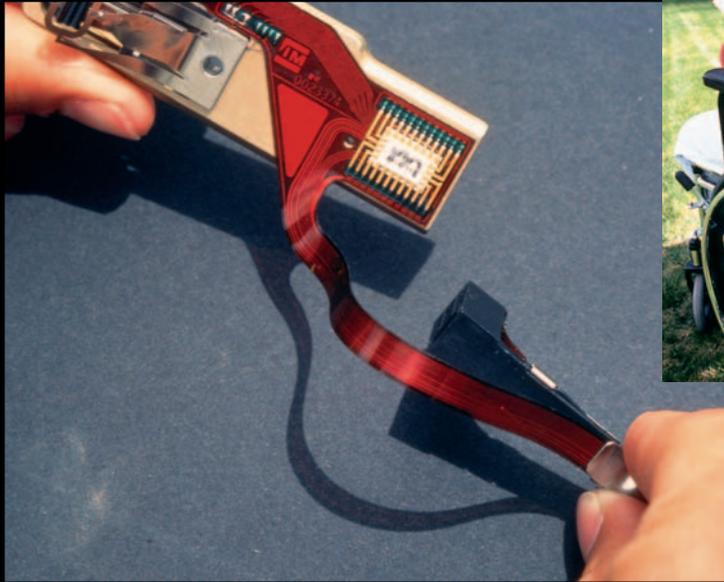
NASA played a key role in creating the Gulf Coast Education Initiative, an innovative effort to promote and support the efforts of six Mississippi counties and one Louisiana parish to develop a quality education system. This program was designed to ensure that students master the skills necessary for future success in America's high-tech environment.

New business is booming at Stennis. The State of Mississippi is constructing a new high-tech aerospace park at Stennis and the first occupant will be the Lockheed Martin Propulsion, Thermal, and Metrology Center. Adjacent to this park will be the new Department of Defense Space-Based Laser Performance Test Facility.

Lockheed Martin's Space Systems and Technology Services companies teamed with the State of Mississippi, Hancock County, and NASA to develop the Lockheed Martin Propulsion, Thermal, and Metrology Center. Construction of the 220,000-square-foot facility began in 2001 and will produce propulsion systems, such as thrusters, used for satellites and other spacecraft the company produces. The thermal control systems produced at the facility will protect space vehicles from the extreme temperatures of the space environment.

The Pentagon's Ballistic Missile Defense Organization has slated construction of a \$140 million facility at Stennis to test its proposed Space-Based Laser (SBL) to begin in the first quarter of fiscal year 2002. The facility will be used to evaluate beam quality, efficiency, and power levels for a prototype megawatt-class hydrogen fluoride laser.

The future is certainly bright for Stennis Space Center. Its employees take pride in meeting the challenges of providing excellent customer service and fulfilling the needs of the American taxpayers who deserve high returns on their investments. ❖



SPECIAL MILLENNIUM

As we begin the new millennium, we look forward to more revolutionary new technologies, products, and services that will be the culmination of partnerships between NASA and the private sector. In this year's *Spinoff*, we take a look back at the many innovations spun off from NASA's space research that provided numerous benefits in the daily lives of the American public, ranging from home and recreation products, to health and medicine technologies, to environment and resources management, as well as industrial productivity and manufacturing technologies. The Special Millennium Feature takes a nostalgic glimpse into the past and revisits some of the products that most heavily impacted our lives. This section sums up the many years of hard work and dedication from the NASA field centers and industry that resulted in solid returns on America's investment in the Space Program.

NEW HELP FOR MS PATIENTS



Multiple sclerosis (MS) is a chronic, progressively disabling disease of the central nervous system that strikes men and women in the prime of life. Wasting of the nerves, caused by loss of a body substance known as myelin, can affect thought processes, vision, dexterity, balance and sensation.

Myelin normally forms a coating around the nerves like insulation around a wire. This insulation allows signals to be conducted through the nervous system; conversely, its absence bars proper functioning of the nervous system. More than 30 years ago it was discovered that body cooling can produce a dramatic improvement in MS symptoms. Experimental data shows that conduction can be temporarily restored to "demyelinated" nerves by cooling tire body's core temperature only one degree Fahrenheit.

Therefore, physicians have long used cold showers, pools and air conditioning to lower the body temperatures of MS patients.

A SPACE-DERIVED

Such treatment is sometimes useful but it has drawbacks. It is not practical for severely disabled patients and it can be uncomfortable. Moreover:

PERSONAL COOLING

patient immersion in a pool can sometimes be self defeating, because body mechanisms—such as shivering and vasoconstriction (constriction of the blood vessels)—go to work to prevent a drop in core temperature.

SYSTEM HEADS A

SAMPLING OF SPINOFF

DEVELOPMENTS IN

However, many patients are now benefiting from a body cooling technique that does not require immersion, nor does it induce shivering or vasoconstriction. It involves use of a "cool suit," a device more formally known as the Mark VII MicroClimate® Medical Personal Cooling System.

THE FIELD OF HEALTH

AND MEDICINE

The suit, which consists of a head cap and a torso vest, is a spinoff from space technology developed

by Life Support Systems, Inc. (LSSI), Mountain View, California. The Mark VII is being used to treat symptoms of MS and other illnesses where temperature regulation can be beneficial, such as HED (hypohidrotic ectodermal dysplasia), peripheral neuropathy, epidermolysis bullosa, spina bifida and cerebral palsy.

The Mark VII system includes a control console—either fixed or portable versions—with a cooling unit and a pump. The pump circulates a water-based fluid, cooled to about 50 degrees Fahrenheit, through "veins" or tubes in the vest and cap. Due to its efficient heat transfer, it can lower a patient's core temperature one degree Fahrenheit in 30 to 40 minutes, with sometimes dramatic improvement in symptoms that continues for two to four hours after a cooling session.

The cooling system is not a cure, nor does it help every MS patient. It has, however, helped many patients although it is still relatively new, and those for whom it works are lavish with their praise. LSSI has received a number of testimonials like this from author/journalist Charles Fox:



A multiple sclerosis (MS) patient at a Glassboro, New Jersey barrier-free housing facility is using a spinoff "cool suit" to lower her temperature and alleviate MS symptoms. The suit consists of a head cap, a torso vest and the cooling unit shown in the foreground. With the patient is John Hudson, Sr., founder and president of the Multiple Sclerosis Association of America, which has placed cool suits in more than 50 MS care centers in the U.S.

"It improves my speech, breathing and thinking. I have fully integrated the use of the Mark VII into my life. It's part of my life, and has brought me more relief than anything I have tried in the last twenty-three years." And this from registered nurse Sharon Giberson: "My neuropathly, speech and overwhelming fatigue improves. My depression subsides. I am blessed with a better quality of life and wouldn't want to live without it (the Mark VII)."

The Multiple Sclerosis Association of America (MSAA) has sponsored a 12-week, 12-patient detailed study of the effectiveness of the MicroClimate system; the study was conducted by Dr. Wallace Tourtellotte of the UCLA Medical Center. Final results were pending at publication time, but a preliminary report indicated that most subjects experienced reduced fatigue and improved mobility immediately after and up to three hours after cooling; four patients reported long term improvements in life quality over the six weeks in which they received daily cool suit treatments.

More MS patients will have the opportunity to see what the cool suit can do for them, since MSAA is expanding the availability of MicroClimate cooling. The association has bought and placed cool suits in more than 50 MS research care centers in the U.S. and it is estimated that, through these clinics, more than 100,000 MS patients will be able to get MicroClimate treatment. (Continued)

®MicroClimate is a registered trademark of Life Support Systems, Inc.

NEW HELP FOR MS PATIENTS (CONTINUED)



Life Support Systems, Inc. (LSSI) did not start out with the intention of producing medical systems. The medical application of the company's cooling technology sought the company. It resulted from nationwide publicity when LSSI began providing cool suits for children afflicted with HED (hypohidrotic ectodermal dysplasia), who have no natural cooling system because they were born without sweat glands. The extraordinary success that accompanied use of the LSSI Mark VII MicroClimate System for alleviating HED symptoms prompted a flood of inquiries from people in the U.S. and abroad about the LSSI cooling technology and sparked development of units especially designed for medical applications.

By that time—in the latter 1980s—LSSI was already an established company, a NASA spinoff company, in fact; its entire line of temperature regulation products stemmed from a NASA technology that the company modified and refined to produce a variety of cooling systems for military, recreational and industrial applications.

The MicroClimate technology had its origin in a 1968 NASA development program at Ames Research Center that produced a spacesuit undergarment for cooling astronauts on the surface of the moon or during extravehicular forays outside a spacecraft or space station; the system circulated a fluid, cooled by a heat exchanger and delivered by a battery-powered minipump, through a network of tubes in the garment.

In 1971, Ames awarded a contract to Acurex Corporation for an extension of the technology: a heat stress alleviating liquid-cooled helmet liner for helicopter pilots. In the mid-1970s, NASA, Acurex and the Bureau of Mines carried the technology a step further with development of a self-contained cooling system for mine rescue work.

In 1980, William Elkins, formerly with Acurex and long associated with cooling system research, founded LSSI to pursue commercial uses of the technology. In the years since, LSSI has refined the technology and brought to the commercial marketplace three generations of improvements.



The Life Support Systems, Inc. (LSSI) Mark VII cooling/control unit can be mounted on the rear platform of a patient's wheel chair; the unit feeds fluids to the cool suit through an umbilical tube. In the near photo is an alternative type of vest cooled by a quick-change ice cartridge.



Wearing an LSSI Integrated Cooling System (blue chest pack and cap), a Hazmat team member is helped into a protective vapor suit by a teammate. The chest pack includes a cooling cartridge and controls.

unpressurized aircraft; for armored vehicle crews; and for shipboard personnel engaged in such heat stressful work as operations in boiler rooms or steam catapult rooms

The range of civil applications is even broader. It includes protection for public service and industrial firefighters, plus workers in such industries as nuclear power, primary metals reduction, glass manufacturing, chemical processing, petrochemical refining, paper production, steel mills and foundries, and agricultural crop dusting.

LSSI has also moved into the sports and recreational field by providing cooling equipment for professional race car and hydroplane drivers; the list of users reads like a Who's Who of those sports.

For its importance and broad potential, LSSI's cool suit was elected to the U.S. Space Foundation's Space Technology Hall of Fame in 1993.

LSSI recently introduced a MicroClimate unit especially designed for hazardous materials handlers who must wear protective clothing for long periods. This system, along with the medical systems, represents a fourth generation of LSSI development of the original technology. The company expects to sell between 5,000 and 10,000 MicroClimate systems over the next five years—and that doesn't include the hazmat and medical systems, whose sales potential have not yet been evaluated. •

The company has grown into a thriving business that has expanded both horizontally—more and more applications—and vertically—increasing orders for some of the principal applications. MicroClimate cooling systems are in service with U.S. and foreign military services who must perform arduous tasks while wearing hot and bulky protective gear; for airmen flying



A variation of the MS patient's cool suit is the Mark I Surgical Personal Cooling System for medical personnel who must wear protective clothing in hot operating room environments.

Dryden Flight Research Center—Spinoff 1997

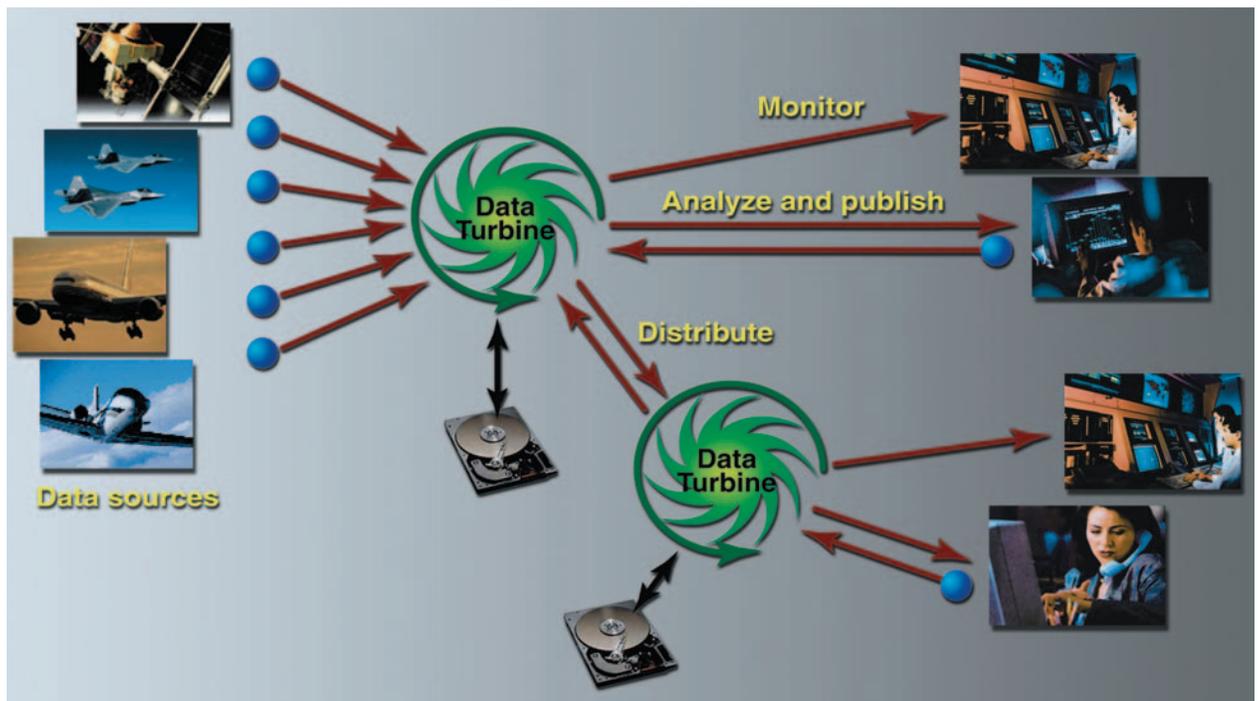
The Center of Attention

With the dizzying amount of software available on the market today, communication across different computer platforms and applications has become a must. A data-collection and processing “middleware” package that was developed with NASA’s **Small Business Innovation Research (SBIR)** funding is making strides in computer systems integration.

Create, Inc., of Hanover, New Hampshire, has made it possible to synchronize interaction among different computer applications. Originally created

in conjunction with NASA’s Dryden Flight Research Center for collecting and processing aircraft vibration test data, DataTurbine™ is now used as a software tool for industrial monitoring, collaborative simulation and modeling, and multimedia data streaming.

DataTurbine serves as “glueware,” allowing communication among dissimilar computer platforms and permitting analysis, storage, and acquisition of shared data. The middleware technology solves many problems posed by real-time or online data management in collaborative environments. These environments must be capable of exchanging large volumes



Create, Inc.’s DataTurbine™ serves as “glueware,” allowing communication among multiple users and dissimilar computer platforms.

of data from dissimilar systems at local and remote sites. DataTurbine's underlying technology, Creare's patent-pending Ring Buffered Network Bus (RBNB), is a software server that provides a buffered network data path between suppliers and consumers of information. Diverse distributed applications pool and share data using DataTurbine as a common intermediate point of contact. Therefore, the RBNB manages all aspects of inter-application data traffic, including storing, retrieving, and routing information within the network.

The RBNB acts as a nerve center within a network of applications, enabling synchronized data distribution, application integration, and collaborative processing. Like a neuron, RBNB uses a mechanism to receive, store, process, and forward signals from many sources to many destinations. A network of DataTurbine servers creates a type of nervous system that bonds applications and data sources together.

The software allows connected users to extract or input audio and video information nearly instantaneously, no matter what type of computers they are using. DataTurbine can separate information, as well as integrate it. If a user wishes to receive only news from a data stream that also includes sports and concert information, he or she can use DataTurbine to filter out only the news

information. Using this method of data extraction, the RBNB can also be used for securing information through authorization restriction on a client-by-client basis.

Many applications for DataTurbine continue to emerge. Advantages of this technology include a possible network-oriented infrastructure for managing information on an aircraft. Continuous updates of weather information to and from an aircraft can be integrated with engine health monitoring and other tools.

The RBNB fills multiple needs that would otherwise require ad hoc and expensive software development. Given the benefits of DataTurbine off-the-shelf products, faster development of more useful software is possible.

DataTurbine™ is a trademark of Creare, Inc.

GLENN RESEARCH CENTER—Spinoff 1996

A Giant Step in Jetliner Propulsion

*A cleaner, quieter,
more economical
aircraft engine
heads technology
transfers in the
field of
transportation*

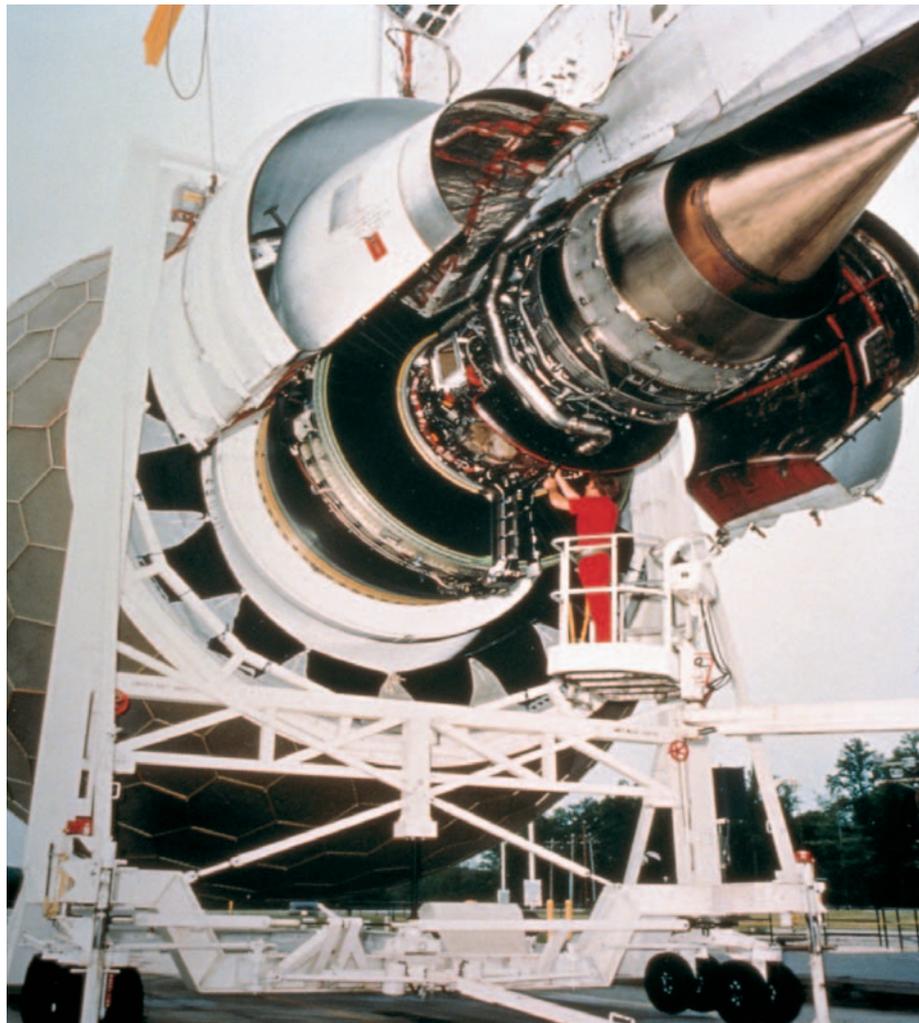
In November 1995, the General Electric GE90 turbofan engine made its flight debut aboard a Boeing 777 jetliner operated by British Airways. Developed and manufactured by GE Aircraft Engines (GEAE), Cincinnati, Ohio, in concert with program participants in France, Italy and Japan, the GE90 is one of the most powerful air breathing engines ever flown. It is also one of the most efficient, one of a trio of advanced technology, very high thrust jetliner engines that offer new levels of operating economy and environmental acceptability.

The GE90's history underlines the lengthy time and large investment—\$1.5 billion in this instance—required to bring a major aerospace system from concept to service entry. By the time it was certified in 1995, the engine had been several years in development. Actually, though, some of the key technologies incorporated in the GE90 trace their roots to joint GE/NASA research in the 1970s.

The GE90 was initially certified at 84,700 pounds thrust, but it is capable of thrust levels well beyond that. Only two engines are required to power the big widebody 777, which approaches in size the four-engine Boeing 747 jumbo jet.

It is a type of engine known as a high bypass turbofan. Used in most modern airliners, the turbofan is a propulsion system in which some of the air taken in is compressed, burned in a combustor and expelled to generate power for driving the fan and compressor. A greater amount of the air bypasses the combustion process. In the GE90, the relatively cool bypass air is pushed rearward by a huge (123-inch-diameter) multibladed fan to mix with the hot exhaust gas; the result is a very large gain in overall thrust with minimal fuel expenditure.

A GE Aircraft Engines technician is dwarfed by the mammoth GE90 jetliner engine, which incorporates multiple technologies developed in joint GE/NASA research programs. The large sphere is a test structure.



Propulsion engineers use the term “bypass ratio” to indicate how much of the ingested air bypasses the combustion chamber; generally speaking, the higher the ratio, the more efficient the engine. The GE90’s very high 9:1 ratio makes a big contribution to noise and fuel burn reductions. Specifically, the GE90 features a fuel consumption rate 10 percent better than the large commercial turbofans of the pre-1995 generation; a noise level two decibels lower; and emission reductions of oxides of nitrogen (35 percent), carbon monoxide (25 percent) and unburned hydrocarbons (60 percent).

These features have great attraction for airline operators. Fuel is one of the major elements of total operating costs, and fuel efficiency of the order the GE90 offers is vitally important to the world’s airlines, who are just beginning to recover financial equilibrium after years of heavy losses. The engine’s environmental characteristics provide a valuable bonus, not only in community good will but in a further contribution to improved airline earnings through avoidance of noise and emissions taxes now being levied by foreign nations.

Although GEAE spent years refining them, the basic fuel consumption and environmental improvement technologies that provided the springboard for what eventually became the GE90 stemmed from the company’s participation in two NASA research programs.

The first, initiated in 1969 and continuing through the 1970s, was the Quiet Clean Short-haul Experimental Engine (QCSEE) program conducted by Lewis Research Center. QCSEE focused on then-advanced technologies to lower engine noise and address the most troublesome aircraft-emitted contaminants. The program was eminently successful; ground tests of research engines in the 40,000-pound-thrust class demonstrated noise reductions 8-12 decibels (60-75 percent) below the quietest engines in civil transport service. They also demonstrated new technologies to effect sharp reductions in emissions of carbon monoxide and unburned hydrocarbons.

Also in the 1970s, GEAE joined with NASA in a joint Energy Efficient Engine (E³) program managed by Lewis Research Center. Like QCSEE, E³ targeted emission reductions, but emphasized new design techniques for minimizing fuel burn. Highlighting that program was development of a new type of compressor core and an advanced combustor. The GE90’s compressor and dual-dome combustor are direct descendants of technology developed in the E³ program and thoroughly proven in extensive ground tests; they are the principal factors in the engine’s economical fuel burn, reduced emissions and low maintenance cost features.

In developing the GE90, the company drew upon technology gained from multiple sources, including the NASA experience; expertise acquired in building high thrust systems for military aircraft; and GEAE’s development and manufacture—in cooperation with SNECMA of France—of the CF6 and CFM56 families of engines, which have years of service with many of the world’s airlines.

The development effort began in the late 1980s and progressed to hardware test in 1992. The ground and flight test program was the most exhaustive ever undertaken by the company, involving some 7,600 hours and 19,000 cycles of endurance testing to simulate more than two years of actual airline experience and maintenance.

Thrust levels of the GE90 series continue to increase. The first growth model—the GE90-92B—achieved its rated thrust of 92,000 pounds in the spring of 1996. Research engines have topped that; the GE90 has operated for more than 150 hours at thrust levels above 100,000 pounds, and has demonstrated a thrust capability of 110,000 pounds. The engine is designed to power all models of the 777 in development or planned, plus other subsonic commercial widebodies contemplated for introduction over the next 20 years.

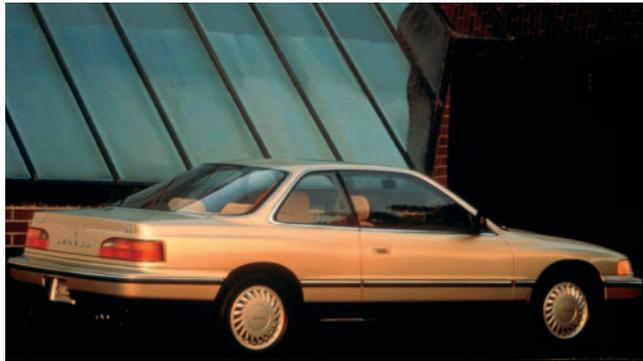
GODDARD SPACE FLIGHT CENTER—SPINOFF 1988

Auto Design

The accompanying photos show exterior and interior views of the 1987 Honda Acura Legend Coupe, which was designed with the aid of the NASA-developed NASTRAN® computer program. The Legend is among the latest cars designed by Honda R&D Company, Ltd., Japan, a longtime user of the NASTRAN program.

The program is an offshoot of the computer design technique that originated in aircraft/spacecraft development. Engineers create a mathematical model of the vehicle and “fly” it on the ground by computer simulation. This allows study of the performance and structural behavior of a number of different designs before settling on a final configuration.

From that base of experience, Goddard Space Flight Center developed the NASA Structural Analysis Program (NASTRAN), a general purpose predictive tool applicable to structural analysis of automotive vehicles, railroad cars, ships, nuclear power reactors, steam turbines, bridges, office buildings—and that's just the beginning of a lengthy list.



The NASTRAN program takes an electronic look at a computerized design and predicts how the structure will react under a great many different conditions. Quick and inexpensive, it minimizes trial-and-error in the design process and makes possible better, lighter, safer structures while affording significant savings in development time. One of the most widely used of all aerospace spinoff technologies, the NASTRAN program is available through NASA's Computer Software Management and Information Center (COSMIC)® at The University of Georgia.

Virtually all U.S. auto-makers now employ the aerospace-derived computer design technique and most employ the NASTRAN program or other NASA-developed programs in the design process. Honda R&D Computer Ltd. has been using NASTRAN for more than a



decade for structural analysis of auto bodies, motorcycles and such components as tires, wheels, engine blocks, pistons, connecting rods and crankshafts. All of the Honda auto products designed in the 1980s have been analyzed by the NASTRAN program. ▲

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JET PROPULSION LABORATORY—Spinoff 1986

DIGITAL IMAGING



Image analysis is the art of obtaining information from pictures, for example, through visual examination of a photograph or x-ray. But visual extraction and interpretation of information is slow, tedious and error prone because it is subjective. To support space requirements, NASA—in particular Jet Propulsion Laboratory (JPL)—developed the technique of digital imaging, computer-processed numerical representation of physical images, such as the planets and moons of the solar system. JPL also played a lead role in developing digital image processing, or enhancement of images to improve their quality and make them easier to interpret. Quantitative digital image analysis goes a step further and includes location of objects within an image and measurement of each object to extract quantitative information.

In the decade of the 1980's, these technologies

are finding scores of non-aerospace applications. In medicine, for example, CAT scanners and diagnostic radiography systems are based on digital imaging; three-dimensional reconstruction techniques are proving a valuable aid to microscopy; and computerized image analysis of cardiological x-rays is providing quantitative data on heart valve and artery functions. In industry, digital imaging is notably employed in quality control inspection systems; it also has applications in chemistry, cartography, manufacture of printed circuitry, metallurgy, ultrasonics and seismography, in addition to many aerospace uses.

Shown in the accompanying photo is the PSICOM 327, a stand-alone work station designed to perform all of the commonly used functions in quantitative digital image analysis. The photo shows a medical application—quantitative measurements of a microscope specimen—but PSICOM 327 is a general purpose system with broad industrial and scien-

tific uses in addition to its clinical applications.

Introduced to the commercial market in 1985, the PSICOM 327 is manufactured by Perceptive Systems, Inc. (PSI), Houston, Texas. PSI is a NASA technology transfer company employing a number of personnel with NASA-acquired technical expertise, operating under a NASA patent license, and incorporating in its products digital imaging technology developed by JPL. The company was founded in 1984 by Dr. Kenneth Castleman, now vice president—research and development, and Don Winkler, vice president engineering. Both are former NASA digital imaging experts, Castleman with JPL and Winkler with Johnson Space Center.

The PSICOM 327, now in use at several universities and industrial facilities, is PSI's first product. The company recently introduced a new PSICOM 427 high resolution imaging system to meet market demand for greater accuracy and image resolution in some applications, and it also developed the first model of a 200 Series that will feature lower cost, smaller, more mobile systems designed for specific rather than general purpose applications. ▲

Spinoff from a Moon Tool

Cordless products based on Apollo technology typify aerospace derivatives for home, consumer and recreational use



Among the most important tasks performed by Apollo astronauts on the moon was collection of lunar rock and soil samples for later analysis on Earth. Much of the material was gathered on the surface, but, for comprehensive assay of the moon's crust, scientists also wanted to look at subsurface soil. This necessitated development of a special lunar drill capable of extracting core samples from as much as 10 feet below the surface.

The drill had to be highly efficient to cut through the sometimes hard lunar surface layer, and, like everything that went to the moon, it had to be lightweight and compact. Most importantly, it had to have its own independent power source. Although the tool could have operated on power from the Lunar Module, the astronauts' home and operating base, scientific requirements dictated sampling at diverse locations, some of them far from the base.



The job of developing the drill was entrusted to The Black & Decker Manufacturing Company, Towson, Maryland, which responded with a battery-powered, magnet-motor system that proved successful in lunar work. In the course of the development, Black & Decker used a specially-developed computer program to optimize the design of the drill's motor and insure minimal power consumption. That computer program, along with the general knowledge and experience gained in developing the drill, provided a stronger technology base for continuing company development of battery-powered implements. Black & Decker has refined the original technology and now produces a line of consumer, medical and industrial cordless tools and appliances.

The most recent device to reach the commercial market is the "Dustbuster," a miniature, hand-held vacuum cleaner for the

Black & Decker's Dustbuster (opposite page), a cordless miniature vacuum cleaner for quick pickup in hard-to-reach places, traces its origin to a battery-powered lunar drill developed by the company for the Apollo program. Among other Black & Decker cordless products rooted in the same technology is a hand-held home drill (upper photo) also usable in construction tasks (right) where a power source is not readily available.

home or auto. The Dustbuster has no hose, no cord, is only 14 inches long and weighs less than two pounds; thus, says the company, it offers a convenient means of quick cleanup after spills without wrestling the standard home vac out of the closet. The Dustbuster also provides an easy way to clean hard-to-reach places where dirt and crumbs accumulate, such as corners, shelves, stairs, around plants and behind cushions. The mini-vac comes with a storage bracket that also serves as a recharger; plugged into a home outlet, it charges the

nickel-cadmium batteries when the appliance is not in use.

Along with the Dustbuster, Black & Decker's line of home-use cordless implements includes drills for the handyman or hobbyist, shrub trimmers and grass shears, all of which are rooted in Apollo technology. The company also manufactures a number of cordless tools used in the sheet metal, automobile and construction industries, and a line of cordless orthopedic instruments for hospital use.



Sporting Goods Lubricants

What crawls at one mile per hour, weighs six million pounds, and is always hungry for a lube job? That may sound like something out of a science fiction film. But in truth, this beast is the huge Mobile Launch Platform, needed to haul the fully assembled Space Shuttle from the Kennedy Space Center Vehicle Assembly Building to a launch pad.

In 1994, Lockheed Martin Space Operations was searching for an environmentally-safe lubricant for the lumbering, gigantic transporter. Sun Coast Chemicals of Daytona, Inc., Flagler Beach, Florida was contracted to formulate a spray lubricant free of environmental drawbacks. Demanding specifications were placed on the lubricant, along with the task of providing the crawler with the utmost in lubrication safeguarding.

Working with Lockheed Martin, Sun Coast Chemicals of Daytona (SCCD) was victorious in devising a Crawler Track Lubricant. From this work, SCCD created and introduced three spinoff products: Train Track Lubricant, Penetrating Spray Lube for rust prevention and other related problems, and Biodegradable Hydraulic Fluid.

SCCD has moved forward with yet another two new products, sparked by the original lubricant work.

The X-1R[®] Super Gun Cleaner and Lubricant (SGCL) has been created for the gun devotee. This product impregnates the gun's barrel and trigger mechanism with microscopic metal pores. Just three to five microns in size, these pores help protect against galling while increasing the velocity action of the gun. A reduction in the heat build-up from rapid fire is also realized.

Designed to clean and lubricate in one step, the X-1R SGCL replaces solvent and oil now commonly used by gun owners. No particulates, such as Teflon[®] or graphite, are carried in the gun cleaner and lubricant. The environmentally safe, non-hazardous, non-flammable product is fortified with IR-39, a special SCCD advanced rust inhibitor. Making use of the X-1R SGCL protects a gun from rust and corrosion caused by extreme environmental conditions.

Sun Coast Chemicals of Daytona has announced another new product, an offspring from their NASA Crawler Track lubricant work. For the fishing enthusiast, SCCD is marketing the X-1R Tackle Pack.

Due to the high cost of fresh and saltwater reels today, preventative maintenance is a must. With the angler in mind, Sun Coast has developed a premium preventative maintenance package to assure optimum lubrication



The Reel Lube & Grease is an environmentally safe cleaner and lubricator.

protection against rust and corrosion. The X-1R Tackle Pack is a blend of SCCD's special Rod and Reel Lube and All Reel Grease. This powerful twosome is a preparation that penetrates, cleans, reduces friction, lubricates, and provides extra protection against rust and corrosion. An angler can cast further with smoother retrievals thanks to the X-1R Tackle Pack.

Once again, the X-1R Tackle Pack is environmentally harmless, non-hazardous, non-flammable, and is used and endorsed by both fresh and saltwater guides and certain reel manufacturers.

Sun Coast Chemicals of Daytona has entered the two new products into retail and wholesale sporting goods markets through the U.S. west coast-based Oshman's Sporting Goods and Academy Sporting Goods chains. SCCD has received its vendor acceptance from the Wal-Mart Super Store chain, as they too have expressed an interest in the SCCD environmentally safe lubricant product line.

Not bad for a company that started out "crawling" just a few years ago, now to become a fast-paced producer of a broad family of environmentally-friendly products.

®X-1R is a registered trademark of Sun Coast Chemicals of Daytona, Inc.

®Teflon is a registered trademark of E. I. du Pont de Nemours and Company.



For the hunting enthusiast, the biodegradable Gun Lube Cleaner & Grease protects against corrosion.

FLEXIBLE CIRCUITS



Flexible circuitry is an arrangement of printed wiring that offers certain advantages over other means of interconnecting the components of an electronic system. First applied on military aircraft and missiles, where size, weight and reliability are of primary importance, the circuitry's flexibility allows it to be molded to the shape of a chassis for marked reduction in bulk. Although flex circuits generally cost more than conventional connectors, they nonetheless offer savings in some applications because they are less costly to install. The flexible circuit is also attractive in dynamic applications, those that involve continuous or periodic movement of the circuitry; in such applications, where reliability must be maintained over millions of flexing cycles, flexible circuits have demonstrated excellent performance.

Now being used in a broad range of civil applications as well as in military and space systems, flexible circuits are produced by combining three materials: an insulating plastic film; a metallic conductor, usually copper foil; and an adhesive, one of several types of polymers, to bind the insulator and the conductor into

a laminated circuit. The adhesive is important to the overall performance of the circuit and it is selected with care, taking into consideration such factors as bond strength; resistance to temperature during processing and in the operation of the end product; resistance to moisture, which can create "voids" or defects in the bond; insulation resistance; and the flexible lifetime of printed circuit.

A new type of laminating adhesive has made its appearance in commercial manufacture of flexible electronic circuits. Developed by Langley Research Center, it is a thermoplastic polyimide resin known as LARC-TPI; it is being used to produce laminates under an exclusive NASA license, by Rogers Corporation's Circuit Materials Division, Chandler, Arizona, one of the nation's largest manufacturers of flexible circuits. NASA has granted a license to Japan's Mitsui Toatsu Chemicals to produce the resin and Mitsui has built a plant for commercial production of the adhesive; NASA is in the process of li-

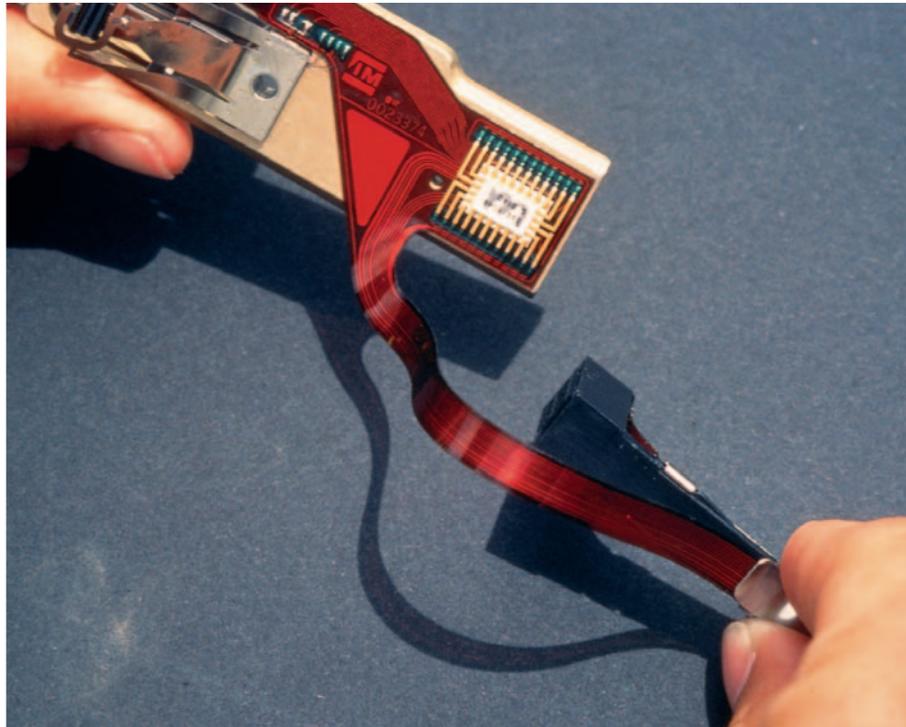
ensing Rogers Corporation and three other companies to make the resin.

The family of linear polyimides of which LARC-TPI is a member are generally tough, flexible and have excellent mechanical and electrical characteristics over a wide temperature range. Hence, they have been used—and are being considered for broader future use—as structural adhesives for bonding together parts of aircraft, missiles and spacecraft subjected to high temperatures, for example, engine nacelles and cowls, or the friction-heated leading edge of a high speed airplane. The problem with linear polyimides is that they have been difficult to process.

Special requirements for bonding components of a proposed space system led Langley Research Center to undertake development of an advanced structural adhesive by chemically altering the structure of the linear polyimide to improve its overall characteristics and eliminate processing problems. The resulting LARC-TPI has substantially improved processability; it can be processed at lower temperature and it has good moisture resistance, both of which contribute to prevent-

ing formation of voids; and it has excellent adherence to a large number of plastics and metals. Although originally developed as a structural adhesive, LARC-TP1 was found to have special utility in laminating flex circuits and it has other applications, such as a matrix for fiber reinforced composite materials; for high temperature resistant films, foams and fibers; and as a molding powder for void-free molded parts.

In its initial commercial application by Rogers Corporation's Circuit Materials Division it is being used as the adhesive that binds the insulating film Kapton® to copper foil conductor material in the manufacture of flexible circuits; the photo at left shows a spool of copper foil and a spool of Kapton®. In the other photos are representative Rogers Corporation flexible circuits; the coins indicate size. The product line of the Circuit Materials Division spans a broad spectrum that includes flexible circuits for such consumer products as electronic watches, cameras, TV games, calculators and burglar alarms; industrial applications such as display panels, medical instruments, test instrumentation, optical controls and electrostatic copiers; computer jumpers,



memories, terminals and printers; aerospace systems such as missiles, transponders, telemetry and avionics; such automotive applications as dashboard clusters, fuel controls, engine controls and pollution controls; and, in communications, CB radios, telephone receivers, telephone switching equipment, pagers and antennas. ▲



© Kapton is a registered trademark of E.I. du Pont de Nemours and Company.

MARSHALL SPACE FLIGHT CENTER—Spinoff 1998

IDENTIFICATION SYSTEM

The parts count for a Space Shuttle is a whopping number in the millions. Take for instance a Shuttle orbiter's protective veneer of heat shield tiles. Each of the thousands of tiles is catalogued as to size, type of tile, and location on the vehicle. To identify, track, and record keep these tiles, digital data matrix technologies were developed at the Marshall Space Flight Center.

Today, individual heat shield tiles on the fleet of orbiters are marked with a high data-density, two-dimensional, machine-readable symbol. This NASA-developed technology helped to launch a new commercial endeavor in product coding.

Through a NASA Space Act agreement, CiMatrix Corp. of Canton, Massachusetts has been able to commercialize the product coding idea by establishing the Symbology Research Center (SRC) of Huntsville, Alabama. Opening its doors for business in August 1997, SRC is commercially marketing a new method of identifying products with invisible and virtually indestructible markings. These laser-etched markings are termed "compressed symbologies."

SRC offers compressed symbologies as a way to automate inventory and cut warehousing costs and avoid part shortages. Other benefits of direct parts marking are updating the part's history in real-time, increasing read rates to virtually 100 percent, guaranteeing part/component integrity, and eliminating paper labels and tracking paperwork.

No longer does a company have to face missing paper labels—labels that can fall off a high-value part or product due to heat, cold, rain, wind, and other inhospitable conditions.

The permanent digital data matrix codes work on practically any surface, be it steel or metal, even plastics, glass, paper, fabric, ceramics, or other material. Compressed symbologies can withstand extreme fluctuations of temperatures, up to 2,200 degrees Fahrenheit and an air flow exceeding 18,000 miles per hour. That is the heat load and speed associated with a Shuttle orbiter during a space mission.



Director of Symbology Research Center, Donald Roxby, inspects laser-applied product labeling.



Permanent direct marking of products assures ease of tracking and record keeping.

The coding technology provides up to 100 times as much information as linear bar coding symbology in the same or less space. Markings can range in size from a mere four microns (read microscopically) to as large as two square feet (read telescopically). Commercial uses for the new labeling technology abound. According to Donald Roxby, SRC's Director, the marking system is attracting a varied clientele with a range of commercial interests. "Everything from electronic parts to pharmaceuticals to livestock," Roxby reports. He sees a growing need for an identification system that can be placed directly on a product, regardless of that product's shape, size, color, and other features.

Additional commercial markets for the marking technology have been targeted. These include counterfeit fasteners that can be discovered and removed without replacing every fastener on the product. Engine parts can be accurately tracked during the product's entire lifetime. Delicate and expensive items can be easily and more accurately inventoried and guarded against theft.

The growing list of customers for laser-etched symbol coding already includes major companies in the automotive business, such as General Motors, TRW, and Borg Warner. In the electrical and semiconductor business sector, Hewlett Packard, Intel, and Motorola are customers. Pharmaceutical suppliers Johnson & Johnson, Eli Lilly, and Parke Davis also use symbol coding on their products.

Quick solutions for overcoming marking problems are available from the Symbology Research Center. Considered the most advanced 2-D symbology research and development laboratory in the world, SRC maintains the country's most comprehensive materials marking database. The center has an ongoing Space Act agreement with NASA to further advance this 2-D technology. Any governmental or commercial entity can request assistance on a specific product identification problem by submitting a problem statement through the Marshall Space Flight Center Technology Utilization Office or directly through the SRC.

STENNIS SPACE CENTER—Spinoff 1993



Resources Management System

**A NEW LINE OF
SOFTWARE PRODUCTS
EVOLVES FROM A
NASA COMPUTER
PROGRAM**

DeltaData Systems, Inc. (DDS), Picayune, Mississippi is a “double-barreled” spinoff company, one formed by a group of former NASA/industry engineers to produce a line of products that evolved from a NASA-developed computer program for processing remotely sensed data.

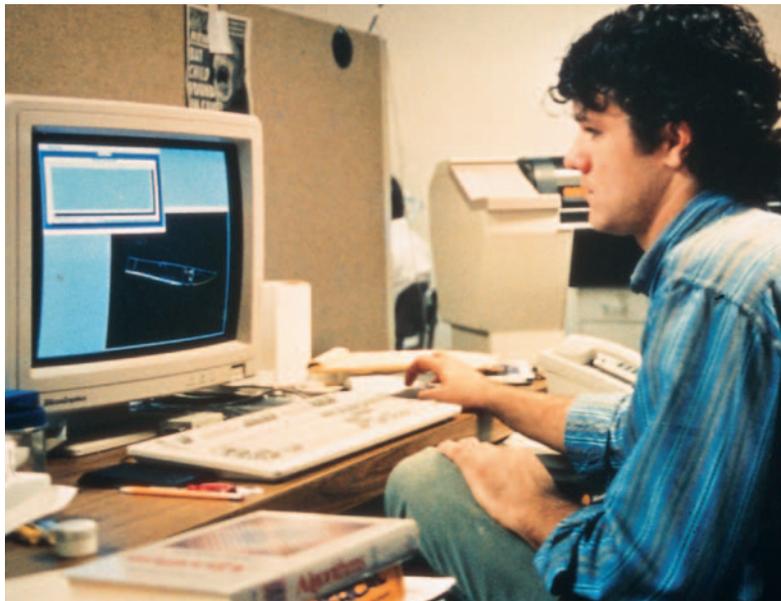
DDS initially used NASA’s ELAS (Earth Resources Laboratory Applications Software) as a “shell” for developing the company’s Atlas Remote Sensing and Information System, used to process satellite and aircraft data, to digitize soil and topographic maps, and to generate land-use maps. DDS

has built on that experience, using ELAS as the algorithmic basis for a number of product advances in the remote sensing/GIS market.

A recent example is AGIS, a hardware/software package designed for geographic information systems (GIS) and land information systems (LIS). AGIS (Advanced Geographic Information System) offers the capability for simultaneous processing of

remotely sensed data (raster) and map data (vector). The system permits operation in raster only, vector only, or raster/vector modes; *below*, DDS employee Deron Risinger is conducting an image analysis on a UNIX workstation with raster/vector simultaneous processing.

The AGIS software was designed to operate on a low cost microcomputer, states DDS sales literature, which adds that “AGIS provides a powerful set of resource management tools that puts GIS/LIS within reach of small and medium-sized operators.” ●





COMMERCIAL BENEFITS

NASA and private industry have a history of working together to create new technologies that benefit the lives of people around the globe. In 1958, Congress mandated that NASA technology and know-how be made accessible to companies and entrepreneurs searching to develop tangible products and services. These products resulting from NASA technology are then made available in the commercial marketplace. This section offers a variety of information on some of these space-age products and technologies, also known as spinoffs.

Assistance to companies seeking to utilize NASA technology for commercial purposes is provided through the NASA Commercial Technology Network (NCTN), a nationwide group of technology transfer organizations. The variety of commercial technology activities conducted by the NCTN, including licensing agreements, research, engineering assistance, and funding have forged strong and successful partnerships between NASA and business over the years. Each of these unique partnerships serves as an icon to NASA's commitment to bring space technology down to Earth.

As NASA continues to push further into space and beyond, new partnerships and innovations will continue to provide products and opportunities that stimulate and support the national economy, and benefit the American consumer.

A NEW FRONTIER FOR CARDIAC MONITORING

Hemodynamics is defined as the study behind the forces involved with blood circulation. Previously, monitoring these forces presented a costly and invasive procedure, but because of NASA funding and technology, cardiac patients were given a non-invasive monitor that gives accurate data about their hemodynamic status. CardioDynamics International Corporation (CDIC), of San Diego, California has created the BioZ® System through a **Small Business Innovation Research (SBIR)** award from Johnson Space Center, providing patients and physicians with a cost-effective and highly accurate monitoring system.

The BioZ non-invasive heart monitor is based on a technology known as Impedance Cardiography (ICG). BioZ provides the physician with vital information about the heart's ability to deliver blood to the body, the force one's heart exerts with each beat, and the amount of fluid in the chest. Specially designed bioimpedance sensors placed on the neck and chest monitor 12 different parameters, including cardiac output, contractility, systemic vascular resistance, and thoracic fluid content. These sensors monitor the electrical conductivity of the body—information that is converted into blood flow data and is displayed in real time on a monitoring screen.

Previously, the most effective method for acquiring information about the mechanical functions of the heart was through pulmonary artery catheterization, also known as

right-heart catheterization. However, this procedure is invasive, risky, uncomfortable, and often requires a hospital stay. Because of the non-invasive nature of BioZ, the same information can, for the first time, be obtained in a physician's office, as well as in a hospital setting.

Recently, NASA used ICG as a means for studying the effects of hypergravity on the cardiovascular system. Originally, ICG was used to monitor the cardiac output of astronauts in space flight. At the time, ICG worked well in healthy astronauts, but had technological challenges to overcome in order to work for the ailing population who needed it the most. CDIC made significant advancements including the addition of its DISQ™ (Digital Impedance Signal Quantifier) technology and the Z MARC™ Algorithm, increasing the accuracy and reproducibility of this technology. The ICG technology continues to be used by NASA for space research programs because of its ability to produce hemodynamic measurements in an accurate and non-invasive manner.

BioZ.com™ and BioZ.pc™ are two additional products that incorporate the same sensors present in the original BioZ system. The “com” in BioZ.com stands for cardiac output monitor. This fully integrated system is essentially a smaller version of the BioZ, combining the same abilities with a compact, lightweight design, while providing greater



The BioZ.com™ noninvasive hemodynamic monitoring system uses Impedance Cardiography to calculate 12 hemodynamic parameters.

portability. The BioZ.pc is a PC-based monitor and has been designed for Internet integration. The information acquired from the sensors in the BioZ.pc is then sent to an Internet database where it can be easily accessed by medical professionals. CDIC is also anticipating the development of BioZ.tel.™ which will allow for hemodynamic monitoring in the patient's home. While this product is not yet available, it will utilize the same base technology and enable the patient to transmit the data to his or her physician through a telephone line or e-mail. CDIC's ongoing effort to reinvent the use of

NASA technology has shown remarkable gains in the field of cardiology and medicine. The BioZ ICG technology has been clinically proven to improve patient prognoses and to decrease costs. With its proprietary ICG technology, the company is able to improve the way medicine is practiced around the world and help the medical community battle the number one killer of both men and women—cardiovascular disease. ❖

BioZ® is a registered trademark of CardioDynamics International Corporation. BioZ.com,™ BioZ.pc,™ BioZ.tel,™ DISQ,™ and Z.MARC™ are trademarks of CardioDynamics International Corporation.



A doctor uses the BioZ.com™ technology to monitor a patient's hemodynamic status in the comfort of an office rather than a hospital.

VERSATILE VIALS

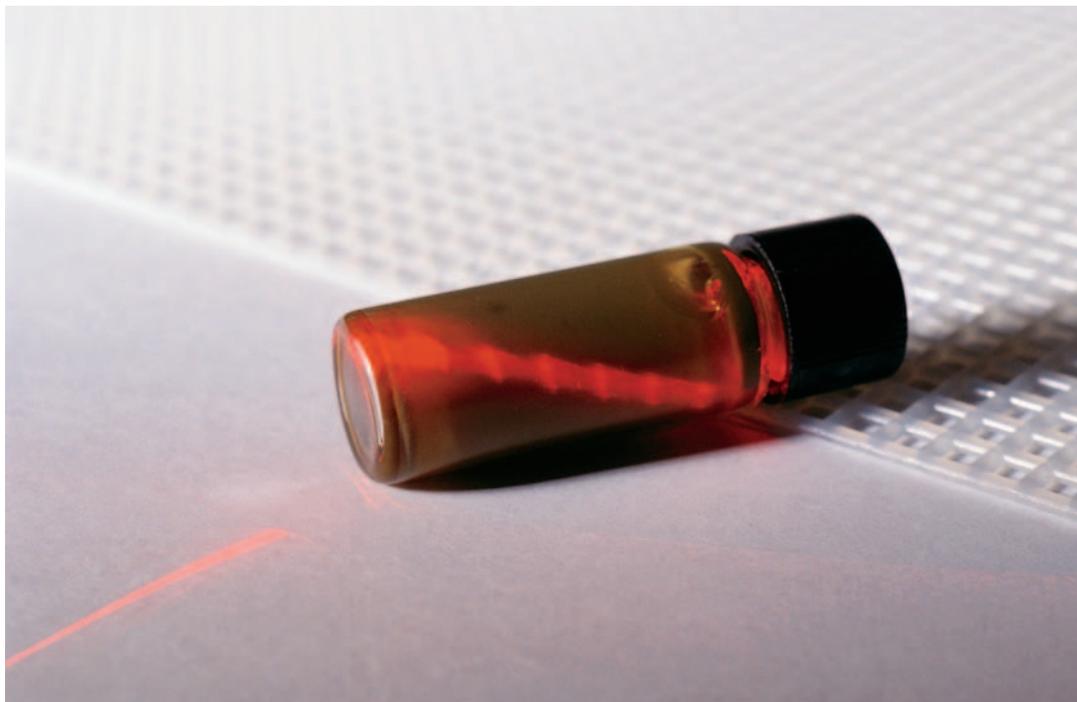
Small Business Technology Transfer (STTR) funding helps create thousands of fascinating beneficial products. Through an STTR contract from NASA's Johnson Space Center, Advanced Fuel Research, Inc. (AFR), of East Hartford, Connecticut, developed an innovative product that provides significant opportunities in a variety of fields.

AFR developed a new sol-gel material coating for sample vials to be used in surface-enhanced Raman (SER) spectroscopy. Raman spectra consist of a wavelength distribution of bands that correspond to molecular vibrations specific to the sample being analyzed. In practice, if a laser is focused on a sample, the scattered radiation, or Raman, is optically collected and directed into a spectrometer. The spectrometer then provides wavelength dispersion and a detector converts the collected photon energy into electrical signal intensity. Due to the low conversion of incident radiation to scattered radiation, Raman spectroscopy has traditionally been limited to applications that were difficult to perform through infrared

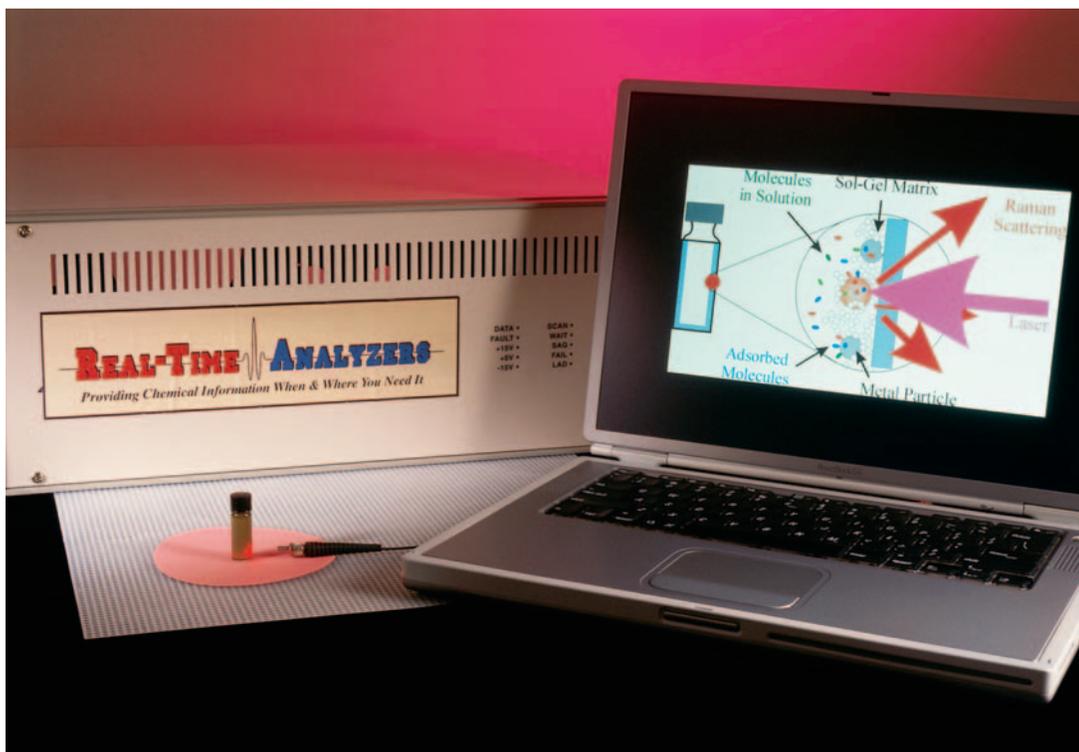
spectroscopy. However, AFR removes some of these limitations with their new SER coated sample vials.

The sol-gel material was developed for NASA to provide trace chemical analysis capabilities, and consists of silver nanoparticles embedded in a porous sol-gel glass. The new material increases Raman scattering by one million times, and sometimes more. Each SER vial is coated with the SER active sol-gel material, enabling it to provide molecular structure information. This patented coating allows researchers to identify and quantify chemicals at parts-per-billion concentration levels.

To use the product, a solution containing the chemical to be tested is injected into the vial. The entire vial is then placed in a Raman spectrometer for analysis. The resulting measurement consists of the wavelength distribution of bands in a unique pattern, which relates specifically to the chemical being tested, enabling simple identification of chemicals, biochemicals, and pharmaceuticals.



A single vial with a laser passing through it during a sampling procedure.



The analyzer takes samples using a laser, which is passed through the sol-gel-coated SER vial. The diagram displayed on the computer explains the sol-gel process.

NASA projects applications of the sol-gel coating technology for monitoring water quality aboard spacecraft and astronaut health through body fluid analysis. The technology provides such improved advantages over traditional analytical methods that it will be used in a variety of fields.

AFR has uncovered numerous commercial applications for the vials. In the fields of biomedical and forensic science, the coated vials are used to identify physiological chemicals present in blood and urine. The vials are used in the pharmaceutical industry in the area of drug development and discovery. In the drug enforcement field, using the vials helps with detection of trace amounts of drugs on surfaces. The SER vials will also help to identify contaminants in water sources, such as various inorganics and pesticides.

The new vials have advantages over other SER materials. Former products required that samples be pre-mixed or

dissolved into specific solvents or reagents. The SER vials do not have these limitations, and measurements can be performed using any solvent. Furthermore, the signal appears in less than one second. The sol-gel material will stay active for at least one year and the vials are compatible with any Raman spectrometer. Most importantly, the SER activity can be duplicated from vial-to-vial, allowing for reproducible results.

AFR is proud to be the only provider of a commercial SER product. As a result of initial sales of the SER vials and the development of a process Raman analyzer, AFR formed a new spinoff company: Real-Time Analyzers. It is the mission of Real-Time Analyzers to provide its unique trace chemical analysis capabilities to various industries. ❖

NEW TECHNOLOGY SPARKS SMOOTHER ENGINES AND CLEANER AIR

Automotive Resources, Inc. (ARI), of Sandpoint, Idaho, has developed a new device for igniting fuel in engines—the SmartPlug.™ With assistance from **Small Business Innovation Research (SBIR)** funding and NASA's John H. Glenn Research Center, Mark Cherry, inventor of the SmartPlug, has revolutionized the traditional spark plug.

SmartPlug is a self-contained ignition system that may be retrofitted to existing spark-ignition and compression-ignition engines. The technology behind the SmartPlug is a pre-chamber containing a catalytic heating element, where ignition starts. A small amount of fuel-air mixture enters the area, where it is ignited by a tiny, heated wire or glow plug. This process is very similar to that of a diesel cycle. However, unlike the diesel cycle, the SmartPlug does not require heavy compression for its glow plug to set off combustion. The SmartPlug needs as little as six watts of power for warm-up, and requires no electricity at all when the engine is running. Unlike traditional spark plugs, once the SmartPlug ignites the engine, and the engine heats up, the power supply for the plug is no longer necessary. The SmartPlug becomes self-sustaining.

SmartPlugs can be used in a variety of industries. For example, in the utility industry they can be used in tractors, portable generators, compressors, and pumps. In addition to general-purpose applications, such as lawn mowers and chainsaws, SmartPlugs can also be used in the recreational, marine, aviation, and automotive industries.

Advantages of the SmartPlug ignition system are numerous. Unlike traditional ignition systems the SmartPlug system requires no distributor, coil points, or moving parts. This

revolutionary system, which has the ability to ignite a variety of fuels, requires no modification to the existing engine. SmartPlugs are non-fouling, with a faster and cleaner burn than traditional spark plugs. They prevent detonation and are not sensitive to moisture, allowing them to be used on a variety of engines. Other advantages include no electrical noise, no high voltage, exceptionally high altitude capabilities, and better cold-start statistics than those of standard spark ignition systems.

Dr. Forrest Bird, famed aviator/inventor from Idaho, volunteered to test-run the SmartPlug in his custom-built J-3 aircraft. Dr. Bird reported an increase of 200 rpm throughout the flight and a noticeable increase in engine smoothness. Tests done by ARI in collaboration with NASA's Glenn Research Center have yielded similar results, with the SmartPlug producing equivalent-to-stock horsepower and other benefits. What does this mean for the aviation industry? For one, it means smoother, more efficiently run aircraft and cleaner emissions. And because SmartPlug can operate using a variety of fuels, a more cost-effective means of air travel is also possible.

Future applications for the SmartPlug are being evaluated by manufacturers in the snowmobile industry for use in reducing air pollution in areas such as Yellowstone National Park. The Environmental Protection Agency (EPA) is interested in the SmartPlug technology because it greatly reduces emissions by enabling an engine to run on an alcohol and water mixture, instead of an oil and gas mixture. The EPA has given the snowmobile manufacturers until 2005 to reduce emissions produced by their machines. Mr. Cherry's SmartPlug technology has the ability to produce cleaner, smoother-running engines, which in turn will support the ongoing efforts for cleaner air. ❖

SmartPlug™ is a trademark of Automotive Resources, Inc.



Automotive Resources' SmartPlug™ technology uses a needle-like ceramic and metal core to deliver fuel ignition without a spark. Once the SmartPlug ignites the engine, the power supply for the plug is no longer necessary, and the SmartPlug becomes self-sustaining.

A POWERFUL NEW ENGINE

An innovation from Moller International, of Davis, California, will make engines cleaner and more efficient. Through **Small Business Innovation Research (SBIR)** funding from NASA's Glenn Research Center, the company created a new coating for rotary engines used for industrial applications, watercraft, and other performance-demanding machines. These coatings significantly improve the fuel consumption of a vehicle while reducing emissions. The new coatings are offered in the new Rotapower® engine, which is produced and distributed by Moller subsidiary, Freedom Motors, Inc. It is this innovative coating that allows the Rotapower engine to function smoother than other models, reducing wear and protecting the engine.

The PS200 plasma-applied engine coating was developed at Glenn Research Center. The engine uses a unique piston-free design that incorporates this advanced rotor coating, which is applied to the housings of the engine and serves to reduce cooling requirements and improve thermal efficiency.

The Rotapower engine has the ability to operate on a variety of fuels, including gasoline, natural gas, diesel, alcohol, and kerosene. Typically, most engines are piston-driven and operate on unleaded gasoline, but the new engine can be easily adapted to run successfully on certain alternative fuels with only minor adjustments.

A small and lightweight engine, it is projected to replace many of today's bulkier versions. Installing a smaller and lighter engine means less energy to move a vehicle or to operate machinery, resulting in saved fuel. To demonstrate size, the 10 horsepower model fits in the palm of one's hand, while the 160 horsepower model fits into a 5-gallon bucket.

Also unique to the Rotapower engine is its low number of two moving parts, which are on roller bearings and move in one circular direction. This elegant simplicity reduces vibration and supports engine efficiency. The optional module has only one moving part so that horsepower can be added without increasing the complexity associated with typical modification kits. Another unique feature of the engine is its charge cooling capability, which reduces the need for cooling components such as pumps, regulators, radiators, and more. These original and effective elements ensure smooth engine operation, leading to a long engine life span.



Incorporating NASA technology into the Rotapower® engine gives it the ability to run cleanly and efficiently on a variety of fuels.

The clean running Rotapower engine is environmentally appealing, because it eliminates over 98 percent of the total emissions given off by traditional piston engines. Fewer pollutants are spewed into the air, making it especially attractive in areas where air pollution is a major problem. Due to the clean-burning nature of the engine, it meets the stringent standards set by the California Air Resources Board.

The engine also has numerous commercial benefits in several types of recreational, industrial, and transportation applications, including personal watercraft, snowmobiles, portable generators, and pumps. Through the efforts of Moller International and Glenn Research Center, the Rotapower engine will continue to change the face of engine-powered products—making them cleaner, cheaper, and more efficient. ❖

Rotapower® is a registered trademark of Freedom Motors, Inc.

Good Enough for the X-38, but Made for Commercial Aircraft

As FAA regulations become more demanding, aviation companies must find new ways to create safer products. Aircraft Belts, Inc. (ABI), of Kemah, Texas, was looking for a way to ensure the safety of its customers by developing a thorough test system for aviation restraint systems. Previous safety restraint test methods did not properly measure the load distribution placed on the restraints, leaving an unknown factor in meeting safety standards. ABI needed to improve its testing methods and update its test equipment. Through a partnership with NASA's Johnson Space Center Technical Outreach Program, the need was met.

After looking for a pre-made testing machine that could meet their requirements, ABI personnel discovered that anything purchased off-the-shelf would have to be totally overhauled in order to obtain the data necessary to give to their customers. Norman Ballard, vice-president of ABI, put out a call for help to Johnson's Technology Outreach Program and work began almost immediately.

Johnson contacted ABI to discuss its facilities, standards, and required test data. ABI was then invited to the Structural Test Lab where NASA personnel demonstrated the testing process for tethers on parachutes that are going to be used on the X-38. Because the safety of astronauts can hang on the quality of the tethers, they are tested repeatedly for durability and strength. The test system used by Johnson to evaluate the performance of the parachute tethers was exactly what the company needed to test its safety belts.

With the assistance of NASA engineers, ABI developed a hydraulic test system that provides the consumer with in-depth data about the load placed on the restraint system throughout the duration of the test. The old systems were only able to detect if the belts could sustain the applied force and could not target the problem of providing load data. In comparison, the new system modeled after the one used by NASA, can collect data that tells exactly what went wrong with belts that break and why. Depending on the test

requirements of various restraint components, the system can exert a subjected force ranging from merely a few pounds to thousands. The test force can be applied to an entire safety restraint system or to its individual parts, including, stitching, webbing, and hardware.

The new test system allows load tests to be conducted in a quick and easy manner. The preparation time for the test has been minimized and all test data is now computerized. Also, the safety to the operator has been improved. Previously, the testing apparatus had no safeguards to protect against flying debris resulting from breaking belts. Suggestions from the engineers at Johnson, led to the addition of a protective wall to shield the operator. NASA know-how allow ABI's customers to receive restraint systems that will ensure the safety of passengers on all sorts of aircraft. ❖



Engineers from NASA's Johnson Space Center helped Aircraft Belts, Inc. to develop a hydraulic test system that provides detailed data about the load placed on aircraft restraints.

LIGHTNING DETECTION IN A FLASH

Thunderstorms may always remain an erratic and unpredictable force of nature. Unfortunately, when lightning strikes serious damage can occur. This risk must be thoroughly analyzed and precautions must be taken—especially when multi-million dollar vehicles, such as Space Shuttles, are at risk. In a joint project with NASA's Kennedy Space Center, Global Atmospheric, Inc. (GAI), participated in the upgrade and commercialization of the Lightning Detection and Ranging (LDAR) System. Under a Space Act Agreement, GAI and Kennedy agreed to the joint development of a new LDAR system that meets the needs of both NASA and private industry.

Kennedy Space Center averages 75 thunderstorm days per year, so lightning warnings are nothing new, especially in the hot, humid months of summer. NASA needed a system that could minimize unnecessary warnings and maximize work productivity without sacrificing the safety of its personnel and projects. The resulting development was a volumetric lightning mapping system.

NASA operates a three-dimensional LDAR system capable of determining the exact location and altitude of in-cloud and cloud-to-cloud lightning. This is done through the analysis of the exact arrival times of electromagnetic pulses. The times are collected using seven antennae stationed around the region that detect VHF radiation. The collected data is then analyzed, geo-located in three dimensions, and transmitted to the Weather Squadron, 45th Space Wing, Patrick Air Force Base, Satellite Beach, Florida, and to the National Weather Service personnel at Johnson Space Center, Texas and in Melbourne, Florida. They use the data to define the existence and volumetric extent of the potential lightning hazard for the space program and Central Florida. GAI was able to see the numerous opportunities and applications of a system that could provide accurate projections of lightning patterns in almost real-time, and made a good thing better.

GAI is the world's largest manufacturer of lightning detection and location equipment, providing service to customers in over 40 countries. They also serve as owner and operator of the U.S. National Lightning Detection Network (NLDN). While the NLDN is able to plot the strike locations of each cloud-to-ground flash, it does not locate in-cloud and cloud-to-cloud flashes.

Under the Space Act Agreement, GAI contributed its wealth of experience and resources to update and improve the current lightning mapping system used by NASA. Previously, commercial systems were only capable of locating cloud-to-ground lightning. The resulting innovations allowed GAI to position the LDAR system for commercial applications. The upgraded product has the ability to measure in-cloud and cloud-to-cloud lightning. Notable improvements have also been made in the system's location accuracy and signal detection.

The new product, known as LDAR II, is targeted for use by utility providers, aviation companies, airports, and commercial space vehicle launch facilities. Presently, forecasting services, research facilities, and a utility company are using the system. Weather forecasting services use LDAR II to view the height and horizontal extension of each lightning flash. The LDAR II antenna consists of a fiberglass lightning mast containing signal processors that provide data to a computer. The user can then interpret the data, analyze the risks, and take the necessary precautions.

There are obvious safety benefits associated with the use of LDAR II. Annually, lightning kills more Florida citizens than any other weather hazard. It is hoped that the widespread use of the LDAR systems will reduce this sort of tragedy. For example, the National Weather Service used the technology to assist with weather forecasts during the World Olympic soccer tournaments held in Orlando, Florida, during the summer of 1996. Without the projective capabilities of the LDAR system, thousands of spectators could have been placed in the path of serious injury with no forewarning of a possible lightning strike. From the protection of people to space vehicles, electric companies to launch pads, GAI and NASA created a technology full of safety and operational benefits. ❖



The LDAR II fiberglass lightning mast contains signal processors that provide data to a computer where the user can then interpret the extent of lightning hazard.

NEW FLUID PREVENTS RAILWAY ICE

Through a licensing agreement between NASA's Ames Research Center and Midwest Industrial Supply, Inc. (MIS), comes a new development to make railroads safer and more reliable during wintry conditions. MIS has been the leading provider of deicing and anti-icing fluids used on railway systems for more than 20 years. Through the licensing agreement, two MIS products have been enhanced with NASA's anti-icing fluid technology.

This NASA technology was designed specifically for use as an anti-icing and deicing agent. It is an effective and environ-

mentally friendly, biodegradable fluid that has proven its capabilities over a broad range of low temperatures. The fluid is also non-corrosive, and will not damage the railways when applied. It is safe to use with the electrical wiring associated with railways, because it is not conductive.

MIS offers the new fluid in two commercial products, the Zero Gravity™ Third Rail Anti-Icer/Deicer and the Ice Free Switch.® Using NASA's fluid technology, these products form a protective-coating barrier that prevents the buildup of ice and snow. Applying the fluid to the railway components prior



Using Ice Free Switch,® enhanced with Zero Gravity,™ helps keep railways free of ice and snow.

to ice or snowstorm works as an anti-icing fluid, remaining in place to melt precipitation as it hits the surface.

It also functions as a deicing fluid. If applied to an already frozen switch or rail, it will quickly melt the ice, free the frozen parts, and then remain in place to prevent refreezing. Additional benefits include the ability to cling to vertical rail surfaces and resist the effects of rain and wind.

Manually freeing frozen switches can take an entire crew several hours. With the Ice Free Switch, it takes only five minutes to treat the switch by spraying, brushing, or pouring on the product. Ice Free Switch requires as little as one gallon per switch whereas other deicing fluids require five to ten gallons of liquid to effectively melt ice.

Zero Gravity serves the same anti-icing/deicing purposes but applies fluid to the third rail through a system that is easily installed onto mass transit cars. A tank of fluid and a dispensing system are placed underneath the train car and the fluid is applied as the train runs its route.

The fluid leaves no build-up, does not become tacky, and will not leave excessive residue on the application site. It also works as a lubricant to keep rails and switches operating smoothly. Due to these beneficial features, the fluid can be left unattended for an extended length of time once it has been applied. This is a significant benefit to consider when treating rail components located in remote areas.

The fluid is effective in temperatures as low as -70°F , which is an improvement over the use of heaters. Heaters have trouble functioning if temperatures are sub-zero, and they have high rates of energy-consumption. Use of the new products has resulted in fewer instances of lost power and stalled trains. Most importantly, passengers can travel safely and with fewer weather-related delays.

MIS is impressed with the results of its enhanced products for railroad operations. The company looks forward to expanding its products to solve similar problems in other industries. Many new applications will likely be found for this remarkable fluid from the space program. If recent successes are an indicator, a smooth ride moving the anti-icing technology forward is assured. ❖



The Ice Free Switch,® enhanced with Zero Gravity™ and manufactured by Midwest Industrial Supply, Inc., uses NASA-developed technology to make railways safer.

Ice Free Switch® is a registered trademark of Midwest Industrial Supply, Inc.
Zero Gravity™ is a trademark of Midwest Industrial Supply, Inc.

CYRANO "NOSE" THE SMELL OF SUCCESS

Cyrano Sciences, Inc., of Pasadena, California, has commercialized a simple, accurate, non-invasive tool that enables "machines to smell." NASA's Jet Propulsion Laboratory (JPL) funded a California Institute of Technology (Caltech) project, which resulted in the creation of technology used in the "Cyanose 320." The Cyanose 320 is used for quality control purposes in the food and chemical industries. NASA further developed Caltech's technology and incorporated it into a unit that monitors closed human habitats such as the Space Shuttle, where air must be recycled. Early detection of spills or leaks is essential in order for the space crew to take immediate action and remedy the situation. Caltech later licensed the technology to Cyrano for commercialization.

Using a sensor array and onboard pattern recognition algorithms, the lightweight, portable device works by

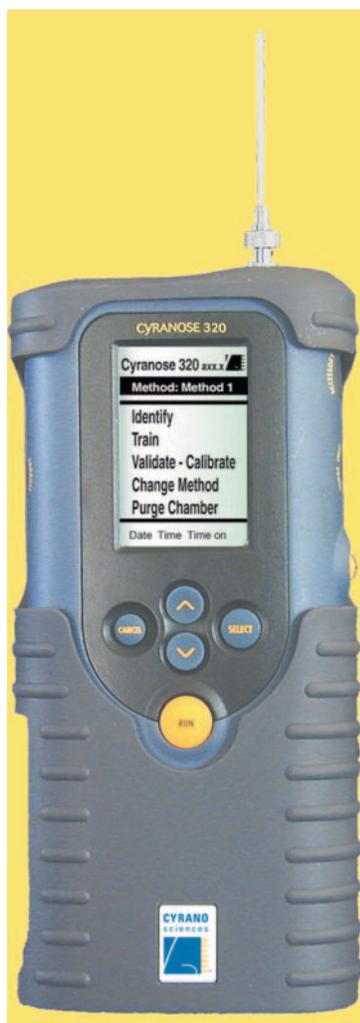
exposing an array of polymer composite sensors to the chemical components in a vapor. When the sensors come in contact with the vapor, the polymer expands like a sponge, changing the resistance of the composites. The change in resistance is measured, and from that measurement, the presence of a pre-trained substance is determined with a quick and accurate diagnosis.

The Cyanose 320 requires a one-time training session in which the user exposes

the sensor to each type of sample that will be encountered during testing, creating a base-group to which all future samples will be compared. The sampling step involves placing the tip of the device near the sample and simply pressing "Run." Air referencing, vapor sampling, sensor measuring, and data processing are all handled automatically and take roughly one minute to complete. If it matches one of the pre-trained samples the unit reports the identity of the sample. If the unit does not recognize the sample, an "unknown" reading is given. The unit automatically resets itself and the polymer composite sensors return to their original resistance.

This real-time, portable device enables food companies to spot test raw materials for batch-to-batch consistency, spoilage, or contamination. The Cyanose 320 is also used by chemical and petrochemical companies for quick assessment of the chemical status associated with various industrial processes. For example, profiling a chemical environment in a hazardous materials situation allows emergency crews to accurately select fire retardants, containment strategies, and protective gear.

Future applications for the Cyanose 320 are fast growing and other uses of this technology are on the horizon. For example, the diagnosis of disease often relies on invasive testing methods, subjecting patients to unpleasant procedures. A tool such as the Cyanose 320, will enable physicians and dentists to provide immediate, accurate diagnosis of chemical components and microorganisms in breath, wounds, and bodily fluid. Welch Allyn, one of the world's most respected medical device manufacturers, is partnering with Cyrano Sciences to develop diagnostic products for primary care providers. In the near future, unpleasant procedures and hospital stays may become less frequent. Because of Cyrano Sciences' technology, a simpler, less invasive diagnosis may only be a trip away to your physician's office. ❖



The Cyanose 320 is a lightweight, portable device, used for quality control purposes in the food and chemical industries.

A Cool Tool for Deicing Planes

When airplanes reach cruising altitude, the high speeds and low temperatures of the air cause thin layers of ice to begin forming on the wings. Ice can present an increased safety risk to the aircraft and its passengers. Thanks to an innovation from NASA's Ames Research Center, this danger could one day be eliminated. Ames patented the Electro Expulsive Separation System (EESS), which is now licensed to Ice Management Systems, Inc. (IMS), of Temecula, California.

EESS is an aircraft ice removal system, appropriately nicknamed the "ice zapper." According to the principle inventor, Leonard Haslim, "It pulverizes ice and removes layers of ice as thin as frost or as thick as an inch of glaze." The EESS consists of layers of conductors encased in materials that are bonded directly to the airframe structure. When ice accumulates on the aircraft, an electric current is sent through the conductors, causing them to pulse. Even though the conductors move less than a twenty-thousandth of an inch in just a millisecond, the movement is sufficient to pulverize the ice. It is this highly accelerated motion that shatters the ice into particles the size of table salt; too small to be harmful to the aircraft.

In 1995, Richard Olson, CEO of IMS, first introduced the ice zapper into the private sector. He has since made improvements that have paid off with recent sales to TRW (Thompson Ramo Woolridge), who purchased the technology for use on a new line of planes. IMS envisions a variety of uses for the EESS technology in the aerospace and automotive industries.

The EESS also offers additional benefits besides the unique ability to deice planes while in flight. According to Haslim, "The ice zapper uses one-thousandth of the power and is one-tenth of the weight of electro-thermal ice removal systems used today." Using less power means that operating costs are lower, while the lighter weight translates into needing less energy to propel the aircraft, resulting in even further cost reductions.

When compared with other systems in use, such as thermal deicers and pneumatic boots, the ice zapper does very well. Thermal deicers are fairly common, although they use an enormous amount of energy and present the possibility of ice refreezing. Pneumatic boots are not always effective because they require an inflation device that is unable to work

until a quarter inch of ice has accumulated. With both systems, the ice that is loosened may still be large enough to cause problems for the plane once dislodged. For instance, in just one winter, 26 F/A-18 airplanes were seriously damaged when sizable chunks of ice entered the engines after having been removed by pneumatic boots. Because the EESS will reduce ice to such tiny particles, the chances for this type of occurrence on a plane using the technology would be very unlikely.

Even though EESS has a clear market in the aerospace industry, another potential use for the EESS is in the automotive sector. Specifically, a modified version of the ice zapper could be fitted to the windshields in cars, making the need for ice scrapers and other cumbersome methods obsolete. The automotive applications may be further explored in the future, but for now IMS is aggressively working to demonstrate value to aircraft manufacturers. ❖



The NASA-developed Electro Expulsive Separation System (EESS) is shown in a testing chamber where it proved it could rid aircraft of ice layers ranging from thin frosts to thick glazes.

A LIFETIME OF SHINE

What do fighter jets, silicon chips, and plumbing fixtures have in common? All incorporate precision surface engineering technology to stay resistant under high-pressure situations. Assistance from the NASA Glenn Research Center, located in Cleveland, Ohio, led to the development of a new product for one of the world's largest commercial plumbing manufacturers. Ohio-based Moen Incorporated identified a market need for more durable polished brass plumbing fixtures. NASA's Glenn Research Center is a leader in surface coating technology, which enhances the physical properties of a wide range of materials. The collaborative efforts of Glenn and Moen resulted in a new polished brass finish called LifeShine.®

Previously, polished brass was not popular in plumbing fixtures because of the finish's short life span. Ordinarily, polished brass is soft, corrodes easily, and is somewhat expensive. Although brass fixtures are very attractive when new, they quickly lose luster and show signs of tarnish, flaking, and discoloration.

NASA Glenn's Electro-Physics Branch worked with Moen to identify, deposit, and evaluate various abrasion and corrosion-resistant coatings. This process allowed researchers to evaluate and visualize the transition from the laboratory to commercial production; and provided a significant advantage to Moen, avoiding dead ends and costly mistakes that could have hindered the project's success.

Based on testing results generated at NASA Glenn, Moen was able to manufacture an affordable, polished brass finish that is as durable as chrome, and resists deterioration. LifeShine is guaranteed to resist normal wear and tear and is even scratch-resistant to cleaning products as abrasive as steel wool.



Monticello® Inspirations® Cathedral® Spout Copper Kitchen Faucet and Copper Liquid Dispenser in LifeShine® Copper.



Moen's PureTouch® AquaSuite™ Filtered Water Dispenser, and Monticello® Cathedral® Spout Faucet in LifeShine® Polished Brass.

With further development, Moen was able to incorporate other colors into the LifeShine finish technology including classic gold, nickel, Satine™, Black Opal™, stainless, and copper. In an effort to improve the quality of its new technology, the company added titanium to LifeShine, making the finish even stronger and increasing its already superior durability. Highly resistant to salt and humidity, the LifeShine finish will remain intact even when the fixture is dented.

The partnership between NASA and Moen resulted in the elimination of costly development efforts for Moen. The use of NASA facilities and the participation of NASA researchers, allowed Moen to avoid significant research costs and delays in the development of its new product line. According to Tim O'Brien, Vice President of Technology for Moen, "NASA assistance helped our company increase market share at a time when foreign competitors were knocking at the door." LifeShine was awarded the 2000 ASM International, Engineering Materials Achievement Award, recognizing Moen's outstanding developments in the application of materials in products. ❖

LifeShine® is a registered trademark of Moen, Inc.
Monticello® is a registered trademark of Moen, Inc.
Cathedral® is a registered trademark of Moen, Inc.
PureTouch® is a registered trademark of Moen, Inc.
Black Opal™ is a trademark of Moen, Inc.
Satine™ is a trademark of Moen, Inc.
AquaSuite™ is a trademark of Moen, Inc.
Inspirations™ is a trademark of Moen, Inc.

THE BEST WORKOUT ON EARTH, AND IN SPACE

SpiraFlex® is a revolutionary new patented technology for storing and delivering mechanical power in industrial, consumer, and fitness equipment. Kansas City-based SpiraFlex, Inc., invented and supplied this technology for use on the International Space Station, with assistance from Wyle Laboratories of Houston, Texas, and NASA's Johnson Space Center. NASA research facilities and funding helped to develop the "Resistance Exercise Device" (RED), powered by SpiraFlex. One of the primary reasons NASA selected SpiraFlex is that it duplicates the benefits of free-weights in a lightweight, portable, and safe system.

During spaceflight, the musculoskeletal system of the human body undergoes changes in response to a microgravity environment. Astronauts can lose up to 19 percent of their bone mass during spaceflights of four to six months. This puts astronauts returning to Earth or arriving on Mars at a disadvantage. Although the effects of atrophy seem easily reversible, the effects of long-duration spaceflight are not yet known.

The RED system is presently aboard the International Space Station (ISS) and is used by the crewmembers as a primary countermeasure against musculoskeletal degradation caused by microgravity. The ISS Expedition I crew completed over 30,000 exercise repetitions on the RED during their 141-day mission. Upon return to Earth, the astronauts were able to walk off the Shuttle under their own power.

SpiraFlex technology uses proprietary elastomer compounds that are molded into a range of patented shapes called FlexPacks,™ which create unique torsional resistance properties. These FlexPacks may operate alone, or linked in parallel or a series to output devices, such as pulleys or transmissions. This patented configuration allows almost any force curve to be achieved by manipulating the size of the

part, number of spokes, durometer of elastomer compound, number of connected FlexPacks, and manipulation of output device, or transmission.

The power to weight ratio of this technology is approximately three times the power per pound of traditional steel springs. Another benefit is a life cycle that far surpasses any other torsional spring. The FlexPacks were cycled at full power to over 2.5 million cycles, without failure or appreciable degradation of the force curve, which is over ten times the life of steel springs in similar applications. In addition, the FlexPacks are non-corrosive and non-conductive.

This technology provides a variety of benefits for anyone seeking a well-crafted, high-grade, strength-training machine. One of the most attractive benefits is that the unit is lightweight and portable. SpiraFlex technology is inexpensively manufactured, easily assembled, and quietly operated because no metal parts are used. Recognizing these benefits, and using SpiraFlex technology, Schwinn Cycling & Fitness, Inc., of Boulder, Colorado, launched an international fitness program for health clubs and select retail distributors, called RiPP™ (Resistance Performance Program). RiPP is an exercise program that uses RiPP Pro machines, powered by SpiraFlex technology. The program generally consists of a 45-minute resistance-training session, taught by a certified "RiPP Coach," that offers participants a motivational group exercise atmosphere.

Whether in the gym or on the International Space Station, SpiraFlex technology is helping people lead healthier lives. ❖

SpiraFlex® technology is a registered trademark of SpiraFlex, Inc.
FlexPack™ is a trademark of SpiraFlex, Inc.
RiPP™ is a trademark of SpiraFlex, Inc.



Left: The RiPP Resistance Performance Program is being used in fitness clubs across the nation.

Above: The RiPP Strength Training machine is compact and easy to use.

TEEING OFF WITH AN ENTIRELY NEW MATERIAL

When plastic was first introduced, people were fascinated by its possibilities. They watched as a new material evolved and extended its applicable uses into thousands of facets of our daily lives. A new technology, known as the Liquidmetal® alloy, is the result of a project funded by the California Institute of Technology (CalTech) in conjunction with NASA's Jet Propulsion Laboratory. Professor Bill Johnson and Dr. Atakan Peker of CalTech discovered the material while working on a research project in 1992. Industry professionals believe that this invention will change the way the world thinks of vitrified metals—similar to the way plastics have.

The Liquidmetal alloy is part of an entirely new class of vitrified metals, and is also known as metallic glass, or Vitreloy®. A vitrified metal is a frozen liquid that fails to crystallize during solidification, unlike common metals such as titanium, steel, and aluminum. Essentially, the technology takes the non-crystalline structure of glass and combines it with the properties of metal, a combination not found in nature, allowing for a product that offers the strength of a

metal with the elasticity of a polymer. This unique technology is more than twice as strong as titanium and has a higher elastic limit.

The fundamental technology behind the Liquidmetal alloy is owned by CalTech and is exclusively licensed to Liquidmetal® Technologies of Lake Forest, California. A spinoff from its parent company, Liquidmetal® Golf presents this space-age development in a complete line golf clubs that are changing the face of the game.

The unique technology is an innovative blend of titanium, zirconium, nickel, copper, and beryllium that allows for properties not achievable with other materials. It is more than twice as strong as titanium, highly resistant to deformation, and has no weak spots, providing for almost total energy transfer. It is also more comfortable to use than a standard golf club. When compared to other golf clubs on the market, clubs made with this technology have a lower vibration response along with a softer, more solid feel. Because less energy is absorbed by the club's head upon impact, more energy is transferred directly to the ball.

The increased energy transfer can also be accredited to the material's lack of atom alignment. Other metals used in golf clubs are aligned in recurring patterns. The sections where these patterns touch are known as grain boundaries that lead to the absorption of energy as opposed to its transfer. Liquidmetal alloy atoms are not aligned, therefore no connecting patterns exist—consequently, golfers can drive the ball longer and straighter than before. Presently, these unique clubs are used by some of professional golf's top players.

Vitreloy was designed for the space program and is used aboard the NASA Genesis spacecraft, as well as numerous Shuttle missions. NASA will also be using it in the construction of a drill that will help astronauts search for water beneath the surface of Mars.

Of course, Vitreloy also has other potential commercial uses. For the recreation industry, it means a whole wave of improved products in sporting equipment: tennis rackets, bicycle frames, baseball bats, and the list goes on. Because it is also biocompatible, the material may find applications in the medical industry for the manufacturing of surgical instruments and prosthetics. The Liquidmetal alloy is projected to replace many high performance materials, such as titanium, in many diverse applications. These applications include numerous opportunities in the industries of aerospace, defense, military, automotives, medical instrumentation, and sporting goods. ❖

Liquidmetal® is a registered trademark of Liquidmetal® Technologies and Liquidmetal® Golf. Vitreloy® is a registered trademark of Liquidmetal® Technologies.



The Liquidmetal® Golf family of clubs offers unsurpassed playing capabilities due to the unique nature of the innovative Liquidmetal® technology.

LEARNING THAT'S OUT OF THIS WORLD

NASA's Ames Research Center developed a new curriculum to educate the space explorers of tomorrow. The *Mars Virtual Exploration* CD-ROM results from the efforts of the Educational Multimedia Group in the Office of External Affairs. The CD-ROM is exclusively licensed to Modern School Supplies, Inc., of Bloomfield, Connecticut.

For decades, humans have been fascinated by the mysteries surrounding Mars. What is it like? Was there ever life? Will we live there someday? These questions and others inevitably arise whenever the planet is discussed. This new learning resource presents some potential answers to these questions and will undoubtedly help to cultivate an eagerness to learn more about Mars and our universe.

The CD-ROM allows students to imagine they are residents of a research team at an advanced facility divided into four different domes. Students experience how scientists approach planetary exploration through interactive exercises in ExoPaleontology, Meteorology, Exobiology, and Volcanology. Once the students have learned the facts and have consulted with the experts, they select a potential landing site. Using QuickTimeVR™ software, the students get a 360-degree view of the potential landing terrain. They are then able to virtually explore the four available sites and select the one they feel is best for conducting research.

The *Mars Virtual Exploration* CD-ROM comes complete with a printable teacher's guide and student logbook. These bonus tools provide additional content and activities for as many as 15 lessons and serve as enhancements to the rest of the material presented.

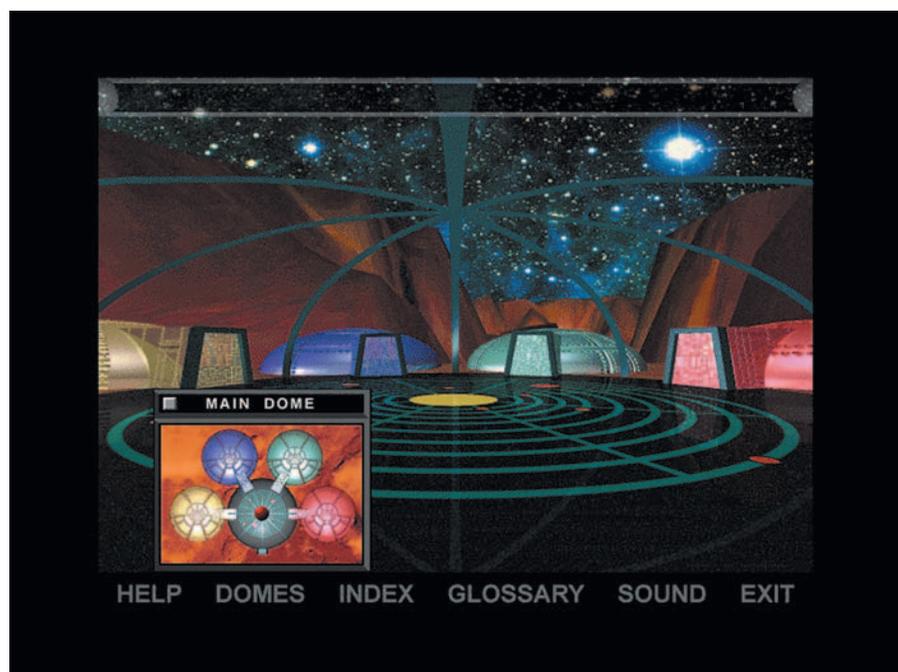
The CD-ROM is designed to target the interest of fourth through eighth grade students. Modern School Supplies, Inc. now provides students with this opportunity to learn about Mars in an interactive hands-on experience that requires the use of their critical thinking

and problem-solving skills—all very valuable assets when exploring the Red Planet. After all, with a manned mission to Mars anticipated for as early as 2018, today's students are tomorrow's astronauts, explorers, and scientists. ❖

QuickTimeVR™ is a trademark of Apple Computer, Inc.



The Mars Virtual Exploration CD-ROM allows students to virtually explore potential landing sites on the Red Planet.



By visiting four different research domes, students learn about Mars and use their newly gained knowledge to conduct a virtual exploration of the planet.

AEROGEL—FROM AEROSPACE TO APPAREL

Aerogel represents what technology experts consider the best insulation material ever invented. It weighs virtually nothing. It's flexible. It's translucent. And, it can hold up under temperatures of minus 3,000 degrees Fahrenheit. Aerogels have unsurpassed thermal insulation values, as well as sound and shock absorption characteristics.

In a process starting in 1993 with a **Small Business Innovation Research (SBIR)** contract from NASA's Kennedy Space Center, Aspen Systems Inc., of Marlborough, Massachusetts, developed an aerogel-manufacturing process that won the company the prestigious SBIR Technology of the Year Award for 1999, in Manufacturing and Materials, from the Technology Utilization Foundation. Since receiving the award, Aspen Systems has launched Aspen Aerogels, Inc.—a spinoff company tasked with commercializing aerogels.

Aerogels, invented over 70 years ago, are extremely fragile, hard to handle, and costly to manufacture by traditional means. For these reasons, the commercial industry found it difficult to produce products that incorporated the material. However, Aspen developed a revolutionary manufacturing method that cut production time and costs, and solved the handling problems associated with aerogel-based insulation products. They can now be manufactured into blankets, thin sheets, beads, and molded parts; and may be transparent, translucent, or opaque. Due to their extremely light weight and often translucent appearance, aerogels are often called "solid smoke."

Aspen responded to NASA's need for a flexible, durable, easy-to-use aerogel system for cryogenic insulation for Space Shuttle launch applications. For NASA, the final product of this low thermal conductivity system, Cryogel,® was useful in applications such as launch vehicles, Space Shuttle



Aerogel is the lightest solid known to man and is sometimes referred to as "solid smoke" or "frozen smoke."

upgrades, interplanetary propulsion, and life support equipment.

Because of its innovative manufacturing process, Aspen is expanding the commercial applications of aerogel to many industries. For the first time, aerogels can be handled and installed like any other thermal or acoustic insulation. Aspen made the material effective for window and skylight insulation, non-flammable building insulation, and inexpensive firewall insulation that will withstand fires in homes and buildings, and also assist in the prevention of forest fires.

In addition to Cryogel, which has low temperature applications, Aspen is working to further their aerogel product line to include Pyrogel,® and Polar Bear,™ for use with high temperature applications. Both Pyrogel and Polar Bear are currently in the development stages. Pyrogel products will find purposes in spacecraft, rockets, engines, and high temperature furnaces. Polar Bear covers most medium temperature applications, including insulation for homes and buildings, clothing, appliances, airplanes, and automobiles. The versatile aerogel products will be found in everything from clothing, to building insulation, to space vehicles.

Another example is Aspen's Spaceloft™ product; an inexpensive, flexible blanket that incorporates a thin layer of aerogel embedded directly into the fabric. An advanced version of this material originally developed under the SBIR contract with Kennedy Space Center, Spaceloft is relatively

Johnson Space Center used the Spaceloft™ material in the construction of these mittens—a precursor to the development of gloves projected for use on a future mission to Mars.

inexpensive, flexible, hydrophobic, and breathable. It is also three times more effective than the best commercially available clothing insulation. Incorporated in jackets manufactured by Corpo Nove, and to be sold by Hugo Boss, these jackets are intended for wear in extremely harsh conditions and activities, such as Antarctic expeditions. As the price of Spaceloft comes down with mass production, it is expected to be more widely used in everyday winter clothing. Recently, NASA's Johnson Space Center used Spaceloft to construct mittens as a precursor to space gloves for Mars exploration.

Along with the many advantages and applications of the superior insulation qualities of aerogels, are the environmental implications of this material. Widespread use of aerogel insulation in homes and buildings has the potential to significantly reduce global energy consumption and greenhouse gas emissions. As the company ventures further into the future, Aspen Systems will keep advancing the applications of aerogel for existing, as well as new and innovative purposes that will significantly better our lives and improve the global environment. ❖



Using aerogel in jackets such as this one will provide wearers with unsurpassed insulation.

Spaceloft™ and Polar Bear™ are trademarks of Aspen Systems, Inc.
Cryogel® and Pyrogel® are registered trademarks of Aspen Systems, Inc.



Corpo Nove incorporated the Spaceloft™ version of the NASA-developed aerogel material into this jacket, which was tested during an Antarctic expedition.

FRESH VEGGIES FROM SPACE

Professor Marc Anderson of the University of Wisconsin-Madison developed a technology for use in plant-growth experiments aboard the Space Shuttle. The University is home to the Wisconsin Center for Space Automation and Robotics (WCSAR), a NASA Commercial Space Center sponsored by the Space Product Development Office at NASA's Marshall Space Flight Center. Anderson's research and WCSAR's technology were funded by NASA and resulted in a joint technology licensed to KES Science and Technology, Inc., of Atlanta, Georgia. This transfer of space-age technology resulted in the creation of a new plant-saving product.

Ethylene is a natural hormone that causes plant spoilage and premature withering if present in excess amounts. Produced by plants, it acts as a chemical cue that tells plants to begin ripening. It is critical to remove ethylene from enclosed plant-growth environments, such as those for growing in space, because high concentration levels can be detrimental to the plants. WCSAR, in conjunction with Anderson's technology, created an ethylene scrubber for plant growth chambers. This innovation presents commercial benefits for the food industry in the form of a new device, named Bio-KES.

Incorporating the WCSAR filter system, Bio-KES removes ethylene and helps to prevent spoilage. The system's fan draws

in air and passes it over pellets treated with titanium dioxide. The titanium dioxide works as a catalyst to break down the ethylene into carbon dioxide and water vapor. This change is triggered by photocatalysis, a process that uses ultraviolet light to activate the titanium particles. The by-products of carbon dioxide and water vapor are then recirculated back into the storage or display area.

The unique process of the Bio-KES systems has advantages over other ethylene removal systems. Most systems simply oxidize the ethylene in the air with an oxidant such as potassium permanganate, and consequently, require frequent maintenance to remove exhausted oxidant pellets. Bio-KES breaks down ethylene catalytically, thereby eliminating build-up, so the system is almost maintenance-free. Because air continuously passes through the device, Bio-KES removes approximately 99 percent of the present ethylene and concentrations are unable to reach harmful levels.

The use of ultraviolet light is another advantage, since it is proven to reduce the presence of mold, bacteria, and odor from produce storage areas. Other devices do not typically involve ultraviolet light.

Ethylene accounts for up to 10 percent of produce losses and 5 percent of flower losses. Using Bio-KES in storage rooms and displays will increase the shelf life of perishable foods by more than one week, drastically reducing the costs associated with discarded rotten foods and flowers. The savings could potentially be passed on to consumers. According to KES president, John Hayman, Jr., "I couldn't even begin to give you the billions of tons of food that can be given, or handed to the end user, in a usable state, rather than something that the grocery stores or the commercial enterprises have to throw out."

A special plant-growth chamber constructed with this technology has flown on numerous shuttle missions. For NASA, the device means that astronauts can conduct commercial agricultural research in space. Eventually, it may also help to grow food in space and keep it fresh longer. This could lead to less packaged food being taken aboard missions since it could be cultivated in an ethylene-free environment. ❖



The Bio-KES system uses NASA technology to remove ethylene gas and airborne pathogens from small storage areas, as well as floral and produce display cases.

MAKING SENSE OF REMOTELY SENSED ULTRA-SPECTRAL INFRARED DATA

Data acquired from very high spectral resolution monitoring of the Earth's atmosphere provides an overwhelming amount of information. This information is gathered when thermal infrared radiation passes through the Earth's atmosphere and reaches a sensor. The infrared radiation forms a highly convolved signal, containing both emission and absorption, from the entire length of the ray path. To harness this data, NASA's Jet Propulsion Laboratory (JPL), Pasadena, California, Earth Observing System (EOS) programs, the Deep Space Network (DSN), and various Department of Defense (DOD) technology demonstration programs, combined their technical expertise to develop the software, SEASCRAPE.

SEASCRAPE, licensed by the California Institute of Technology (Caltech), automatically inverts complex infrared data and makes it possible to obtain estimates of the state of the atmosphere along the ray path. Former JPL staff members created a small entrepreneurial firm, Remote Sensing Analysis Systems, Inc., of Altadena, California, to commercialize the product. The founders believed that a commercial version of the software was needed for future U.S. government missions and the commercial monitoring of pollution.

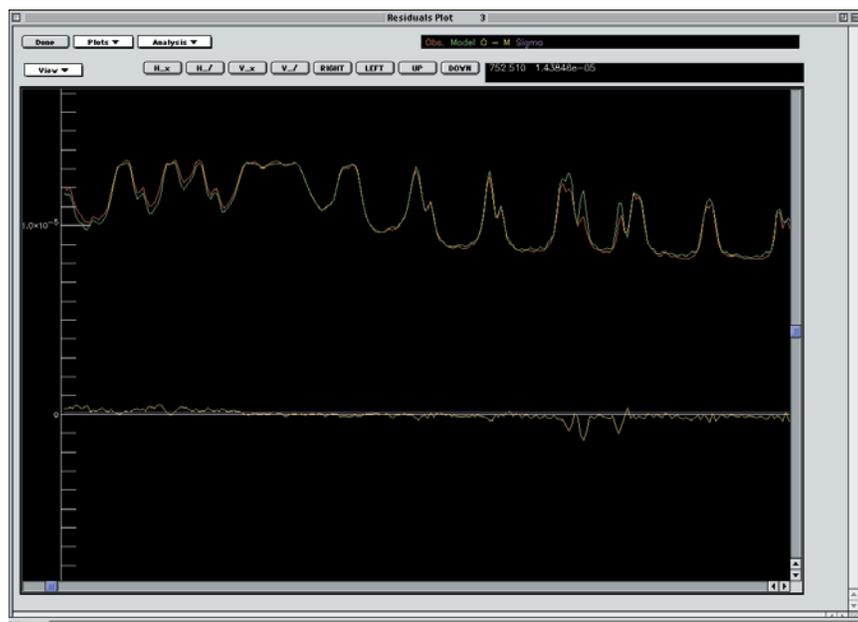
With the inversion capability of this software and remote sensing instrumentation, it is possible to monitor pollution sources from safe and secure distances on a noninterfering, noncooperative basis. The software allows the user to determine the presence of pollution products, their location and their abundance along the ray path.

The inversion process utilizes first principle physical modeling, rather than the usual "differencing" of observa-

tions. The capabilities of this technique allow for maximum sensitivity of the instrument. In addition, the inversion can be done on individual pixels if desired, meaning there is no inter-pixel dependence forced upon the analysis. The observer is free to make use of whatever data is available, without having to obtain data sets that are composed of "pollution" and "pollution-free" pixels for comparison.

Given that the inversion is a quantitative statistical product, not only are estimates of the pollution obtained, but also the uncertainties in those estimates. Knowing the uncertainty associated with each estimate is a very useful by-product of this technique. In short, one knows how much of a particular substance would have to be present under the observed scenario for the instrument to detect its presence. For pollution control conformance monitoring, that is as important a measurement as the detection of the pollution class itself.

This software, now known as SEASCRAPE_Plus, is currently available for Macintosh, HP, Sun, Dec, and Alpha machines in executable form. Porting it to PCs and to other UNIX/LINUX machines is straight-forward since the source code, while large (over one million lines), is written in ANSI Standard C. Currently, the graphical user interface (GUI) used to interact with the code, is written in Interactive Data Language, (IDL). The software has been cleared by the Department of Commerce for export, and is currently used by numerous research and engineering organizations around the world. Hopefully, SEASCRAPE will assist researchers in combating pollution. ❖



SEASCRAPE software allows the user to determine the presence of pollution products, their location, and their abundance.

NOT YOUR ORDINARY GEM

You could really say that Geophex, Ltd., of Raleigh, North Carolina, has a lot of sense—or maybe, sensors. Through **Small Business Innovation Research (SBIR)** funding from NASA's Stennis Space Center, Geophex devised a new design for broadband electromagnetic sensors. NASA's original goal was to find an advanced airborne electromagnetic remote sensor to monitor various coastal environments. To meet this goal, Geophex developed a patented sensing technology, capable not only of coastal monitoring, but also a variety of other functions, including environmental pollution characterization, groundwater contamination detection, archaeological study, and mineral detection. The new technology is offered in several of the company's products—the GEM-2, GEM-2A, and the GEM-3.

The Geophex products consist of two primary electromagnetic coils, which are stimulated by alternating currents that generate a magnetic field in the object targeted for investigation. An electromagnetic sensing coil that measures the magnetic field induced in the target is also needed. While other apparatuses have been constructed with these same general components, Geophex's sensor has been drastically compacted, and yet still contains the needed specifications of a sensor instrument.

In the Geophex version of sensing technology, the coils are situated in close proximity of each other. Previously, the coils were placed as far apart as possible, making for a rather large instrument. This distance was thought to be necessary in order to prevent the excitatory magnetic field of the primary coil from overwhelming the relatively weak field of the sensing coil. Geophex's compact size is achieved through the use of a concentric design where the smaller sensing coil is placed within the larger primary coils, creating a magnetic cavity at the center of two concentric loops, allowing for the accurate detection of weaknesses in electromagnetic fields.

Geophex creates products of unrivaled accuracy and efficiency in a wide range of Earth-related fields. For instance, the GEM-2 is a handheld, lightweight, programmable, digital device. It consists of a broadband electromagnetic sensor, a rechargeable battery, and operating software. Characteristics like its advanced sensing ability and compact size make the GEM-2 ideal for smaller geological and environmental surveys. In one noted case, the GEM-2 was used to rediscover decades-old radioactive waste that had been buried in Tennessee.

The same sensing capabilities are offered in the GEM-2A, an airborne version of the sensor. Suspended from a helicopter, the GEM-2A is used to search for mineral deposits and to



The GEM-2A airborne sensor is commercially used for surveying large areas of land, in search of minerals, metals, and hydrocarbons.

survey large tracts of land. One Australian mining company succeeded in its search for diamond deposits and other precious and base metals by employing the GEM-2A.

The third version of this technology is exhibited in the GEM-3. Like the other GEM products, it can be used for environmental site characterization, but it also has another unique function. The GEM-3 is capable of detecting buried landmines and other active munitions. While other products are able to perform similar functions, the GEM-3 goes above and beyond their capabilities by identifying landmines by their brand names. Because each landmine has its own unique electromagnetic response to the broad frequency band emitted by the GEM-3, bomb identification and disposal strategies are made easier.

While Geophex has enormous success with these products, more is yet to come. It is hoped, future applications of this technology will allow for the detection and identification of concealed weapons. Medical-related applications include using tomography to image the conductivity of the body. This technology also has the potential for detecting water and other fundamental resources necessary for establishing human colonies on other planets. Based on the success of the GEM family of sensors, NASA's Jet Propulsion Laboratory has awarded Geophex a contract for the development of an electromagnetic sensor to be mounted on a Martian rover. Sensor technology will help us map out opportunities in space, as we continue to map out those here on Earth. ❖



The GEM-3 can be used for detecting and identifying buried unexploded ordnance and landmines. Each landmine shows a distinct electromagnetic response in a broad frequency band, which can be used as a fingerprint to identify it by its brand name.

CYBERSONICS—TAPPING INTO TECHNOLOGY

Just this year, NASA successfully landed the NEAR (Near Earth Asteroid Rendezvous) spacecraft on the asteroid Eros as part of a space exploration project. As NASA space exploration expands, the need for revolutionary new technologies increases. A company from northwestern Pennsylvania has stepped up to the plate and delivered an innovative technology with infinite possibilities. Cybersonics, Inc., of Erie, Pennsylvania, with the assistance of **Small Business Innovation Research (SBIR)** funding from NASA's Jet Propulsion Laboratory (JPL), Pasadena, California, has developed an ultrasonic drill with applications ranging from the medical industry to space exploration.

The drill, which has the ability to take a core sample of the hardest granite or perform the most delicate diagnostic

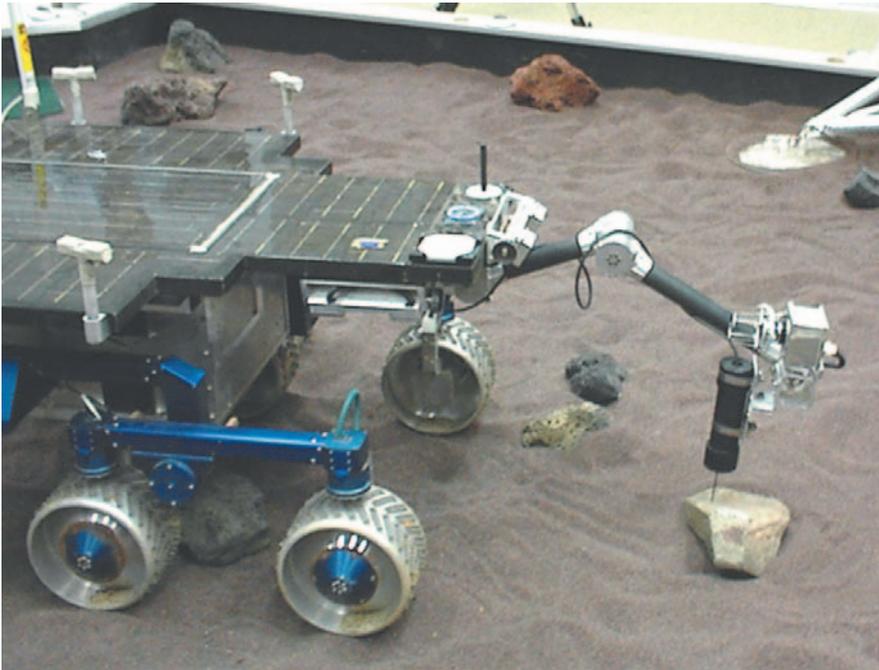
medical procedure, is a lightweight, ultrasonic device made to fit in the palm of the hand. Piezoelectric actuators, which have only two moving parts and no gears or motors, drive the components of the device, enabling it to operate in a wide range of temperatures. Piezoelectricity is the generation of electricity in dielectric crystals (crystals that do not conduct electricity) subjected to mechanical stress.

There are three main sections to the drill: an ultrasonic actuator, a free-mass resonator, and a drill stem. The device operates when vibrations from the ultrasonic actuator excite the free-mass resonator. Acoustic energy in the resonator is transferred to the drill stem and then to the surface of the interface, where the interface is excited past its ultimate strain, and fractures.

The most remarkable aspect of the drill is its ability to penetrate even the hardest rock, such as basalt, with minimal force application. The ultrasonic device requires 20 to 30 times less force than standard rotating drills, allowing it to be safely guided by hand during operation. This is an important feature when attempting to drill a core sample in zero gravity, where an astronaut's positioning to the interface is not always optimal. Also, the drill is operable at a level as low as three watts of power, where conventional drills require more than three times this level.



Requiring 20 to 30 times less force than standard rotating drills, Cybersonics' ultrasonic drill has the ability to penetrate even the hardest rock, with minimal force application.



Research members of the Nondestructive Evaluation and Advanced Actuators (NDEAA) team at JPL are currently developing a flight model of the ultrasonic drill, like the one seen here attached to a space rover. NASA hopes to include a flight unit drill in the Mars 2003 exploration mission.

This revolutionary device has a vast array of advantages over traditional drills. For one, the coring bit of the drill creates a hole that is slightly bigger than the bit itself, reducing the likelihood of the drill jamming due to a buildup of accumulated interface material. Another advantage is that the ultrasonic drill bit need not be sharp because ultrasonic vibrations are responsible for the drilling action. The piezoelectric actuators power the drill through the surface without concern of wear. Because the drill can operate without rotation, the core samples can be square, round, or any other desirable shape.

Research members of the Nondestructive Evaluation and Advanced Actuators (NDEAA) team at JPL are currently developing a flight model of the ultrasonic drill, which will have the ability to abrade weathered layers of rock in order to expose pristine surfaces for analysis. NASA hopes to include the flight unit in the Mars 2003 exploration mission.

The JPL team and Cybersonics are also developing an additional prototype drill that is intended to reach meters deep, allowing for a more accurate core sample. The device, named the Ultrasonic-Gofer, will be reeled down to the drilled well, where it will core the ground and upload a sample to the surface. If successful, this device will be included in the Mars 2007 mission.

This exciting technology, which actually began as a device to treat kidney stones, offers an optimistic future for any number of professions. Currently, Cybersonics provides a variety of medical institutions with variations of this technology customized to fit their specific needs. Future applications for the ultrasonic drill are too numerous to name, but include potential applications in rock and soil sampling, medical procedures that involve core sampling or probing, landmine detection, building and construction, and space exploration. ❖

TURNING GAS INTO GREENS

For space missions, food must be carried aboard the shuttle. As we embark upon longer explorations into the unknown, more provisions will have to be packed for these longer missions. In order to lengthen the amount of time humans can spend in space and still launch minimal payloads, astronauts will have to be able to cultivate their own food. So, how do you turn an astronaut into a farmer? NASA asked the same question. The answer is an experimental greenhouse that uses methane from decomposing trash to fuel a system that makes food.

Through grant and research assistance from NASA's Goddard Space Flight Center, scientists from Cook College, Rutgers University, and Stevens Institute of Technology have been conducting studies at the Burlington County Research and Demonstration Greenhouse, located at the Burlington County Resource Recovery Complex in New Jersey. Although the combination of garbage and growth may seem unusual, it has turned out to be a perfect match, by providing tomatoes that are firm, juicy, and a big hit at local food markets.



Through NASA funding and assistance, the Burlington County Research and Demonstration Greenhouse in New Jersey, uses a revolutionary growing system to produce tomatoes sold in local grocery stores. It is hoped that research done at the greenhouse will lead to methods for growing food in space.

Biogasses created by the anaerobically decomposing trash are necessary to fulfill the energy needs of this revolutionary greenhouse. The primary emission, methane, is piped to the greenhouse boiler and used to fuel the hot water heating system. Thus far, the use of biogas has drastically reduced the operating costs of the greenhouse, eliminating the need for non-renewable fuels. The biogas will also generate electricity for the greenhouse in the near future.

In order to keep the system relatively closed, the plants are irrigated with recycled plant nutrients such as nitrogen, phosphorus, potassium, calcium, and magnesium. These nutrients are delivered through hydroponics, the cultivation of plants in a nutrient solution rather than in soil.

Also unique to the greenhouse are the high-pressure sodium lamps that augment the natural light, thereby boosting production and reducing cropping time. A total of 16 hours of light are provided to the crop each day, year-round. The most unique aspect of the process is one that is the least high-tech—bees are kept in the greenhouse to pollinate the tomato flowers.

Because the elements of this new method work together so efficiently, it only takes about 90 days for a seed to germinate and produce a tomato harvest. Not only is the food produced faster, the manual labor needed for the upkeep of the plants is also drastically reduced.

The system was designed to produce tomatoes on a year-round schedule. According to David Specca, Director of Developmental Programs at Rutgers University and Greenhouse Manager, the greenhouse produces "about ten times the amount of tomatoes that would be grown outdoors in a similar space." When at full production, the operation is capable of producing 10 pounds of tomatoes per square foot per year. That's a lot of marinara.

All of the tomatoes are sold to RLB Distributors, Inc., of West Caldwell, New Jersey, and then retailed at King Supermarkets, also of New Jersey. The tomatoes are individually marked with stickers, identifying their premium quality. Presently, the demand for these space-age tomatoes is exceeding the supply.

While the primary product of the greenhouse is the tomato, other food crops can be added. Because of NASA's ongoing efforts and assistance, these innovations in agriculture will provide future space missions with renewable food sources, as well as innovative methodologies in commercial farming. A system of this capability could provide food sources for areas that are, for various reasons, incapable of traditional agriculture, such as third-world countries and desert lands. NASA assistance has enabled the creation of a truly innovative process. Hopefully, the work done at the greenhouse will one day provide food not only for New Jersey residents, but for the rest of us on Earth and those in space as well. ❖

MAKING SENSE OF PLANT HEALTH

Through **Small Business Innovation Research (SBIR)** funding from NASA's Stennis Space Center, comes a new product that measures the photochemical efficiency of plants. Ciencia, Inc., of East Hartford, Connecticut, created a new device, known as a Portable Photosynthesis Analyzer, or Phase Fluorometer, that provides real-time data about the photochemical efficiency of phytoplankton and other plant forms. The commercial version of this technology is used for photosynthesis research and offers major benefits to the field of life science. This new instrument is the first portable instrument of its kind. Through a license agreement with Ciencia, Oriel Instruments, of Stratford, Connecticut, manufactures and markets the commercial version of the instrument under the name LifeSense.TM

LifeSense is a 70 MHz single-frequency fluorometer that offers unrivaled capabilities for fluorescence lifetime sensing and analysis. Fluorescence lifetime refers to the lifetime of the fluorescence process, whereby certain materials emit light at certain wavelengths after absorbing light of shorter wavelengths. The core behind this technology was developed in collaboration with Stennis in an attempt to create a device that could measure the photochemical efficiency of phytoplankton in the oceans.

Presently, NASA uses the Portable Photosynthesis Analyzer for various in situ oceanographic applications. A shipboard version of the instrument was developed for conducting

phytoplankton studies. These studies will lay a foundation for comparison, or a ground truth, for data gained from satellite remote sensing of ocean color, human habitability, and biology in space.

The new technology also has other applications. According to Dr. Salvador Fernandez, president of Ciencia, the most significant commercial potential of this technology lies in its instrumental use for photosynthesis research, and in systems for high throughput screening of compounds in agricultural chemical research and drug studies.

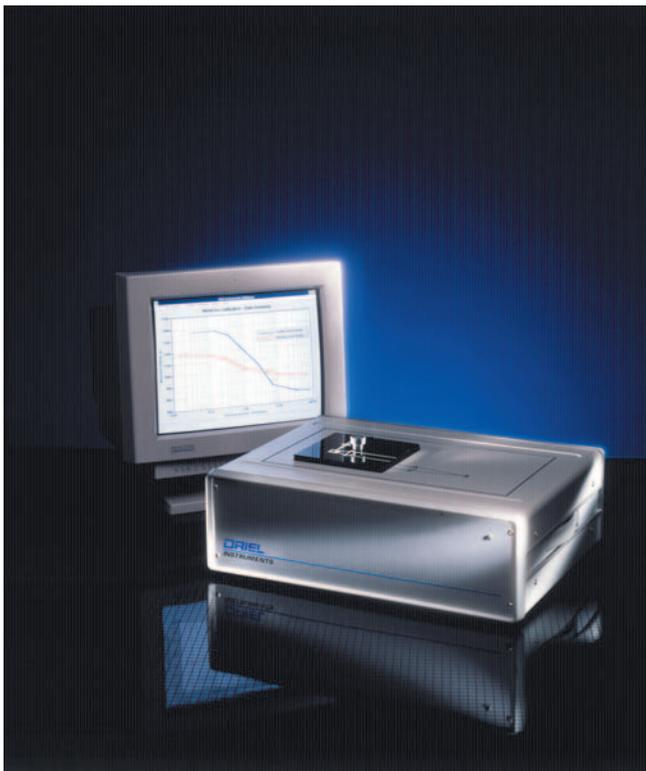
LifeSense provides information about all varieties of photosynthetic systems. Photosynthesis research contributes important health assessments about the plant, be it phytoplankton or a higher form of plant life. With its unique sensing capabilities, LifeSense furnishes data regarding the yield of a plant's photochemistry, as well as its levels of photosynthetic activity. The user can then gain an extremely accurate estimate of the plant's chlorophyll biomass, primary production rates, and a general overview of the plant's physiological condition. One of the major LifeSense advantages, is the instrument's ability to model chlorophyll fluorescence and photosynthesis, both of which are related to long, healthy plant lifetimes.

Until now, fluorescence lifetime sensing required expensive equipment. However, with the LifeSense device, the user gets high-resolution, high-sensitivity, rapid measurement time, and broad spectral versatility, all at a relatively low cost.

While NASA benefits from utilizing the portable analyzer on several projects, including the Sea-viewing Wide Field-of-view Sensor (SeaWiFS), the Moderate-resolution Imaging Spectroradiometer (MODIS), and the Space Station Biological Research Program, Ciencia's plans for the future are more down to earth. The company anticipates further potential commercial applications in the areas of precision agriculture, aquaculture, forestry, and food safety.

Recently, Ciencia entered into a licensing and development agreement with HTS BioSystems, of Hopkinton, Massachusetts, to develop further applications of this technology for high throughput screening in drug discovery. Under this agreement, Ciencia will be providing analysis, design, instrumentation, development, systems integration, and prototype fabrication services to HTS. ♦

LifeSenseTM is a trademark of Oriel Instruments.



The LifeSenseTM instrument is a 70 MHz single-frequency fluorometer that offers superior fluorescence lifetime sensing and analysis capabilities.

SENSIBLE SUCCESS

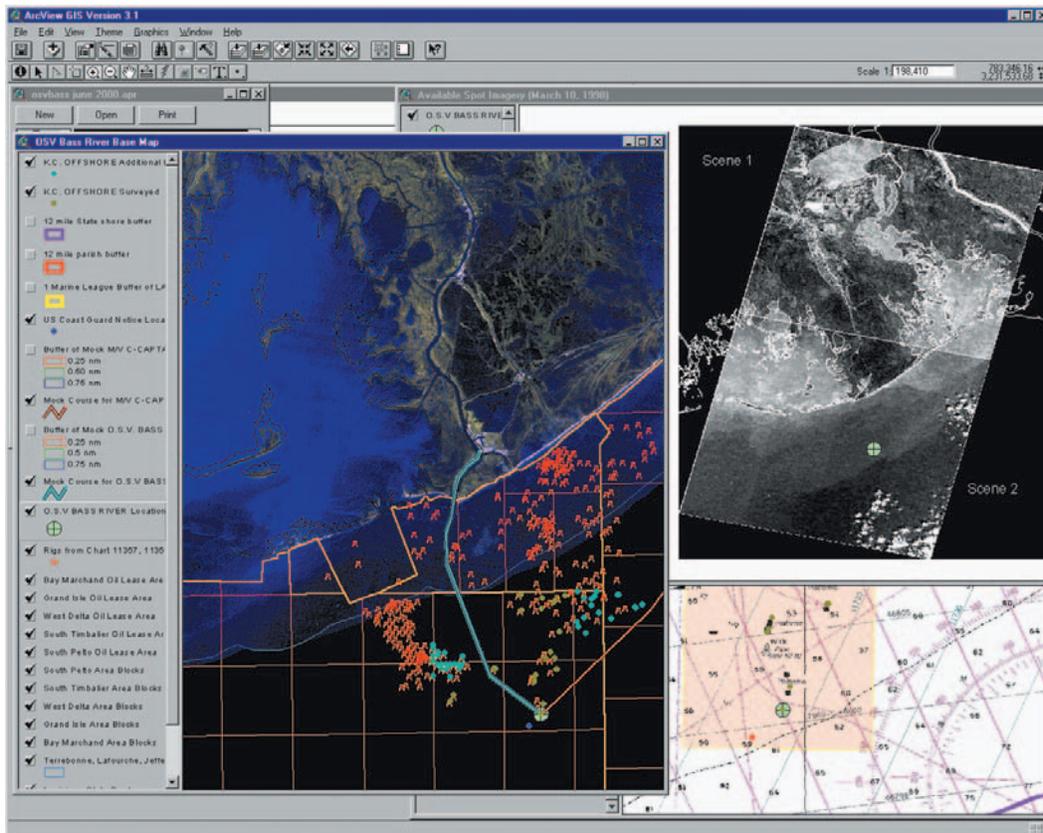
Every now and again, something comes along that has far-reaching applications in a variety of fields. This is the case with services provided by Crowsey Incorporated, of Charlottesville, Virginia. Founded by Rick Crowsey in 1996, the company built on his expertise in providing spatial information services and products for the legal, medical, health, and financial fields. Before starting his own firm, Rick Crowsey was an engineer, working at NASA's Stennis Space Center on a variety of projects, including the NASA Commercial Remote Sensing Program. Presently, Crowsey Incorporated is a proud partner in NASA's Mississippi Space Commerce Initiative, with research offices at the John C. Stennis Space Center.

Commercial remote sensing uses satellite imagery to provide valuable information about the planet's features. By capturing light reflected from the Earth's surface with cameras or sensor systems, usually mounted on an orbiting satellite, data is obtained for business enterprises with an interest in land feature distribution. Remote sensing is practical when applied to large-area coverage, such as agricultural monitoring, regional mapping, environmental assessment, and infrastructure planning. For example, cellular service providers use satellite imagery to select the most ideal location for a communication tower.

Crowsey Incorporated has the ability to use remote sensing capabilities to conduct spatial geographic visualizations and

other remote-sensing services. Presently, the company has found a demand for these services in the area of litigation support. By using spatial information and analyses, Crowsey helps litigators understand and visualize complex issues and then to communicate a clear argument, with complete indisputable evidence. In one particular case, the company was retained to assist in the defense of a tugboat company hired to help transport an oil-drilling rig. After the rig was moved and in position, the legs of the oil rig platform were lowered, one of which punctured a hole in a natural gas pipeline, resulting in a conflagration. Consequently, the oil rig company sued the tug boat company for excessive damages. Crowsey created a comprehensive geographic information system that was summarized with a single visualization. The revelation of this summary exhibit was reported to have been the primary reason for the parties to reach a private settlement, saving the tugboat company millions of dollars.

Remotely sensed data, systems analysis, and graphic information systems will further our understanding of how Earth's features have the potential to affect private industry. Using the experience and technology of NASA, Crowsey Incorporated will continue to provide unique services to their clients. ❖



This image depicts some of the geographic information system (GIS) data used to support a case in which Crowsey Incorporated was retained to provide mapping, analysis, and scenario visualization of a collision between two vessels. The left-hand side of the GIS shows the most probable track of the vessels as blue and red lines with the collision location as a green-circled plus sign. The upper-right portion is a thumbnail of two Radarsat scenes over the area near the time of the incident with the green-circled plus sign indicating the collision location. The bottom-right image shows a National Oceanic and Atmospheric Administration navigation chart with the collision location identified by the same green-circled plus sign.

OCEAN DRIFTERS GET THE FACTS

Through **Small Business Innovation Research (SBIR)** funding from NASA's Goddard Space Flight Center, of Greenbelt, Maryland, a new kind of vessel has taken to the seas. Clearwater Instrumentation, of Watertown, Massachusetts, created a multi-sensor array ocean drifting station. Well-known for its complete line of drifters, the newest member of the Clearwater family is the ClearSat-Autonomous Drifting Ocean Station (ADOS).

ADOS was developed to support observations of Earth by NASA satellites. It is a low-cost device for gathering an assortment of data necessary to the integration of present and future satellite measurements of biological and physical processes. Clearwater Instrumentation developed its ADOS technology based on Goddard's Sea-viewing Wide Field-of-view Sensor (SeaWiFS) project, but on a scale that is practical for commercial use.

Drifters are data collection instruments that are comprised of a surface float tethered to a drogue, but the ClearSat-ADOS is not your ordinary drifter. It is used for the in situ measuring of ocean surface layer properties such as ocean color, surface thermal structure, and surface winds. Changes in ocean color can signify the presence of various amounts of marine phytoplankton.

ADOS uses sensors that observe the color of seawater by measuring solar irradiance and the strength of upwelling light at specific SeaWiFS

frequencies. Each sensor is encased in waterproof housing to eliminate biofouling, which is the effect ocean water and phytoplankton have on the sensor. The caps on the housing are removed at predetermined intervals to permit the activation of a second, unfouled sensor, allowing for the evaluation of the effects biofouling had on the first sensor and the deployment of a new upwelling light sensor array. A third sensor performs the same function at a later point in the life of the drifter.

ADOS also measures the seawater temperature profile at 13 depths from sea surface to 120 meters utilizing 12 SmartSensors. Using the WOTAN (weather observations through ambient noise) technique, ADOS is able to measure the wind, while wind direction is determined with an electronic compass. All of the information about ocean color, wind, and temperature is collected via the Argos satellite, which locates ADOS by measuring the Doppler shift of the transmitter.

Thus far, multiple ADOS units have been sold to The Scripps Institution of Oceanography, where they are being applied in the field of academic science research. Fisheries can also benefit, because ADOS can locate prime cultivation conditions for this fast-growing industry. Clearwater Instrumentation expects continued success with the product as more and more uses are found in the commercial market. ❖



ADOS is used for the in situ measuring of ocean surface layer properties such as surface winds, surface thermal structure, and ocean color. The information gathered by ADOS is then collected via satellite.

WASHING OUT THE COMPETITION

AJT Associates, Inc. (AJT), of Cape Canaveral, Florida, worked with NASA to develop a revolutionary ozone-based laundry system. Through the transfer of space technology, AJT's TecH₂Ozone® wash system presents its customers with an energy-efficient, cost-effective, and environmentally safe way to perform commercial laundering. AJT was under contract with NASA's Kennedy Space Center to perform studies for the Solid Rocket Booster Parachutes used in the Shuttle Program. Once the boosters detach from the Shuttle during the launch, parachutes open to prevent the booster from falling to the bottom of the ocean, making booster retrieval relatively easy. However, the parachutes must be treated and repaired before they can be used in another launch. This job is performed at Kennedy's Parachute Refurbishment Facility (PRF).

The area surrounding Kennedy is part of Merritt Island National Wildlife Refuge and is composed of fragile wetlands and forest. Under a permit issued by the Florida Department of Environmental Protection, parachute rinse water was discharged into the drainage ditch, which emptied into the wetlands. As the permit approached its renewal date, Kennedy staff decided to investigate methods to recycle the wastewater. AJT conducted a bench study to evaluate the purification and reuse of the deck and wash waters of the PRF. A test unit

designed to measure the effectiveness of various water purification systems showed potable water used at the PRF retained chlorine, which would require removal prior to discharge. Kennedy personnel determined that a closed-loop water reuse system would not only be more cost-effective than continued treatment and discharge, but would also be more environmentally responsible. Although AJT's treatment and reuse system initially used at the PRF was replaced by Kennedy's regional wastewater recycling approach, it was eventually adapted and used at a number of other facilities and commercial systems at the Center.

The research and design that went into the AJT system led to the creation of TecH₂Ozone, the machine manufactured by AJT for commercial laundry facilities. While performing the study for the design of the system at the PRF, AJT recognized the sanitizing abilities of ozone. Ozone is reactive and short-lived, yet resists mixing and solution. These characteristics presented a hurdle in obtaining the level of ozone required to successfully treat the water. AJT's answer to the problem was the development of contact columns to be inserted in the wash tanks. The columns allowed for the proper transfer and concentration of ozone to be added to the water. This is the revolutionary technology behind the success of TecH₂Ozone. Not only was the proper solution of ozone achieved, but levels



This version of the commercial laundry system shows the ozone generator mounted beside the laundry machines with the unit controllers mounted on top of the washers.

could now be measured and adjusted according to various tasks—such as more ozone for dirtier laundry.

TecH₂Ozone significantly reduces the amount of water and chemical used as compared to traditional commercial laundry systems. This reduction has resulted in lower cost and shorter wash cycles. And due to the reduced use of chemicals, a significant portion of the rinse water is recycled back into the system for reuse.

TecH₂Ozone customers, such as hotels and other large commercial laundry facilities, have felt the benefits of this equipment. Because of the reduced cycle times, fewer washers are needed and there is a notable increase in the cleanliness of the laundry. Customers are particularly excited about the ironing time saved due to the generation of fewer wrinkles through TecH₂Ozone's use of cold water, and the fact that colored and white laundry can be washed together without fear of bleeding dyes. Fabrics cleaned with TecH₂Ozone are fluffier and more absorbent, making towels softer and more comfortable to use. The reduction in chemical residues is a boon to those with allergies and to those prone to skin irritation from chemicals retained in regular laundry. Vice President Richard Wood says, "This also has the potential to reduce bed sores for those who are hospitalized for long periods of time, since bed sores are often caused by an interaction of perspiration and alkali residue in bed linens."

Along with dramatic reductions in chemical costs, customers save tens of thousands of dollars each year due to reduced energy use and water consumption. Return on investment for hotels and commercial laundries is 18 to 24 months, with a 50 percent cut in overall costs.

Agrimond L.L.C., the AJT company responsible for selling the TecH₂Ozone system, is approaching the commercial laundry marketplace with great excitement. They believe this space age technology will become the industry standard because of tremendous cost savings, environmental benefits and increased product quality. And it all started with a bench study and a system designed to solve a water contamination problem at Kennedy's Parachute Refurbishment Facility. ❖

TecH₂Ozone® is a registered trademark of Agrimond, L.L.C.



A chemical sample is cleaned in the laboratory using ozone.

DETECTING PLANT STRESS

A new tool helps farmers, foresters and other growers, detect unhealthy crops before the human eye can see the damage. Through an exclusive patent license from NASA Stennis Space Center, Spectrum Technologies, Inc., of Plainfield, Illinois, has developed a hand-held tool, called Observer,[™] for detecting plant stress.

Developed by two NASA researchers, the Observer shows the viewer which plants are under stress through multispectral imaging. Multispectral imaging is the use of specific wavelengths of the light spectrum to obtain information about objects—in this case, plants. With this device, several wavelengths of light obtain information about the plant and results are immediately processed and displayed.

Plant stress is caused by unfavorable environmental conditions, such as a lack of nutrients, insufficient water, disease, or insect damage. If conditions are unfavorable, leaf

chlorophyll content will begin to decrease. Without instrumentation, this decrease is virtually undetectable until a leaf begins to change color. However, by the time discoloration occurs, the plant may already be too damaged to save.

NASA research found that previsible signs of stress can be detected by measuring the chlorophyll content based on light energy reflected from the plant. The Observer detects stress up to 16 days before deterioration is visible to the eye. Early detection provides an opportunity to reverse stress and save the plant.

The Observer is a hand-held, easily operated device. The operator simply points it at the leaf and pushes a button to achieve immediate readings. Since the unit is designed for close range use, optimal readings are achieved when the device is held approximately 18-24 inches from the leaf. However, results have been recorded from as far as 20 yards away from the plant. Once the button has been pressed, the multispectral imaging process goes to work and results are supplied within several seconds. Because the unit works in both natural and artificial light, it is suitable for outdoor or indoor planting.

In terms of cost, the device can mean substantial savings. When compared with costly, lengthy laboratory tests, Spectrum's device comes out top dollar. The Observer is not only cheaper and more accurate than previous detection methods, but it also aids in crop preservation. It replaces laboratory testing, freeing more resources to advance crop and forest science.

Commercial applications are found in almost any field where plant life is present, including agriculture, precision farming, horticulture, and plant research. Farmers using the Observer will lose less crop, ensuring maximum harvest. Entire forests could be saved through the early detection of various tree diseases. There is a very real opportunity to create an overall healthier plant life for commercial growers.

Mike Thurow, president and founder of Spectrum Technologies, Inc., expects this device will cultivate healthier plants, reduce chemical expenditure, and monitor the physiological effects of plants. ❖

The Observer[™] is a trademark of Spectrum Technologies, Inc.



The Observer[™] is a hand-held device used to assist with monitoring the health of plants by providing information about nutrient and water levels, and possible disease or damage.

Think Tanks

Storage tanks are absolutely critical to the needs of the petroleum and chemical industry. However, they must be periodically inspected in order to prevent leakage that could result in soil and groundwater contamination. Present inspection methods require that tanks be completely drained and then cleaned before inspection workers can enter the tank. The workers then conduct an in-depth visual inspection to search for flaws. This method presents a serious health risk as residual contaminants can lead to asphyxiation or even explosion.

A new inspection robot from Solex Robotics Systems, of Idaho Falls, Idaho, was designed to eliminate hazardous inspections. The submersible robot, named Maverick, is used to inspect the bottoms of petroleum and chemical storage tanks, keeping the tanks operational during inspection.

Maverick was developed through an agreement between the Idaho National Engineering and Environmental Lab and Solex's parent company, Solex Environmental Systems. By working with NASA/MSU TechLink, of Bozeman, Montana, Solex Robotics gained NASA assistance under a Space Act Agreement from Johnson Space Center.

Maverick's first swim lesson took place at the Johnson Neutral Buoyancy Laboratory, a 40-foot-deep, 6.5-million-gallon pool used to simulate weightlessness. NASA provided the unique testing capabilities that could not be offered elsewhere. Because of Maverick's many control and supply hoses, Solex was interested in relating NASA's experience with tether management back to their robot. Should its hoses become entangled, the tanks would have to be drained and

refilled; so Maverick had to prove extremely efficient in managing its lines. Needless to say, Maverick took to the water like a fish and is now able to provide services that will make manual tank inspections obsolete.

During a typical Maverick inspection, the robot is lowered into the full storage tank. With traction wheels, it moves across the tank floor using a specialized sensor and imaging system to inspect the welded steel of the tank, carefully searching for corrosion and wear. Ultrasound technology measures the thickness of the metal. While the inspection is conducted, Maverick's remote human operators remain safe outside of the tank.

The risk to human health and life is now virtually eliminated. The risk to the environment is also minimal because there is a reduced chance of spillage from emptying and cleaning the tanks, where previously, tons of pollutants were released through the process of draining and refilling.

Using Maverick also saves about 80 percent of the cost associated with inspections. The costs of draining and cleaning the tank, combined with lost revenues from downtime, can be upwards of \$50,000 to \$500,000 per tank. These time-consuming, labor-intensive, and costly steps are no longer necessary since the tanks remain operational while Maverick is in use.

As Maverick changes the face of tank inspection, it strengthens the robotic inspection standard set forth by the American Petroleum Institute. ❖



The submersible Maverick robot allows for the safe inspection and cleaning of storage tanks.

A GENUINE TEAM PLAYER

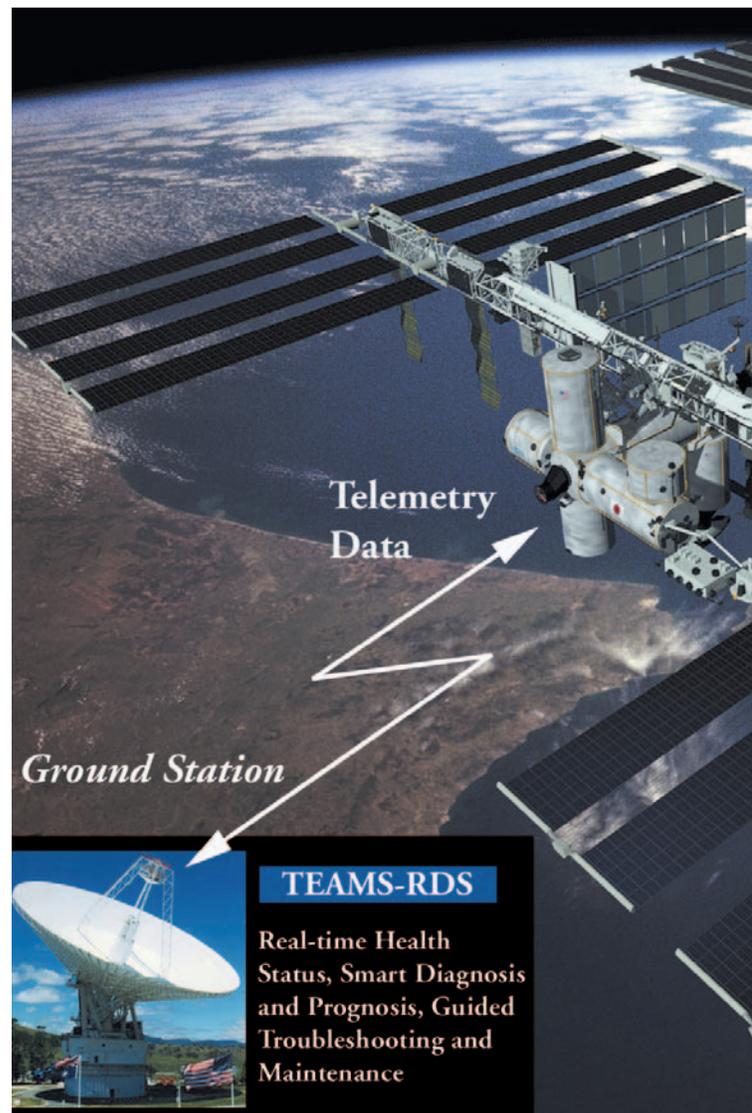
A new software system that quickly detects and isolates faults in complex, high-value systems such as the International Space Station is an extremely valuable product. Now, take that system, place it on a central computer and operate it remotely over the Internet, and you have a key enabling technology for the fast growing after-market service business that is using the Internet to generate new service revenue. What's more, the system covers all phases of a product's design, development, and support—a unique, comprehensive software system that could revolutionize the way diagnostics are designed, implemented, and deployed.

This software, with capabilities of multisignal modeling, diagnostic analysis, run-time diagnostic operations, and intelligent interactive reasoners, all in one package, sounds like a product of the future. But this is exactly what Qualtech Systems, Inc. (QSI), of Wethersfield, Connecticut, provided to the International Space Station crew. Through the **Small Business Innovation Research (SBIR)** program with NASA's Ames Research Center, QSI developed a complete multisignal modeling system that analyzes integrated systems during all stages of product design and maintenance. This software package, which is commercially available as the TEAMS (Testability Engineering and Maintenance System) tool set, can be used to reveal unanticipated system failures.

In the past, modeling systems could handle only one signal. QSI revolutionized the modeling process by taking the common model-based approach and developing it into a multisignal package, capable of providing a complete diagnostic solution for a variety of applications all based on a common model of the system design and diagnostic characteristics. The TEAMS software package is broken down into four companion tools: TEAMS-RT, TEAMATE, TEAMS-KB, and TEAMS-RDS.

TEAMS-RT identifies the good, the bad, and the suspect components in the system in real-time. It reports system health results from onboard tests, and detects and isolates failures within the system, allowing for rapid fault isolation. For example, TEAMS-RT could be sitting on a computer in Atlanta, Georgia, that is being fed data from 10 radar sites in the southeastern United States. Based on TEAMS models of the various radar systems and the sensor data arriving over the network, TEAMS-RT will automatically detect and isolate the failed or failing component. The diagnostic results can then be posted on a web page for the system operators, equipment manufacturers, and the on-site maintenance personnel.

The TEAMATE tool provides an intelligent, dynamic reasoner to efficiently drive the electronic maintenance procedure on a handheld or portable maintenance computer.



With TEAMATE, the maintenance process is optimized for the time or cost, such that the root cause of the fault is isolated in the least amount of time or for the least cost. TEAMATE also logs each step of the maintenance process, the time required to complete each task, and the result of each maintenance step. TEAMATE can take over from where TEAMS-RT left off and intelligently guide the maintenance technician through the troubleshooting procedure, repair actions, and operational checkout.

TEAMS-KB serves as a model management and collection tool for various maintenance sites in addition to archiving the TEAMATE logged data. For instance, TEAMS-KB stores



The International Space Station uses Qualtech's TEAMS multisignal modeling technology to analyze and manage its complex integrated system from one central computer.

“site profiles” listing the support equipment, personnel skill levels, and capabilities available at various maintenance sites. TEAMATE then generates optimized maintenance procedures for a particular maintenance site with the available resources and capabilities. After maintenance is complete, TEAMATE logs every action/result/time interval back to TEAMS-KB for record keeping, tracking, trending, and data mining applications. It is also applied in model management, scheduled and unscheduled maintenance, and technical data management.

TEAMS-RDS (TEAMS-Remote Diagnostic Server), the newest member of the companion tools, has the ability to continuously assess a system and isolate any failure in that system or its components, in real time. RDS incorporates TEAMS-RT, TEAMATE, and TEAMS-KB in a large-scale server architecture capable of providing advanced diagnostic and maintenance functions over a network, such as the Internet, with a web browser user interface. RDS is a key enabling technology for emerging business-to-business e-commerce after market services with unparalleled capability for remote monitoring, diagnostics, expert guidance, and maintenance logging. QSI fully expects large manufacturers to be thrilled by the leading-edge telemaintenance functionality of this new software. TEAMS software is currently used by leading aerospace companies such as Sikorsky, Honeywell, BAE SYSTEMS, Boeing, and others. QSI sees potential commercial applications of the TEAMS software in industries such as plant machinery, automotive, building systems, utility systems, medical equipment, rail systems, home appliances, information systems, and software testing. ❖

BATCHING SYSTEM FOR SUPERIOR SERVICE

Sitting in a downtown traffic jam is a frustrating experience; similar to computer users who experience “gridlock” as they try to process the ever-increasing data on their machine. Many engineers today encounter problems with computer software applications competing for limited memory to execute sophisticated operations. Although large enterprises most likely possess the necessary computing power, systems often exceed supply in some areas, while resources in other areas are under-utilized. Funding, research assistance, facilities, and equipment provided by NASA Ames Research Center, of Moffet Field, California, enabled a technology solutions company, Veridian, of Arlington, Virginia, to develop a flexible batch queuing and job management system to handle these difficult technical tasks.

Veridian’s Portable Batch System (PBS) was the recipient of the 1997 NASA Space Act Award for outstanding software. A batch system is a set of processes for managing queues and jobs, whereas a batch server creates, routes, executes, modifies, and deletes jobs. Without a batch system, it is difficult to manage the workload of a computer system.

By bundling the enterprise’s computing resources, the PBS technology offers users a single coherent interface, resulting in efficient management of the batch services. Users choose which information to package into “containers” for system-wide use. PBS also provides detailed system usage data, a procedure not easily executed without this software. Ames implemented this state-of-the-art system to replace their existing NQS (Network Queuing System), which was the first UNIX-based batch scheduling system.

PBS operates on networked, multi-platform UNIX environments. Veridian’s new version, PBS Pro™ has additional features and enhancements, including support for additional operating systems. Veridian distributes the original version of PBS as Open Source software via the PBS website. Customers can register and download the software at no cost. PBS Pro is also available via the web and offers additional features such as increased stability, reliability, and fault tolerance.

A company using PBS can expect a significant increase in the effective management of its computing resources. Tangible benefits include increased utilization of costly resources and



Veridian’s PBS technology offers users a single coherent interface, complete with a usage data log for ultimate efficiency.

enhanced understanding of computational requirements and user needs. The user-friendly system also reduces dependency on system administrators and operators, allowing them to focus their attention on more relevant activities. The system facilitates expandability by supporting the distribution of production workloads across wide-area networks (WANs), in addition to the logical organization of physically separate computing systems.

Veridian’s system has proved a big success for many large corporations including the Numerical Aerospace Simulation (NAS) Facility. After installation of PBS, the facility saw system utilization rates jump from 20 to 70 percent. David Lackner of the Ames Commercial Technology Office calls the PBS software commercialization a true success story. He said, “It becomes evident to the American taxpayer that their investment is paying off when products like PBS are spun out and become commercially viable, solving a real need.” ❖

PBS Pro™ 5.0 is a trademark of Veridian.

Bitsy Thinks Big

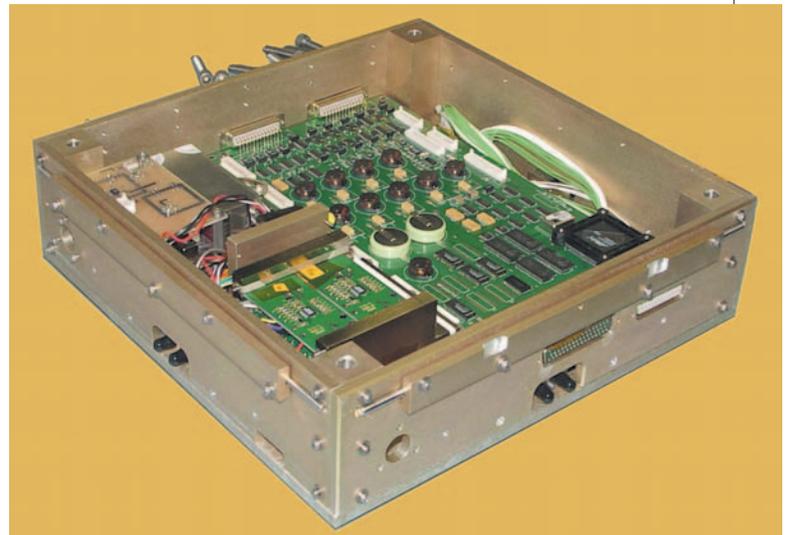
Launching satellites is not just for NASA any more. Today's commercial satellite industry is shooting for new frontiers beyond space exploration. The fast growing information and communications service markets are continually increasing efforts to make our everyday lives easier, by searching for more efficient methods of providing customers with quality service. Realizing the tremendous need for a multi-mission design, AeroAstro, of Herndon, Virginia, with assistance from NASA Marshall Space Flight Center, developed a nanospacecraft core module capable of developing recyclable spacecraft designs using standard interfaces. From this core module, known as the Bitsy™ kernel, custom spacecraft are able to connect mission-specific instruments and subsystems for variation in mission usage. Typically, all spacecraft require the same basic subsystems: power and power distribution, command and data handling, communications, and guidance. Although the general composition is the same, it has been the industry standard to develop spacecraft as unique designs, for specific missions, resulting in \$50 to \$100 million designs that were expensive and difficult to reuse. A generic design would greatly improve space missions, but this concept has not been readily accepted into the satellite industry due to the tremendously high costs of differing mission details, large size and mass, and the need to maintain two parallel development teams: the payload and the spacecraft.

The Bitsy kernel is designed to meet three key criteria. First, the kernel must be reliable. To achieve maximum reliability, Bitsy incorporates straightforward design, thorough testing, and standard interfaces and components. The next key element is cost; the kernel must be inexpensive. The versatility of the kernel keeps costs down by using a reproducible model capable of serving multiple missions. Finally, the kernel must be easy to use, which is achieved through Bitsy's flexible and extensive capabilities that are applicable to a variety of missions. Bitsy is small, lightweight, and is able to operate in any orbit, making it very appealing to the commercial market. Advanced technology such as Lithium-Ion batteries and dense field programmable gate array electronics make the unit efficient. When equipped with vaporizing liquid thrusters and structural propellant tanks the unit is easily maneuvered.

The nanospacecraft core module may be used in conjunction with an existing microsatellite bus or customized to meet specific requirements. Building on this premise, AeroAstro has

developed a line of satellite communications equipment, sun sensors, and Lithium-Ion batteries which are all incorporated in its complete line of mission-specific nanospacecraft. The Bitsy technology is also a key component in AeroAstro's satellite inspection products and orbital transfer services. In the future, AeroAstro plans to market an even less expensive version of the Bitsy technology. The plan, which is targeted to universities, markets a sort of "satellite in a kit," for less than \$1 million. This technology would allow universities to build true space hardware for a fraction of the cost of launching a regular satellite. Available alone as the core module component, or as a complete spacecraft based on the Bitsy system, the Bitsy kernel offers commercial customers limitless designs to meet the needs of specific missions. ❖

Bitsy™ is a trademark of AeroAstro.



The Bitsy™ nanospacecraft core module component offers commercial customers limitless designs to meet the needs of specific missions.

THE PAPERLESS SOLUTION

We are constantly moving closer to a paperless society as computers allow us to transmit data electronically. Through a **Small Business Innovation Research (SBIR)** contract from NASA's Goddard Space Flight Center, REI Systems, Inc., of Annandale, Virginia, brings our society one step closer to relief from the "paper trail."

Led by Dr. Barry E. Jacobs, researchers from Goddard, in partnership with REI, developed a software solution that uses the Internet to eliminate the paperwork typically required to document and manage complex business processes. The data management solution, called Electronic Handbooks (EHBs), is presently used for the entire SBIR program processes at NASA. "The idea," said Jacobs, "is that processes are regarded as Internet 'plays' in which the characters of the play are physically distributed and communicate in the play through Electronic Handbooks."

The NASA SBIR application, which manages roughly 50 percent of all new NASA contracts, is one of the largest, end-to-end, completely electronic Internet uses in the Federal

Government to date. Approximately two-thirds of all new technologies are developed by small businesses—so saving time and money is crucial. The EHB-based system is ideal for programs and projects whose users are geographically distributed and are involved in complex management processes and procedures. EHBs provide flexible access control and increased communications while maintaining security for systems of all sizes. Through Internet Protocol-based access, user authentication and user-based access restrictions, role-based access control, and encryption/decryption, EHBs provide the level of security required for confidential data transfer. EHBs contain electronic forms and menus, which can be used in real time to execute the described processes. There are only six basic elements needed for the creation of an EHB: database forms, report forms, e-mail forms, document templates, wizard packages, and instructions.

EHBs use standard word processors that generate ASCII HTML code to set up electronic forms that are viewed within a web browser. EHBs require no end-user software distribution, significantly reducing operating costs. Each interactive handbook simulates a hard-copy version containing chapters with descriptions of participants' roles in the online process. For example, by visiting a company's Internet address, customers log on to their specified area of that business's database and find all of the forms needed for a transaction, including instructions. Completed forms are sent to the intended recipient and the database is instantly updated. All submissions are archived and stored in a secure system, without the need for paperwork.

Almost any process requiring extensive paper documentation can be converted to an EHB performable online task. The EHB paradigm requires virtually no training and can be operated on any computer with Internet access. These characteristics make it an attractive package for users of almost all skill levels.

Electronic Handbook users enter data into a user-friendly form, such as this one implemented in NASA's SBIR proposal process.

NASA SBIR 2001-1 Solicitation

Form 9A - Proposal Coversheet

Please read the **instructions** carefully before proceeding.

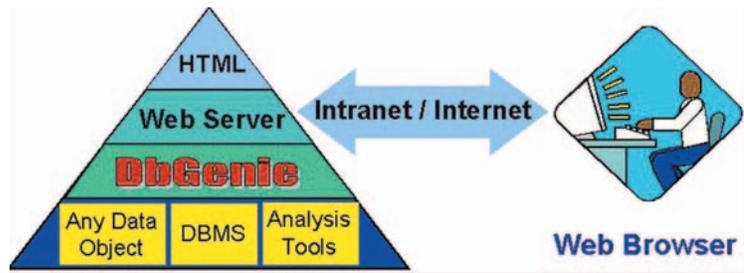
To save updates, click the "Update Coversheet Information" button at the bottom of the form.

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|---|---|--|---|
| Proposal Number: | A1.01.9973 (last 4 digits are system-generated) | | |
| Topic: | A1 | Subtopic: | 01 |
| Proposal Title: | Safety in Flights and Submarines | | |
| Firm Name: | REI Systems Inc. | | |
| Mailing Address: | 7620 Little River Turnpike | | |
| City: | Annandale | | |
| State: | VA | ZIP: | 22003-2620 Need help for ZIP+4? |
| Phone: | (703) 256-2245 | | |
| Fax: | (703) 256-9372 | | |
| EIN/TAX ID: | 123456789 | | |
| DUNS + 4: | 672194987 | What is DUNS? | |
| CAGE Code: | 4AE35 | Get CAGE from Central Contractor Registration(CCR) | |
| Amount Requested: | \$70000 | Duration: | 6 months |
| ACN Name: (Authorized Contract Negotiator) | Veer Bhartiya | | |
| ACN E-mail: | sbir@reisis.com | | |

Time and cost savings associated with REI's Electronic Handbooks have stimulated demand for a variety of applications. "With EHBs, we can achieve roughly a one-third reduction in the time required to process 2,000 SBIR proposals, while simultaneously achieving a significant increase in the quality and quantity of information that is available," said Paul Mexcur, NASA's SBIR Program Manager.

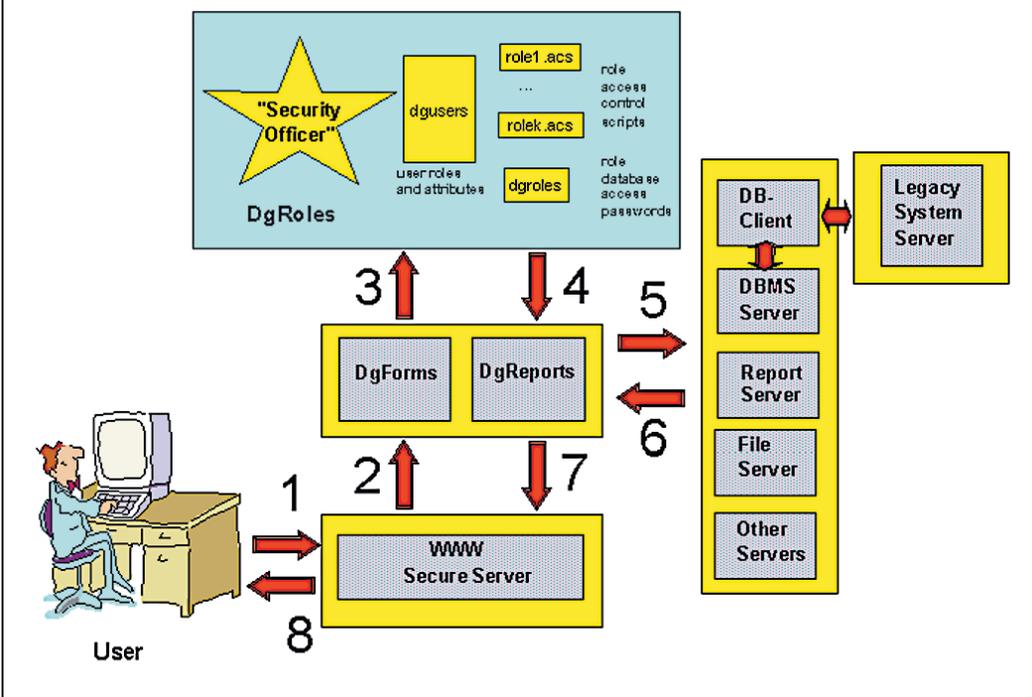
REI also offers the Database Genie, referred to as the DbGenie. It is a middleware solution that simplifies the creation of web database applications, such as EHBs. DbGenie uses a model designed on data specified in a pre-made HTML template. The DbGenie's scripts are driven by the template and are flexible with relation to modification and revision. Any database-oriented application for information gathering, exchange, and/or publishing that has a geographically-distributed user community and can exploit the expressive capabilities of the web is a potential candidate for Database Genie. This product is commercially available to the private sector and is another example of REI's advancement towards paperless applications.

EHBs have already proven their worth to NASA and other branches of the federal government including the Department of Justice, Department of the Interior, Department of Health and Human Services, and Community Development Financial Institutions. REI also continues to expand upon the vast commercial opportunities in the private sector. When considering the paperwork that goes into the fields of law, medicine, and insurance, REI's also highly praised technology can reduce mass quantities of paper waste, time, and cost while revolutionizing the face of data management. ❖



DbGenie is a middleware solution that simplifies creation of web database applications.

Data Flow Architecture



Using the Electronic Handbooks (EHBs) software solution eliminates the paperwork usually required to document and manage complex business processes.

BUSINESS IS BEAMING

It's a bird! It's a plane! It's your...Internet network?! An innovative service provider of metro gigabit IP connectivity, has developed a point-to-multipoint solution to solve the Internet last-mile bottleneck barrier. Terabeam, of Seattle, Washington, has developed a Fiberless Optical™ Network that transmits broadband data from office buildings to the nation's wide-area networks (WANs), without digging up the streets.

A key component of Terabeam's Fiberless Network is Large Aperture Holographic Optic technology, developed by Ralcon Development Lab, of Paradise, Utah. Ralcon developed the Holographic Optical Element (HOE) technology with assistance from a NASA Goddard Space Flight Center **Small Business Innovation Research (SBIR)** contract. Terabeam further developed the HOE technology and incorporated it into its Fiberless Optical Network—sending an immeasurable amount of information soaring overhead.

Data on the Internet is sent at rapid speeds over thousands of miles on long-haul networks before reaching its final destination. When the data reaches its urban termination point, it must pass through a final mile to reach the customer

site. The track that carries the data over this last leg of its journey is usually composed of copper and is low in bandwidth, resulting in an information back-up, or last-mile bottleneck. Efforts to solve this problem use existing fiber-optic cable leads. However, installing new or additional fiber-optic leads would require costly construction permits, street trenching and traffic disruption.

To combat this problem, Terabeam developed its Fiberless Optical Network using a proprietary HOE to transmit data. The unit is mounted near an office window and has the ability to beam safe, low-power, invisible data through the air at gigabits-per-second speeds to anywhere in the service area. Gigabits-per-second speeds are thousands of times faster than the speeds of current broadband transmissions. This allows businesses to connect to local-area networks (LANs) as well as WANs, in a quick and affordable manner. The Fiberless Optical Network is cost effective because it does not require a licensed spectrum, or any of the other costly and time consuming procedures associated with other network set-ups, such as laying fiber-optic cable and prolonged deployment time.



Terabeam's Fiberless Optical™ Network transmits broadband data from office buildings to the nation's wide-area networks (WANs) through the air.



It is projected that the broadband Internet access market will be \$33 billion by 2003. Realizing the potential of Terabeam's technology, Lucent Technologies joined forces with Terabeam to develop and deploy this revolutionary system. "Periodically, technology is developed that has the power to significantly change the landscape," said Rich McGinn, chairman and CEO, Lucent Technologies. He added, "Terabeam's Fiberless Optical Network system is such a disruptive technology. We are pleased to be working with Terabeam to help them bring their gigabit-speed Internet access to customers."

One investment company chose Terabeam's connectivity network because they needed to move large data files between their West Coast locations. Terabeam's network provided their business with high-speed data access that was installed in a

The system unit is easily mounted near an office window and has the ability to beam safe, low-power, invisible data to anywhere in the service area at astonishingly fast gigabits-per-second speeds.

matter of weeks, instead of months. In an effort to maintain the highest quality service, the Four Seasons Olympic Hotel, Seattle, Washington, chose to provide guests with this cutting edge network to allow them to connect to their offices or the Internet at speeds 2,000 times faster than the typical hotel dial-up connections. Terabeam has provided its Fiberless Optical Network service to a variety of businesses and plans to continue its efforts to revolutionize the broadband service industry. ❖

Fiberless Optical™ Network is a trademark of Terabeam.

KEEPING TRACK EVERY STEP OF THE WAY

When it comes to helping businesses manage and share their intellectual assets, NASA and its employees are an excellent resource. One of those resources, Kevin Barquintero, is co-founder of Knowledge Sharing Systems, Inc. (KSS), of Raleigh, North Carolina, a significant and influential provider of software applications.

Barquintero was employed at NASA Headquarters in the Commercial Technology Program, making him an expert on the many efforts and successes resulting from the Agency's various technology transfer activities. Combining his experience with the knowledge of co-founders Steve Monteith and Simon Wright, they formed KSS—a company that produces intellectual assets management software systems for clients in the federal government, universities, non-profit laboratories, and private companies.

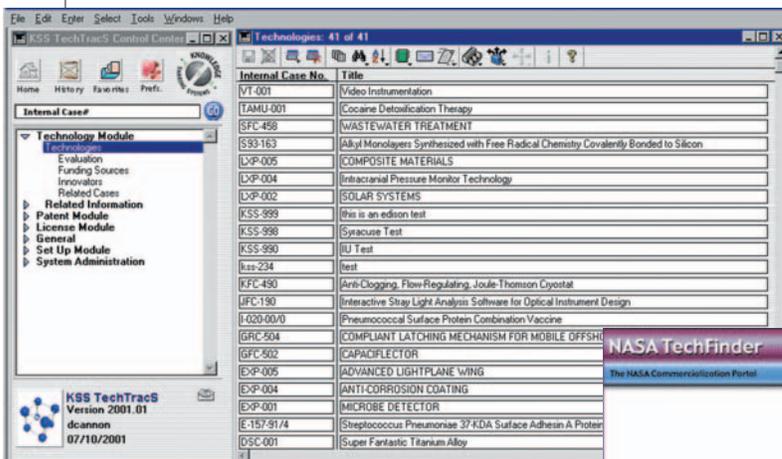
KSS constructed and presently manages the NASA Technology Tracking System, also known as TechTracS, under contract to Langley Research Center. TechTracS identifies and captures all NASA technologies, manages the patent prosecution process, and then tracks their progress en route to commercialization. The system supports all steps involved in various technology transfer activities, and is considered the premier intellectual asset management system used in the federal government today. NASA TechTracS consists of multiple relational databases and web servers, located at each

of the 10 field centers, as well as NASA Headquarters. The system is capable of supporting the following functions: planning commercial technologies; commercialization activities; reporting new technologies and inventions; and processing and tracking intellectual property rights, licensing, partnerships, awards, and success stories. NASA TechTracS is critical to the Agency's ongoing mission to commercialize its revolutionary technologies in a variety of sectors within private industry, both aerospace and non-aerospace.

NASA TechTracS benefits not only the NASA community, but also the private sector by making technology transfer information available through its NASA TechFinder web site at <http://technology.nasa.gov>. NASA's TechFinder provides users with a searchable database containing almost 20,000 publicly available technologies. A simple search by keyword, state, NASA field center, or reference number, allows people and businesses to easily view the many technology opportunities that NASA currently offers to private industry.

While Langley manages the system, running it effectively requires the expertise of KSS employees, as well as the cooperation of all the field centers. Each center provides input and is actively involved in the system's improvement process. Agency-wide involvement is unique to the development of the TechTracS software, making it a shining example of how NASA not only supports the development of innovative new technologies, but also assists in their refinement.

Both Langley Research Center and Kennedy Space Center nominated NASA TechTracS for the prestigious Software of the Year award for 2001. Recently, KSS launched its commercial intellectual asset management system, KSS TechTracS, which is aimed particularly at universities and non-profit laboratories. KSS and NASA TechTracS exemplify the efforts of NASA and private industry working together to provide people and businesses with the benefits enjoyed from the country's investment in aerospace research. ❖



Each technology entered into KSS TechTracS is given a tracking number and is carefully followed through all aspects of licensing, patenting, awards, and other commercialization efforts.



NASA's TechFinder web site, which is fed information by TechTracS, offers users a wealth of information regarding technologies available for commercialization.

INNOVATIVE SOLUTION TO VIDEO ENHANCEMENT

Video observation systems have become common fixtures in our everyday lives. Cameras mounted obscurely on walls, ceilings, and even traffic lights, capture the average person on videotape several times a day. Banks, gas stations, convenience and retail stores, and office buildings use video systems for business, customer, and employee safety. Through a licensing agreement, Intergraph Government Solutions, of Huntsville, Alabama, adapted a technology originally developed at NASA's Marshall Space Flight Center for enhanced video imaging, in developing its Video Analyst™ System. Barco Inc. Display Systems, Duluth, Georgia, also has a licensing agreement with Marshall and is incorporating the technology into its new computer hardware, designed for real-time video image enhancement, stabilization, and tracking.

Marshall's scientists developed the Video Image Stabilization and Registration (VISAR) technology to help FBI agents analyze video footage of the deadly 1996 Olympic Summer Games bombing in Atlanta, Georgia. VISAR technology enhanced nighttime videotapes made with hand-held camcorders, revealing important details about the explosion.

Intergraph's Video Analyst System is a simple, effective, and affordable tool for video enhancement and analysis. It combines high-end broadcast-quality systems with an easy-to-learn, user-friendly interface. Currently, the Video Analyst System is available for use with Microsoft® Windows® 2000, Adobe®, and Premiere® applications.

Many of the benefits associated with the Video Analyst System include support of full-resolution digital video, frame-by-frame analysis, and the ability to store analog video in digital format. Up to 12 hours of digital video can be stored and maintained for reliable footage analysis. The system also includes state-of-the-art features such as stabilization, image enhancement, and convolution to help improve the visibility of subjects in the video without altering underlying footage.

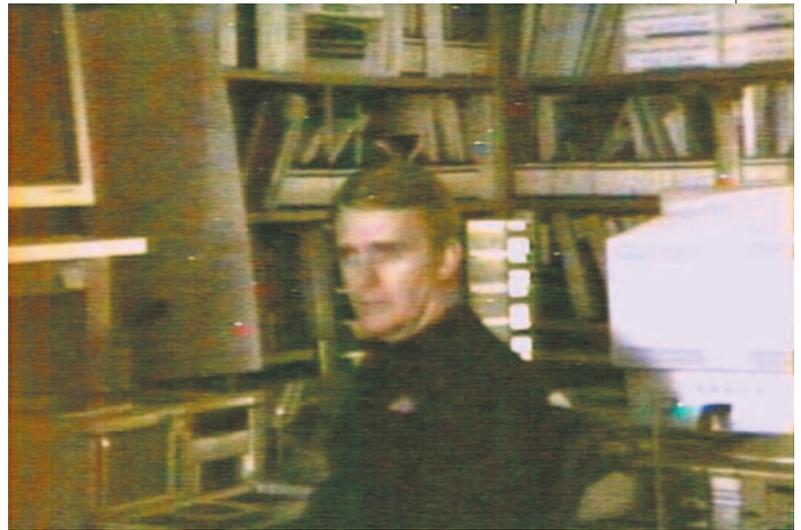
Adding to the appeal of this innovative technology is its price/performance value. The coupling of the system's highly technical workstation abilities with the cost-effective Microsoft Windows 2000 operating system, provides an unparalleled graphics-intensive video analysis. Even a novice can quickly learn to operate the system, eliminating the need for costly video specialist training.

Adaptable to many uses, Intergraph's Video Analyst System meets the stringent demands of the law enforcement industry in the areas of surveillance, crime scene footage, sting operations, and dash-mounted video cameras. Military applications include security, video feed from aircraft, target identification and confirmation, weapons deployment, damage assessment, surveillance and reconnaissance, training, and mission debriefing. The Video Analyst also adds significant value to the sophisticated surveillance systems prevalent in the intelligence field. With features such as enhancement, image tracking, and the ability to accept sonar data, the

system greatly enhances the use of satellite or aerial video. The affordable, easy-to-use characteristics of the Intergraph system benefit both government agencies and the commercial sector.

From satellite imaging to catching criminals, the collaborative efforts of NASA and Intergraph Government Solutions have brought another NASA technology down to Earth. ❖

Video Analyst™ System is a trademark of Intergraph Government Solutions, Inc. Microsoft® and Windows® 2000 are registered trademarks of Microsoft Corporation. Adobe® and Premiere® are registered trademarks of Adobe Systems Incorporated.



The Video Analyst™ System has the ability to stabilize, register, and zoom selected frame areas. This unprecedented method improves dark surveillance video with dramatic effect.

MAKING THE EZ CHOICE

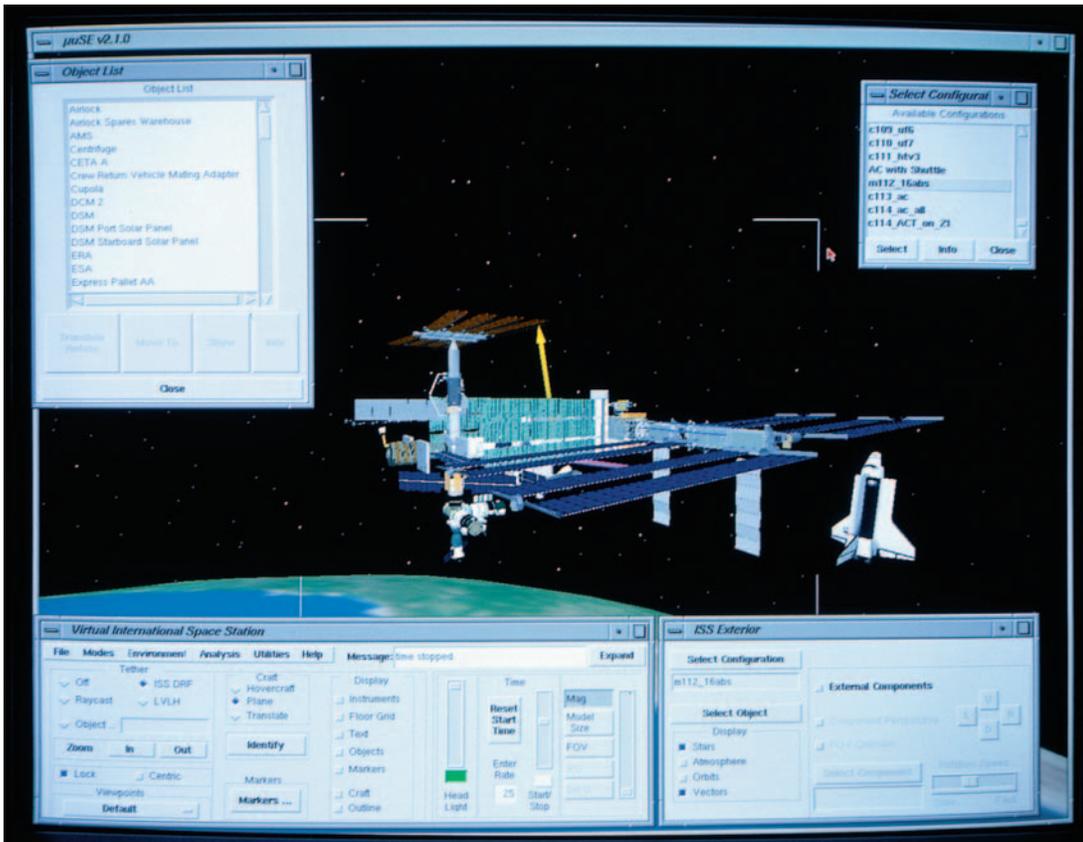
While most of us see the need for a toolbox, NASA saw the need for an optimal control tool kit. Analytical Mechanics Associates, Inc. (AMA), of Hampton, Virginia, strongly agreed and created an application through **Small Business Innovation Research (SBIR)** funding from NASA's Langley Research Center. The new EZopt software is a user-friendly tool kit that provides quick and logical solutions to complex optimal control problems.

Any process that can be mathematically formulated into an ordinary set of differential equations with constraints can be managed with EZopt. It can solve most general linear and nonlinear optimal control problems through the use of collocation or differential inclusions. In its most basic form, EZopt converts process data into math equations and then proceeds to utilize those equations to solve problems within control systems. EZopt successfully proved its advantage when applied to short-term mission planning and onboard flight computer implementation.

AMA is a company that provides dynamics, controls, modeling and simulations solutions, as well as engineering assistance. Dr. Hans Seywald, an AMA scientist and current vice-president, designed EZopt around a theory entitled "Trajectory Optimization via Differential Inclusions." The basic notion of the theory is that control variables can be removed from an optimal control problem formulation. These controls can then be replaced with constraints on accelerations, within which the software works to solve a problem. The theory provided the framework EZopt needed for reducing the number of design parameters involved in the optimization problem while at the same time, preserving or even improving the convergence robustness observed in collocation. But how will this software be used outside of NASA?

EZopt has solved multiple real-life engineering problems faced in numerous commercial operations. Mechanical engineers use EZopt to solve control problems with robots.





The EZopt program runs a simulation of Space Shuttle docking trajectories.

Chemical plants implement the EZopt software to overcome situations with batch reactors and temperature control. In the emerging field of commercial aerospace, EZopt is able to optimize trajectories for launch vehicles and perform potential space station-keeping tasks. The software helps control electromagnetic devices in the automotive industry. Additionally, numerous universities are presently using the software for various academic and research purposes.

The success AMA is experiencing with EZopt has led to further applications. DOCKSIM, the Optimal Docking Simulator, was created with the technology behind EZopt. Currently, DOCKSIM is integrated with the International Space Station to generate optimal docking paths for visiting space vehicles. AMA will continue to utilize the EZopt software to present optimal control opportunities to companies who need cutting-edge control solutions. ❖

Dr. Hans Seywald discusses the EZopt program with other team members as it runs a trajectory analysis for space station simulations.

ELASTOMERS THAT ENDURE

The Space Shuttle generates an enormous amount of heat during liftoff. To protect the launch structure, NASA has researched and experimented with various heat-protecting coatings since the 1980s. In the early 1990s, NASA joined with Dow Corning® to develop some type of protection for the Mobile Launcher Platform, the gantry structure, and other valuable equipment exposed to heat and chemicals given off by the Shuttle during liftoff. Through assistance from NASA's Kennedy Space Center, Dow Corning developed the 3-6376 Fast Cure Elastomer, a strong protective coating with applications in a variety of fields.

Previously, NASA used silicate coatings that simply failed to adequately protect, which resulted in the frequent recoating of the damaged areas. Of particular concern were the preservation of the weather protection curtains and the launch pad structure, which received most of the damage and required recoating following each launch. The enormous expense of this repeat procedure led Kennedy's Materials Science Laboratory to investigate the possibilities of ablative-type coatings. An ablative coating is a material that forms an insulating char when exposed to extreme heat. It is the char that protects the underlying coating and surface. The investigations resulted in the creation of a silicone ablative material known as the Dow Corning 3-6376 Fast Cure Elastomer.

By definition, an elastomer is a material that has significant elastic qualities. In this case, the 3-6376 elastomer is a 100 percent silicone material, giving it an extremely high level of elasticity. The Fast Cure Elastomer does not require a primer coating. The material is simply applied through the

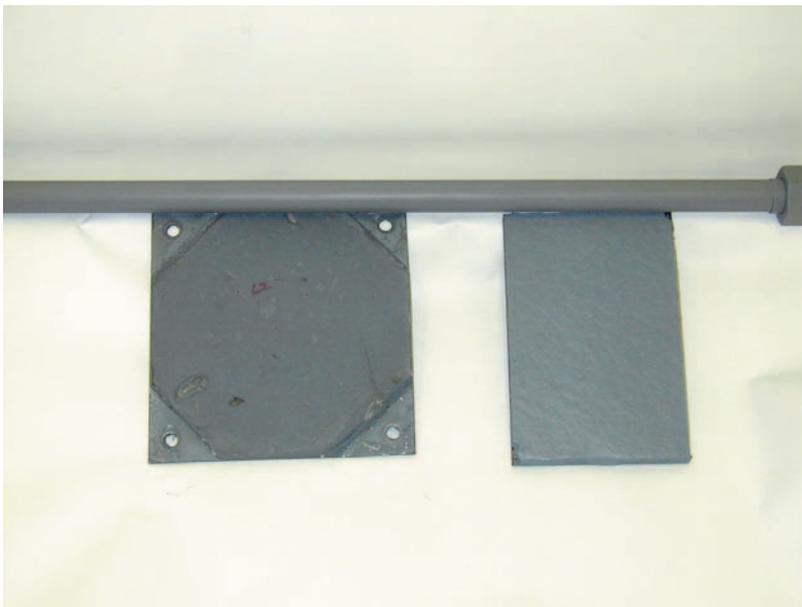
use of special spraying equipment and techniques. These developments have provided some major benefits.

The new product saves NASA money on materials, equipment, and labor. Because the new coating is sprayed onto large areas, fewer solvents are needed to protect the delicate area surrounding the launch pad. The decreased amounts of solvent and specialized spray techniques also help reduce the amount of overspray. The previously used trowel application is no longer necessary—since less work is performed, fewer materials are expended.

Less work also means less time wasted. The Fast Cure Elastomer reduces the turnaround time for reuse of the launch structure because of fewer refurbishing operations. This means that NASA is not held up due to repairs when it comes time to launch another Shuttle. To date, the Agency has launched dozens of successful missions without the need for recoating.

The elastomer is currently used in the automotive and aerospace industries and serves as an exceptional coating for engine compartment firewalls. Dow Corning's elastomer has also proved to be an effective sealant. The product offers widespread benefits for NASA and the commercial sector. As commercial opportunities expand, the Fast Cure Elastomer will continue to provide its unique and efficient coating benefits to those who use it. ❖

Dow Corning® is a registered trademark of Dow Corning Corporation.



Dow Corning's® 3-6376 Fast Cure Elastomer was tested at NASA's Kennedy Space Center on various panels and tubing before being applied to the launch structure.

KEEPING COOL IN EXTREME HEAT

A new foam knows how to keep its cool even under extreme high temperatures. NASA's Langley Research Center needed a lightweight foam that could retain its structural integrity under temperatures ranging from -423 to +482 °F, for its second-generation Reusable Launch Vehicles (RLV). Langley's RLV airframe design required new insulation material for the fuel tanks, which are exposed to extreme temperature changes over a matter of seconds.

Through a partnership with Unitika Ltd., NASA's Langley Research Center created a foam based on high temperature resistant polyimide chemistry. The patented foam, named TEEK, is non-exclusively licensed to SORDAL, Inc., of Holland, Michigan.

The new low-density foam can be processed into forms or used to fill structures such as honeycomb. Also unique is its ability to foam in place during installation and repair operations. Most foam must be cut to fit a certain area, and then inserted and molded. This process takes time, and usually a great deal of the product is wasted in the attempt to fit the foam. The new foam is directly applied to the installation or repair site, eliminating the excess foam that is typically cut away and discarded. TEEK offers superior insulation and support qualities, but its greatest advantage is its heat and flame resistance abilities. The TEEK polyimide foam met all of NASA's needs and also managed to drastically reduce the weight of the RLV.

SORDAL recognized the various advantages of the foam and its potential applications, and decided that the new foam would be a wonderful addition to SORDAL's use of composite structures. Within six months of receiving licensing, SORDAL created a successful marketplace for the polyimide foam. Many of the materials already produced by the company are compatible with the foam. "The addition of the NASA polyimide foam technology is a natural compliment to our product line," states Dale Danver, CEO of SORDAL.

Thus far, SORDAL has focused commercialization of the foam in the shipbuilding industry. It has proven to be a practical selection for hull insulation, but it has numerous potential applications in other fields. It is projected that the foam will also be used in aerospace applications, fire-resistant construction materials, and a wide range of consumer products that will improve safety and energy efficiency. Other

opportunities are available in the areas of automotive coatings and sealants, electrical components, and recreational equipment. Defense and aerospace contractors have utilized the foam because of its unique physical and chemical properties.

SORDAL has introduced its new product in several different forms, under the name "SOLREX." Besides the basic foam, SOLREX can also be purchased in either commercial or maritime grades. It can be preprocessed into neat and syntactic foam, or as foam-filled honeycombs or shapes. Microspheres are also offered. Presently, SORDAL is developing a new product called SORDAL Paper.TM The new product will be used in conjunction with the polyimide foam to offer thermal protection in various products. SORDAL anticipates the use of the companion products in the areas of wireless communications, fire resistant garments, prosthetics, and in many others. ♦

SORDAL PaperTM is a trademark of SORDAL, Inc.



SORDAL, Inc. offers NASA's TEEK polyimide foam in several forms, including microspheres, preprocessed neat and syntactic foam, and foam-filled honeycomb.

TAKIN' THE HEAT

What do you get when you combine Unitech LLC with NASA's Langley Research Center? You get an exciting new high-temperature polyimide with versatile applications. Langley has licensed this technology to Unitech, of Hampton, Virginia, and J. D. Lincoln, Inc., of Costa Mesa, California. Through a Memorandum of Agreement (MOA) and its license, Unitech is now selling the new polyimide, RP46.

Dr. Ruth Pater, of NASA Langley, developed RP46 for aerospace applications. The material was designed for re-entry vehicles and high-temperature engine components; however, its versatile nature makes it applicable as a molding, adhesive, coating, composite matrix resin, foam, or film. RP46 can also be fabricated over mesh for use in molds. Unitech is currently searching for a way to apply RP46 to injection molding, a process that forces or injects material into a mold.

RP46 presents a profitable option to manufacturers, because the ease of manufacturing the resin and the reduction in curing time saves money. Consumers save money because RP46 is more durable than similar products. For instance, PMR-15, a predecessor to RP46, was susceptible to microcracking when used as a coating or adhesive in high-temperature situations and often required reapplication. The chances of microcracking are significantly reduced with RP46 because of its unsurpassed ability to resist heat and corrosion. With a temperature range of -150 to 700 °F, it is difficult to find a resin with similar heat-resistant capabilities. It is also less toxic than its predecessor, which contains a toxic carcinogen. The elimination of the carcinogen makes the product safer for the consumer, the manufacturer, and the environment.

Unitech is a recognized manufacturer of specialized coatings, resins, and paints. The unique combination of the MOA and licensing agreement means that the company can modify the properties of RP46 to meet the specific needs of its customers. According to Wayne LeGrande, president of Unitech, the MOA allows his company to draw on Langley's expertise as they further tailor RP46 to commercial applications: "It's a perfect example of how research can make an effective transition into the marketplace." Technical assistance is also provided to Unitech under a NASA Space Act Agreement.

Unitech, a client of the NASA Hampton Roads Technology Incubator (HRTI), has achieved numerous sales to the



Unitech's custom lab reactor can generate multiple sample requests of RP46 as well as small production quantities of up to two tons per month.

private sector. Of particular interest is the sale to a company that tested the product for use as a potting material. However, the company was unable to overcome a curing problem until Unitech chemists stepped in and the company was able to resume its evaluation of RP46.

Liquid and powder forms have been sold to various companies in the aerospace industry. Unitech plans on further applying the benefits of RP46 to automotive components, marine engines, drilling operations, and high-temperature lighting and heating units. Presently, the government uses it for various aerospace operations, such as reusable launch vehicles, space exploration systems, and advanced aircraft engine components. The material exhibits additional opportunities in the areas of electronic and circuit boards, commercial aerospace, automobile manufacturing, corrosion protection, and thermal insulation.

Marine manufacturing companies have shown particularly high levels of interest. Resins used in marine environments usually fail quickly, but RP46 withstands the extreme effects of heat and saltwater corrosion. The use of RP46 allows companies to protect their equipment, thereby lengthening the life span. Because of its unique positioning with NASA, Unitech will continue to provide private industry with customized applications of this breakthrough material. ❖

PAPER-THIN COATING OFFERS MAXIMUM PROTECTION

Can you imagine a coating that with a paper-thin layer, protects your property from structural fire damage from the ground up? Wessex Incorporated has recently taken a technology that was originally developed for NASA as a protective coating for ceramic materials used in heatshields for space vehicles, and modified it for use in applications such as building materials, machinery, and transportation. The technology was developed at NASA Ames Research Center as a protective coating for flexible ceramic composites (PCC). Wessex, of Blacksburg, Virginia, obtained a license for the PCC and is proceeding to further develop it for numerous applications. Wessex describes this innovative technology as, “a significant advancement in thermal protection for the aerospace industry.”

The NASA-developed material is environmentally safe, water-based, and contains no solvents. Many other flame-retardant materials contain petroleum-based components, which can produce toxic smoke under flame. The ceramic components of PCC do not produce any type of toxic fumes during exposure to elevated temperatures.

An emissivity agent is attributed to PCC's remarkable thermal properties. Emissivity is the relative power of a surface to emit heat by radiation. This principle, along with PCC's non-combustible material makeup, is what increases the temperature capability of underlying insulation from high temperatures. Because the emissivity of the PCC helps radiate thermal energy at the surface, it reduces heat transfer to the underlying material. The coating essentially reduces the likelihood of the underlying material becoming so hot that it

combusts and thus inhibits the “flashover” phenomenon from occurring.

Wessex versions of PCC can be used to shield ceramics, wood, plasterboard, steel, plastics, fiberglass, and other materials from catastrophic fires. They are extraordinarily tough and exhibit excellent resistance to thermal shock, vibration, abrasion, and mechanical damage. One thin layer of coating provides necessary protection and allows for flexibility while avoiding excessive weight disadvantages.

Wessex sold the PCC product to Danser, Inc., of Parkersburg, West Virginia, a producer of ceramic-lined commercial ductwork. Sales have also been made to Encapsulation Technologies, a manufacturer who is applying PCC to venetian blinds to make them more fire-resistant. Potentially, the PCC material can be used in the home, in the garage area, where many volatile chemicals are often stored, in the kitchen to prevent cooking and appliance fires, as a lining to prevent chimney fires, and also as a firewall between the garage and the house. PCC applications could be beneficial in automobiles, trucks, boats, aircraft, storage facilities, and high-rise facilities, as well.

Wessex has developed several other coatings for substrates such as woods and metals, and is currently working with a plastic manufacturer to use PCC on fiberglass doors. Currently, fiberglass doors are extremely flammable and produce noxious smoke in the event of a fire. Fiberglass doors treated with PCC could be a low-cost, lightweight alternative to the expensive, heavy steel fire doors currently available in today's market. ❖



Two silicon-dioxide-based ceramic tiles were tested using an oxy-acetylene torch (hot enough to cut metals). The untreated tile on the left melted and turned to glass beads within 30 seconds. Under the same conditions, the tile on the right with Wessex's PCC coating, was tested for 2 minutes and showed little damage.

MORE THAN JUST A POLYMER

Creating low-cost spacecraft with extensive lives and improved performance capabilities is one of NASA's goals. Thanks to a new family of polymers that goes by the name of TOR,[™] NASA is one step closer to this goal. Through a **Small Business Innovation Research (SBIR)** contract from NASA's Langley Research Center, Triton Systems, Inc., of Chelmsford, Massachusetts, made a dramatic improvement to the field of aerospace materials.

TOR stands for Triton atomic Oxygen Resistant polymers. The new polymer comes from a Langley-developed polymer technology, which marks a new class of aerospace materials that resist the extreme effects of low Earth orbit (LEO). The need for materials with these resistant properties is growing as more satellites are placed in LEO. When applied to spacecraft surfaces, TOR polymers protect against erosion caused by the atomic oxygen and radiation present in space. Other polymers, such as Teflon[®] and Kapton[®] are subject to degradation from atomic oxygen and ultraviolet radiation, but TOR polymers use atomic oxygen to their advantage.

TOR polymers contain phosphorous to provide greater resistance to the effects of atomic oxygen. When atomic oxygen and phosphorous react, a protective phosphate layer is produced that works to reduce erosion without sacrificing chemical properties. This reaction is what makes TOR polymers resistant to erosion, giving them a survival period of greater than 10 times longer than other polymers, such as Kapton. A long-lasting protective barrier means major savings in the cost of spacecraft maintenance and the time spent performing repairs.

Triton developed various processing methods for manufacturing the material. Because the polymers lend themselves to diverse forms, they can be used for diverse purposes. The TOR family of polymers is offered in the forms of powder, adhesive tape, solution, fiber, thread, fabric, or film. For instance, the fiber form of the polymer can be twisted into thread for making insulation blankets, or braided for use in tethers.

While the obvious application of this material lies with the aerospace industry, an underlying benefit is found in the field of electronics. TOR polymers are inherently resistant to high voltage, making them an excellent high-voltage insulator for power generation applications. In another version, TOR polymers can be made electrically conductive. In their



TOR[™] polymers are offered in a variety of forms and can be used for the protection of satellites or as high-voltage insulators.

conductive form, they can be utilized in the creation of sensors that react to the presence of chemical and biological agents by exhibiting a detectable change in electrical conductivity. These sensors have applications in the defense, medical, and industrial sectors since they can detect substances by recording changes in the resistance of conductive polymers.

Due to the increased presence of voice and data transmission, companies are focused on ways to effectively maintain their communications satellites. TOR polymers present an affordable option that will greatly extend the life of these crafts. It is projected that TOR-insulated satellites will save industry millions of dollars in annual satellite insulation repairs.

TOR is offered as a complete family of products that address a variety of LEO-based spacecraft needs. Triton is a leading materials product and process development firm that provides its customers with superior solutions. Triton and Langley Research Center were jointly awarded the R&D100 award for the year 2000—presented for the 100 most technologically significant new products of the year. ❖

TOR[™] is a trademark of Triton Systems, Inc. Teflon[®] and Kapton[®] are registered trademarks of E.I. du Pont de Nemours and Company.

Good Vibrations

Surface vibration provides useful information for products in a variety of industries. For example, automobile manufacturers measure surface vibrations to ascertain noise sources and to evaluate disk brake performance. Surface vibrations provide aircraft manufacturers with valuable information about the structural quality of panels, turbine blades, and critical aircraft body components. Musical instrument manufacturers measure the vibration of their instruments to confirm purity of sound.

A **Small Business Innovation Research (SBIR)** sponsorship from NASA's Dryden Flight Research Center, assisted MetroLaser, of Irvine, California, in the development of a self-aligned laser vibrometer system. VibroMet, capable of measuring surface vibrations in a variety of industries, provides information on the structural integrity and acoustical characteristics of manufactured products.

Currently, the most common device used to measure surface vibration is the accelerometer. Although useful in some aspects, accelerometers are generally time consuming and awkward to operate. In order to measure vibration, they must be attached to the surface of the subject and wired to a recording system. In some cases, this may actually dampen the vibration measurement. On the other hand, laser vibrometers provide a non-contact alternative to the accelerometer, eliminating the risk of an incorrect calculation.

MetroLaser's research and development of the vibrometer led to the VibroMet system, which analyzes the frequency and amplitude returned from the surface evaluation. This low-cost, easy-to-use sensor performs vibration measurement from distances of up to three meters without the need for adjustment. The laser beam is simply pointed at the target and the system then uses a compact laser diode to illuminate

the surface and to subsequently analyze the reflected light. The motion of the surface results in a Doppler shift that is measured with very high precision. The Doppler shift illustrates that sound waves have a fixed wavelength or distance between two crests. Simply explained, if a subject is moving away from the source, the sound wave will take a little longer to reach each crest, and a perceived longer wavelength will be heard. In contrast, if the subject is approaching the source, the soundwave will meet each crest a little earlier, and a shorter wavelength will be perceived.

Nicolet Instrument Technologies, of Madison, Wisconsin, uses the laser diode vibration sensor technology in its Orion Laser Doppler Vibrometer (LDV). The LDV is able to measure the smallest vibration without the need for scrupulous setup or surface preparation. The LDV can work on almost any surface and is capable of off-axis measurements. Because Nicolet's product is easy to use it is attractive to a variety of industries. Common uses of the company's product are rotating applications, such as automotive drive shafts, alternators, generators and tires; multi-point measurements in machinery and modal analysis; surface vibration measurements in small structures such as hearing aids, tissue membranes and micro-sensors; as well as applications in production testing, including hand tool assemblies, electric motors, and piezoelectrics.

The collaborative efforts of NASA and these companies have refined the laser vibrometer into a user-friendly, cost-effective surface vibration measurement system. VibroMet is considered one of the many behind-the-scenes tools that can be relied on to assure the quality, reliability and safety of everything from airplane panels to disk brakes. ♦



MetroLaser's VibroMet is a self-aligned, easy-to-use system for measuring surface vibrations that provide key information on the structural integrity and acoustical characteristics of manufactured products.

A NEW KIND OF CURING

A new curing method using automated tape placement (ATP) with electron beam (EB), or e-beam, produces a combination known as in situ e-beam curing. Through a **Small Business Innovation Research (SBIR)** contract from NASA's Marshall Space Flight Center, Science Research Laboratory, Inc. (SRL), of Somerville, Massachusetts, created the in situ e-beam curing technique, which uses a low-energy electron beam gun to cure various composite materials. The new process is a valuable tool in the aeronautics, aerospace, and automotive industries.

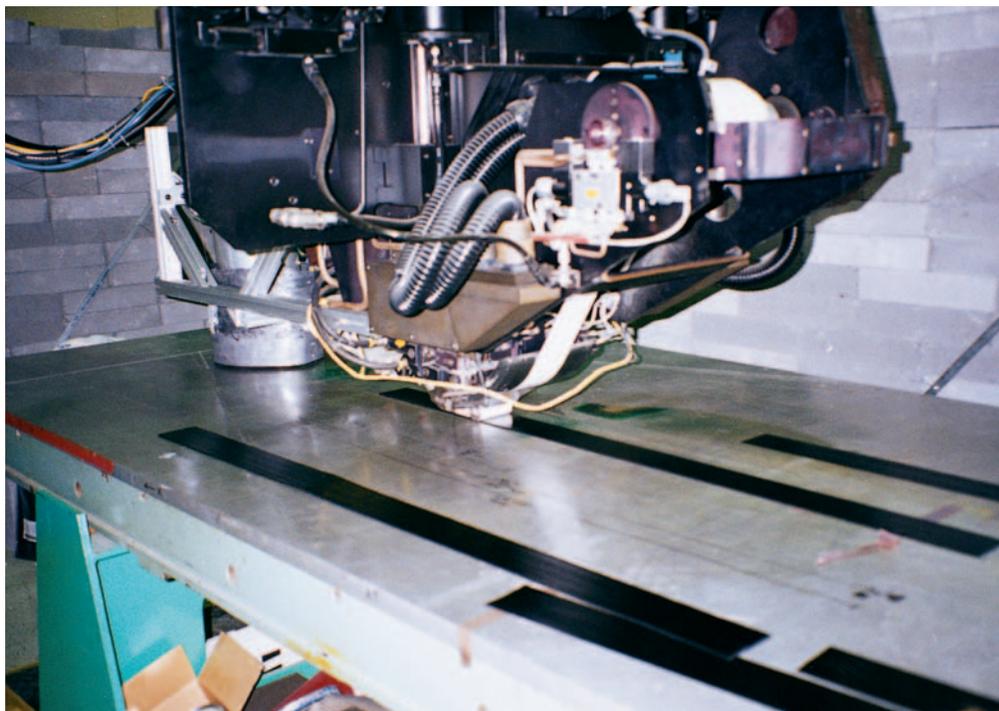
While e-beam curing is not new, SRL's use of a low-energy gun for in situ e-beam curing is truly innovative. One important benefit is the technique's utilization of room temperature curing, which lessens the chance of mismatching the thermal expansion coefficients of different materials. For instance, metals and composites will expand at different rates when heated, but the low-energy e-beam gun reduces the expansion differential. Using a low-energy gun also results in less x-ray shielding, significantly reduced capital costs, reduced facility space, and increased processing capabilities for larger parts. However, using a low-energy gun also means that each tape layer is treated individually because the gun can penetrate only one layer at a time.

Previously, two separate facilities were needed: one for ATP and another for e-beam or autoclave curing. The e-beam gun combines these two steps into one process, leading to the added benefit of potentially faster throughput, since ATP lay-up and the curing process are completed at the same time.

Usually, the first step required that the tape or material be laid out, followed by debulking under a vacuum bag. The second step called for the curing by either an autoclave for heat and pressure, or a high-energy e-beam. An autoclave is like a pressure-cooker for materials that need to be hardened, or cured, before they can be used. Typically, using an autoclave can be expensive and time-consuming. Additionally, an autoclave cannot cure parts that are unable to fit inside it. The costs associated with the construction of both an autoclave for the large composite parts presently being designed, and a building to house it, are high. However, the new in situ e-beam curing technique can cure large parts by adding a low-energy e-beam gun to an existing ATP facility; and because this new system cures the material as it is laid, less power is needed.

The e-beam gun emits lower energy x-rays, which are more easily shielded than those emitted by previous guns. The low-energy system is relatively portable due to its light weight and small size. The gun weighs about 70 pounds and can be easily mounted on a robotic arm or an ATP head. Furthermore, these convenient developments have not detracted from its capabilities. The gun still delivers electrons with sufficient energy for composite part fabrication and bonding. Since curing is conducted during the placement of tape, a large volume of tape can be placed and cured in only one step.

Keeping with the efficient nature of the new technique, an easily reconfigured x-ray shield is the only other accessory required. Portable shielding is comparatively lightweight and



A portable electron beam gun for in situ curing was fabricated at Science Research Laboratory, Inc. before installation on the ATP head at NASA Marshall Space Flight Center.

consists of either lead panels on wheeled supports or readily available cement blocks. It is easily added to already existing facilities when the EB system is installed. Portable shielding also contributes to the cost saving features of this product. As much as half of the costs of developing high-energy EB facilities involve the construction of concrete x-ray shielding walls and ceilings. By eliminating the need for high-energy EB facilities, construction costs are significantly reduced.

While primary applications are in the aerospace industry, future uses for the EB-ATP system in the automotive industry are anticipated. Chrysler is experimenting with this technology to develop a concept composite car and may apply the EB curing technology to the manufacture of various automotive parts.

Present users of the EB-ATP in situ curing system are impressed with its flexible and productive nature. In an effort to advance the system, SRL created a spinoff company, Electron Solutions, Inc., which sold and installed a similar electron gun system for the Boeing Radiation Effects Laboratory in Seattle, Washington. Scientists at Marshall are planning on using the in situ e-beam curing system to cure parts used in the construction of rocket fuel tanks for reusable launch vehicles. Using the new product will lead to reduced costs—and not just pennies, but millions of dollars. As SRL continues to improve its system, the company will continue to provide innovative curing options to both NASA and private sector manufacturers. ❖



The electron gun at the bottom center of the picture is mounted to the ATP head, which is black. The e-gun high-voltage power supply is in the top half of the picture, mounted to the crossrail that supports the ATP head and moves it horizontally.

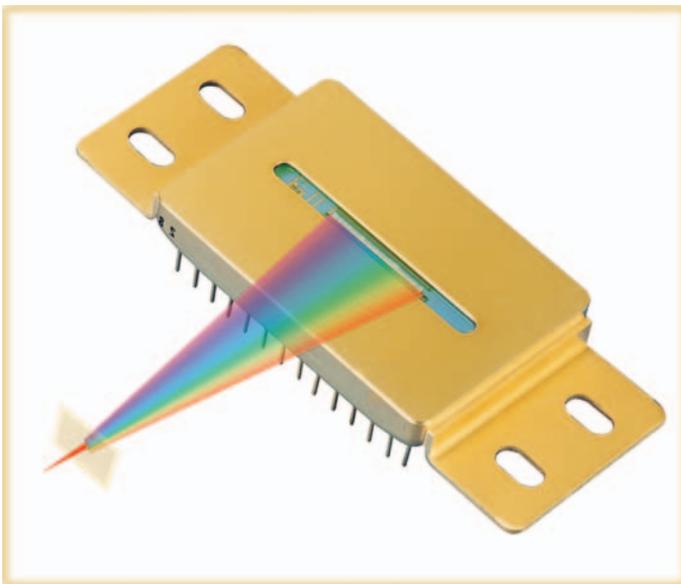
OFFERING AN ARRAY OF IMPROVEMENTS

A long-time veteran of NASA's **Small Business Innovation Research (SBIR)** program successfully incorporated an SBIR-funded technology in the commercialization of several products. Sensors Unlimited, Inc., of Princeton, New Jersey, with SBIR funding from NASA's Langley Research Center, Goddard Space Flight Center, Marshall Space Flight Center, and the Jet Propulsion Laboratory, developed a monolithic focal plane array for near-infrared imaging. Innovative technologies derived from this development have enabled telecommunication companies to optimize existing bandwidth in their fiber-optic networks.

The Internet offers an infinitely expanding demand for information. Early web sites were mostly text based; however, an increase in technology led to more graphic-oriented sites, resulting in larger volumes of data, creating a need for faster connections and increased bandwidth. Sensors Unlimited, recognizing these new requirements, developed one- (1-D) and two-dimensional (2-D) imaging arrays consisting of a highly reliable InGaAs p-I-n diode as a photodetector for monitoring a variety of applications, including single element device applications in receivers.

A 1-D imager is comprised of a one-dimensional, linear array of photodiodes to detect light, and a readout integrated circuit (ROIC) to interpret the image. A 2-D imager includes the same ROIC, but contains a two-dimensional array of photodiodes, increasing light detection and therefore, performance. Sensors Unlimited developed a method of combining the photodiode array and the ROIC monolithically in an infrared imager. The high-performance InGaAs array is integrated with a junction field effect transistor (JFET) that acts as a switching element for each pixel. Advantages of such a detector include low dark current, high quantum efficiency, subnanosecond response, and room temperature operation.

The InGaAs 1-D and 2-D arrays have many applications.



For example, they monitor the performance of dense wavelength division multiplexing (DWDM) systems—the process of packaging many channels into a single fiber-optic cable. Sensors Unlimited draws on the example of a prism in front of a fiber-optic cable to demonstrate how multiple wavelengths of light are separated from one another, “With DWDM, each of these colors is a separate channel carrying a separate stream of data.” Sensors Unlimited commercially offers its LX™ and LY™ Series InGaAs linear arrays for reliable DWDM performance monitoring. The LX and LY arrays enable instrument module designs with no moving parts, which provides for superior uniformity, and fast, linear outputs that remain stable over a wide temperature range.

Many infrared imaging arrays are hybrid devices. The photodetectors utilized in these systems are interconnected to silicon multiplexer readout arrays by either flip-chip or wire bonding. A hybrid system is not the most efficient system due to the complex manufacturing steps and additional handling processes involved. Sensors Unlimited also produces linear photodiode arrays for optical monitoring by incorporating an innovative, scalable, manufacturing process, allowing production capacity to stay ahead of market needs. This permits optical networks employing the array to grow proportionately to the demand for high-speed bandwidth. Sensors Unlimited's technology facilitates telecommunication providers' needs to increase bandwidth in order to support a high volume of network traffic. At the same time, the technologies obtained from the monolithic focal plane array have the potential for reducing costs, while increasing performance from Sensors Unlimited's current product lines.

According to Sensors Unlimited president, Greg Olsen, the support of SBIR funding has helped to build a technology company with tremendous value. “As a leading supplier of InGaAs technology and products, Sensors Unlimited will continue to be a dominant force in the fiber-optic industry, because we make the products that allow high bandwidth Internet operations, which is an area experiencing tremendous growth. We owe our auspicious start to the SBIR awards, which enabled us to conduct state-of-the-art research and development and secure partnerships that we need to bring our technology to the market.” ❖

LX™ Series InGaAs linear photodiode array is a trademark of Sensors Unlimited, Inc.
LY™ Series InGaAs linear photodiode array is a trademark of Sensors Unlimited, Inc.

Just as a prism separates colors into different channels, Sensors Unlimited's linear photodiode array separates multiple streams of data into fast, linear outputs that remain stable over a wide temperature range.

THE MATERIAL WITH A NEED FOR SPEED

Through licensing from NASA's Langley Research Center, yet another company is enjoying the benefits of NASA's technology transfer program. A Langley-developed material, known as PETI-5, was created for use in the High Speed Research (HSR) program. The technology was licensed to four companies: Culver City Composites, of Culver City, California; Cytec Engineered Materials, of Havre de Grace, Maryland; Fiberite, of Greenville, Texas; and Imitec, of Schenectady, New York. The licensing generated the largest upfront royalty income in NASA's history. Since the original licensing was obtained, Cytec Engineered Materials and Fiberite have merged to form one operation under the name Cytec Fiberite, Inc.

PETI-5 is the commonly used term for phenylethynyl terminated imide oligomers, and the 5 refers to the fifth formulation out of 200 compositions. It is a chemical material that can be used as both a resin and an adhesive. PETI-5 also combines superb mechanical properties and extreme durability with easy processing and environmental stability. For example, the material has temperature capabilities of 350 °F for a lifetime of around 60,000 hours. It is prepared from commercially available materials, making it relatively low cost to manufacture. Curing is done with the application of heat and mild pressure, which results in the formation of a strong, resistant polymer. Due to the nature of this preparation, it is fairly easy to create large and complex parts using PETI-5.

The chemistry behind the creation of PETI-5 involves the preparation of oligomers, or low-molecular-weight imide

materials. The oligomers are then capped with phenylethynyl. It is the low molecular weight of the oligomers that allows PETI-5 to be easily processed.

Due to its unique combination of benefits, PETI-5 will be used in the development of the high speed civil transport (HSCT), a concept 300-passenger commercial plane that will travel at a speed of Mach 2.4. Because currently available metals are too heavy and cannot withstand the extreme high temperatures resulting from flying at such high speeds, composite materials made from graphite fibers and PETI-5 are necessary. These materials will withstand the heat, and make the plane strong enough and light enough to be economically viable. Without the characteristics present in PETI-5, it would be impossible to attempt the development of the HSCT.

PETI-5 was the winner of the NASA Commercial Invention of the Year award for 1998. The material received *Research and Development* magazine's R&D 100 award. Cytec Fiberite and Imitec have achieved huge successes with the material in the commercial aerospace industry. And as supersonic civil transports are further investigated by commercial aircraft carriers, the market potential of PETI-5 will continue to expand. Unique opportunities continue to present themselves in the areas of electronic components, jet engines, high performance automotive applications, and beyond. ❖



Cytec Fiberite, Inc., is a global supplier of high-performance composites and adhesives for extreme environments, and offers the PETI-5 material in a wide variety of product forms.

NEW TOOL CREATES A BIG STIR

NASA inventors and engineers are constantly developing revolutionary new technologies. Jeff Ding, an engineer at NASA's Marshall Space Flight Center, invented a new self-adjusting pin tool for a process known as friction stir welding. The technology is jointly licensed to MTS Systems Corporation, of Eden Prairie, Minnesota, and MCE Technologies, Inc., of Seattle, Washington.

Friction stir welding is a process that makes straight-line welds without bringing the parent material to a liquid state. This is accomplished through high-speed rotation, which generates frictional heat between the welding tool and the piece being welded. This heat causes the material to soften to the point of plasticity without allowing it to melt. The plasticized material is then transferred from the front edge of the welding tool to the trail edge, where it joins the pieces being welded. However, a major flaw of this method is its reliance on a single-piece pin tool. The weld is left unfinished and a hole remains where the pin was inserted. The hole must be covered with a rivet in order to preserve the integrity of the weld. Using the new NASA-developed pin tool eliminates the need for this finishing step.

The friction stir welding process used in MTS and MCE systems includes the new self-adjusting, retractable pin tool. The pin is inserted between the two pieces of material to be joined. Passing back to the original point, the pin slowly retracts back into the tool. This retraction allows continuous rewelding at lesser depths, until the hole is completely closed.

Because the automatic pin tool makes a 360-degree weld with no insertion holes, these systems have an advantage over welding systems that do not use the tool.

With this NASA technology, welding of higher strength alloys, as well as non-planar and variable thickness structures can be achieved, and the technology is now used in the manufacturing of components for the Space Shuttle. According to Jeff Ding, "This new welding process will allow for stronger and more reliable welds on NASA's Space Shuttle External Tanks." The retractable pin produces a more stable weld of the Tanks' metals that have varied thicknesses.

The new process is a great success in the private sector. "Friction stir welding technology is revolutionizing the fabrication industry," said Mike Skinner, MTS Business Development Manager for Advanced Manufacturing Technology. He continued, "It is already used to manufacture Delta rockets, marine vessels, and automobiles, and will soon be used for commercial aircraft. We're seeing active interest from companies worldwide." The growth potential is exciting and the adjustable pin tool technology will make many new applications feasible.

Currently, the new technology is utilized in the manufacturing of aerospace and aircraft frames. Applications are projected for the defense industry, and according to Ding, the technology could be used to weld shut canisters used for the containment of radioactive waste. ❖



The MTS Friction Stir Welding Process Development System uses the NASA-developed self-adjusting, retractable pin tool to offer welding capabilities that were previously unachievable with other welding systems.

RHENIUM REDEFINED

Through a Small Business Innovation Research (SBIR) contract with NASA's Glenn Research Center, another business is delivering an innovative new product. Rhenium Alloys, Inc., of Elyria, Ohio, developed a new method for producing rhenium combustion chambers. While the method provides major benefits to NASA, the benefits and conveniences also extend to the private sector.

Rhenium is one of Earth's rarest naturally occurring metals and is required by NASA for various space applications. It has an extremely high melting point of 5756 °F, and can maintain its durability through thousands of repeated temperature changes. This makes it attractive because a rocket made of rhenium could be cooled by simply radiating its heat into space, instead of being cooled by alternative means, which are presently a major source of fuel inefficiency in spacecraft. Unfortunately, this metal had a reputation for being difficult to work and form.

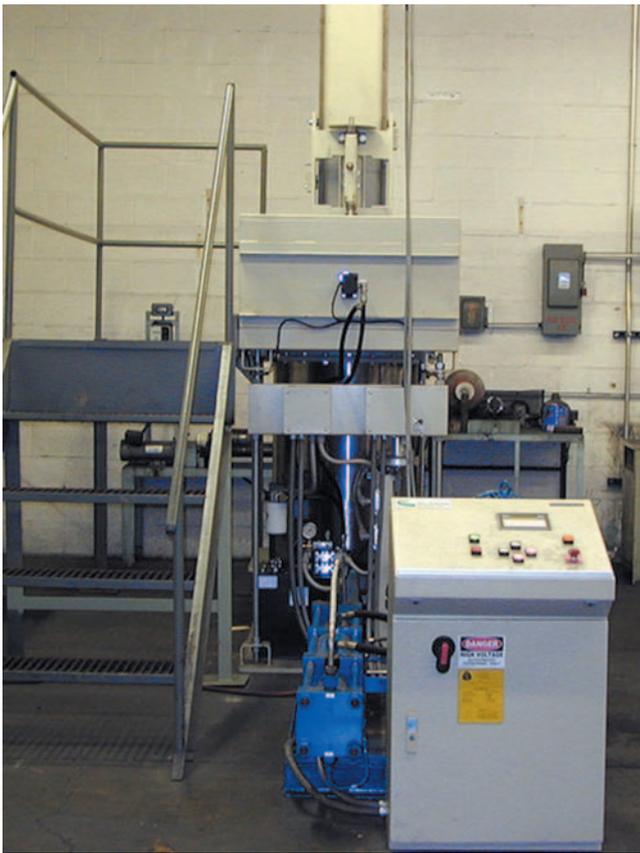
Glenn researchers found several less costly methods for forming the metal, but decided the manufacturing industry would be the ideal source for perfecting and refining these developments—enter Rhenium Alloys, Inc. Using room temperature isostatic pressing, the company compacted

rhenium powder to a high density and into the approximated end shape and dimension of the rocket thruster. The item was then subjected to sintering and containerless hot isostatic pressing, increasing the density of the powder metallurgy part. With the new manufacturing process, both production time and costs are reduced while quality is significantly increased. The method enabled the company to deliver two chemical rocket thrusters to Glenn Research Center. Not only was the new method good for creating rocket thrusters, but also for other commercial purposes. For instance, Rhenium Alloys, Inc., used its innovative process to manufacture a rhenium hemisphere for a commercial customer, and can also create other custom parts as needed.

Rhenium Alloys, Inc., makes rhenium a practical choice in manufacturing fields, including the aerospace, nuclear, and electronic industries, with upcoming opportunities projected in medical instrumentation.

Todd Leonhardt, director of technology at Rhenium Alloys, Inc., attributes part of the company's success to NASA and the SBIR program: "We would never have been able to develop these processes without the financial and technical support of the SBIR contracts. The advice and encouragement we received from Glenn researchers was [*sic*] also invaluable."

With their innovative new processing capabilities, Rhenium Alloys, Inc., will continue to remain a premier global supplier of rhenium and rhenium alloy products. ❖



Rhenium Alloys, Inc., uses their cold isostatic press to compact rhenium powder to a high density. The pressed compact is the approximate shape of the component.



Rhenium Alloys, Inc., uses NASA-developed methods to manufacture custom parts from rhenium, such as the two domes displayed here.

Hollow RETROREFLECTORS Offer Solid BENEFITS

A technician who lead a successful team of scientists, engineers, and other technicians in the design, fabrication, and characterization of cryogenic retroreflectors for the NASA Cassini/Composite Infrared Spectrometer (CIRS) mission to Saturn, developed a hollow retroreflector technology while working at NASA Goddard Space Flight Center. With 16 years of NASA experience, James Lyons teamed up with Patricia Losch, also from NASA, and started a company, PROSystems, Inc., of Sharpsburg, Maryland, to provide the optics community with an alternative source for precision hollow retroreflectors.

Retroreflectors are comprised of three flat mirrors bonded together at right angles to form a corner of a cube. These assemblies are used as tilt-insensitive mirrors in situations where it becomes necessary to maintain tilt down to the arc second level, a very difficult task in an unstable environment. Until the Cassini mission, there was no industry standard for maintaining alignment in a thermally unstable environment. Although hollow retroreflectors are much more difficult to manufacture than the predecessor solid retroreflectors, advantages gained make up for the extra effort. Solid retroreflectors are much heavier and cause dispersion. Hollow retroreflectors are much lighter and eliminate dispersion.

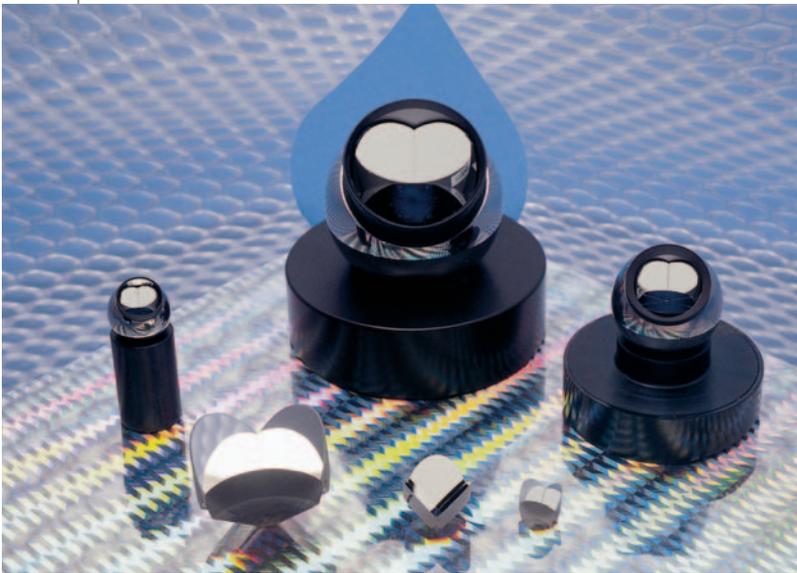
The hollow retroreflectors from PROSystems are front surface glass substrates assembled to provide many advantages

over existing hollow retroreflectors and solid glass retroreflectors. PROSystems offers hollow retroreflectors in sizes ranging from .3 to 4 inches in diameter. Previous to this new technology, some companies chose not to use hollow retroreflectors due to large seam widths and loss of signal. The “tongue and groove” facet design of PROSystems’s retroreflector allows for an extremely small seam width of .001 inches. Feedback from users is very positive regarding this characteristic.

The manufacturing methods of PROSystems generate small-diameter hollow retroreflectors with small beam deviation. Beam deviation is the angle of the incoming beam versus the angle of the outgoing, returned beam. Ideally, the beam deviation is zero. The small beam deviation from PROSystems is notable, because as the aperture diameter shrinks, it is much more difficult to obtain small beam deviations.

The design for joining facets allows a stable bond configuration over broad changes in temperature. This creates a stable alignment within the system where the retroreflector is being used, thus ensuring the successful performance of the instrument in its specified operating environment. Additionally, PROSystems uses the glass mount design to fabricate cryogenic hollow retroreflectors in applications that require a large temperature range. This glass mount design permits the metal-to-glass interface to be remounted from the retroreflectors glass substrates, thereby eliminating distortion caused by the interface of differing materials. The retroreflectors’ used in the Cassini/CIRS instrument remained stable at an operating temperature of 170 degrees Kelvin.

PROSystems offers its hollow retroreflectors with a variety of coatings, including protected gold, bare gold, protected silver, protected aluminum, and bare aluminum to fit customers’ needs. Most of PROSystems’s primary customers mount the hollow retroreflectors in chrome steel balls for laser tracker targets in applications such as automobile manufacturing and spacecraft assembly. Recently, PROSystems also made sales of this technology to the telecommunications industry for use in fiber optic networks. The company anticipates future applications of the hollow retroreflector technology in the commercial spectrometer market, incorporating them into standard products. PROSystems plans to continue developing its retroreflector technology to provide the optics industry with the highest quality precision product available. ❖



Three different sizes of retroreflectors are shown on stands with three unmounted retroreflectors (assembled mirrors) shown in the foreground.

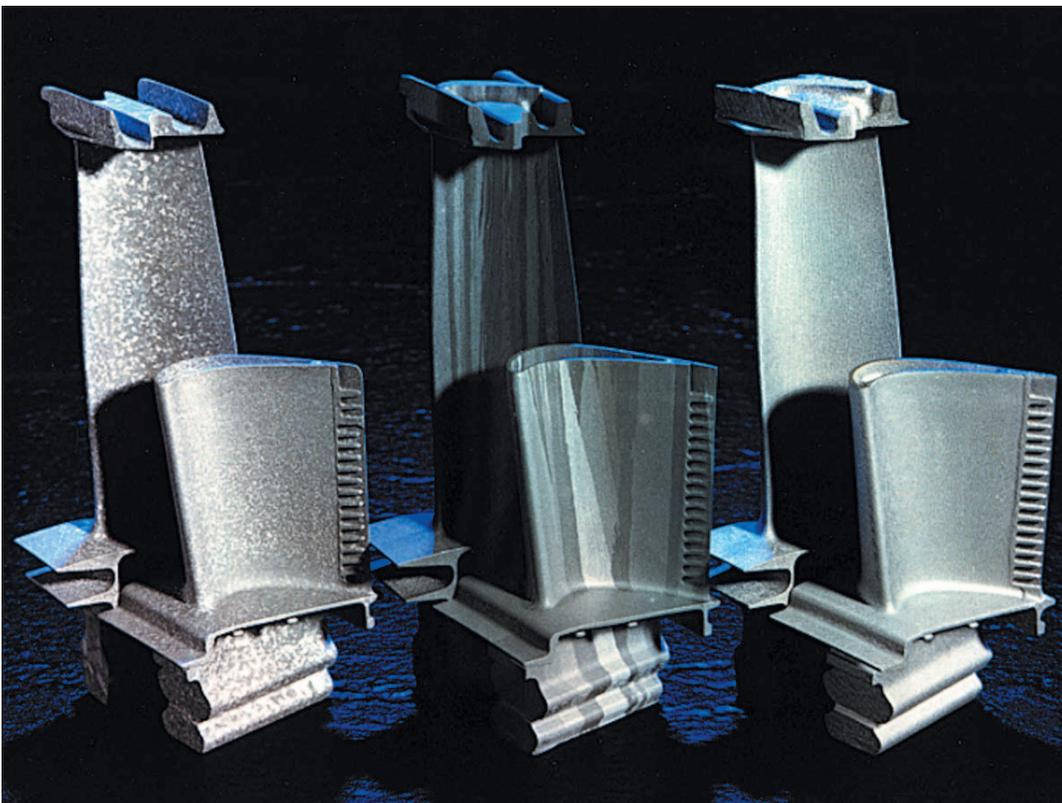
A WINNING CAST

Howmet Research Corporation, of Whitehall, Michigan, a leader in materials research and manufacturing technologies, was the first to commercialize an innovative cast metal technology developed at Auburn University, Auburn, Alabama. With funding assistance from NASA's Marshall Space Flight Center, Auburn University's Solidification Design Center (a NASA Commercial Space Center), developed accurate nickel-based superalloy data for casting molten metals. Through a contract agreement, Howmet used the data to develop computer model predictions of molten metals and molding materials in cast metal manufacturing.

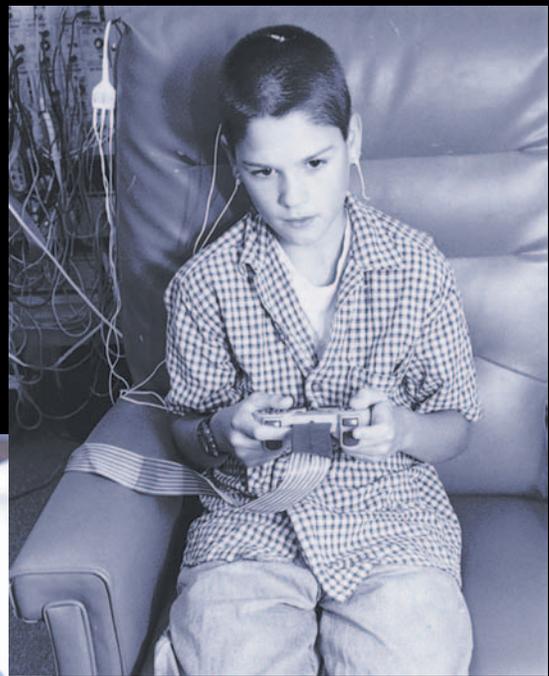
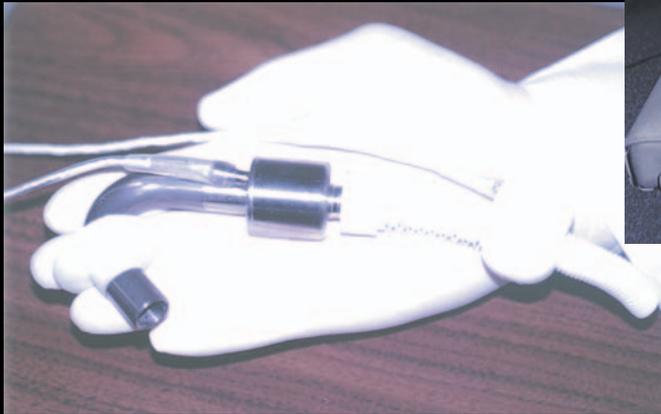
Howmet Metal Mold (HMM), part of Howmet Corporation Specialty Products, of Whitehall, Michigan, utilizes metal molds to manufacture net shape castings in various alloys and amorphous metal (metallic glass). By implementing the thermophysical property data from by Auburn researchers, Howmet employs its newly developed computer model predictions to offer customers high-quality, low-cost, products with significantly improved mechanical properties. Components fabricated with this new process replace components originally made from forgings or billet. Compared with products manufactured through traditional casting methods, Howmet's computer-modeled castings come out on top.

Howmet's Whitehall facility is a leading producer of complex cast turbine components for the aerospace and industrial gas-turbine industries. Cast turbine components include blades, vanes, and other high-temperature hardware for turbine engines. Howmet's commercial customers comprise a long and impressive list, which includes names like G.E. Aircraft Engines, Pratt & Whitney, Rolls Royce, Rocketdyne, and Honeywell. According to Dr. Thomas Tom, director of advanced technology for Howmet, "Applying the NASA and Auburn University-led research to turbine blade castings has enhanced our capabilities, helped us realize a cost savings, and accelerated the development cycle for rocket hardware."

Professor Tony Overfelt, director of the Solidification Design Center at Auburn University, notes that many manufacturing processes (shaped castings, electronic crystals, food processing, chemical manufacturing, etc.) require advanced materials data to support improved process designs. "We're doing the long range research that industry really needs to improve its final products," said Overfelt. "We're benefiting the American public—those who pay for the research and use the products." ♦



Howmet utilizes computer model predictions to produce high-quality, low-cost, mechanical replacement components like the cast turbine blades seen here.



TECHNOLOGY TRANSFER

NASA established the Commercial Technology Network to ensure that the Agency's research and development efforts reach the widest possible audience and have the broadest impact. By supporting numerous nationwide organizations, the network helps U.S. businesses access, utilize, and commercialize NASA technology.

Commercial Technology Offices at each NASA field center work closely with NASA incubators, Regional Technology Transfer Centers, the Small Business Innovation Research and Small Business Technology Transfer Programs, and others to successfully serve private industry with valuable technology transfer activities. To keep pace with the dissemination of NASA's technology, the network will continue to expand its operations to better serve the Agency and the public.

The following section is a condensed guide to the many organizations that comprise the Commercial Technology Network. It offers insight as to how the transfer of NASA technology makes business sense, as well as human sense.

OUTREACH ACHIEVEMENTS

While many of us are familiar with the technologies resulting from aerospace research, we often fail to consider the vast array of outreach success to which NASA research and development efforts have contributed. The benefits are far-reaching and often times allow those other than astronauts, to reach for the stars.

In the past, visually impaired students were unable to experience images from space. But now, a new book entitled *Touch the Universe: A NASA Braille Book of Astronomy* combines tactile illustrations with images of planets, star clusters, and nebulae captured by the Hubble Space Telescope. The book was made possible by a grant from NASA's Office of Space Science, and the efforts of astronomer Bernhard Beck-Winchatz, of DePaul University, Chicago, Illinois, and author/astronomer, Noreen Grice. Grice developed clear tactile overlays for each image. The overlays were sent to science teacher and astronomy enthusiast, Benning Wentworth, at the Colorado School for the Deaf and the Blind. Wentworth's students evaluated images for clarity and provided important suggestions. The resulting book contains tactile thermoform pages, placed in front of the color Hubble images, making the book appealing to readers of all visual abilities.

Retired NASA professionals are now applying their skills to the medical industry. Enterprising space veterans, who helped establish what we can now call the "Space Age" are dedicating their time to Volunteer Professionals for Medical Advancement. Retirees from NASA's Jet Propulsion Laboratory work with doctors and other medical professionals, attempting to develop new medical technologies. The organization's ultimate goal is to provide hospitals with free services that are otherwise unaffordable. To date, the organization can claim credit for a number of medical advancements

including: using a stent to solve a blood-clot problem that could cause heart attacks; the preliminary design of an automated oxygen-enrichment system for premature infants; and the creation of an advanced database private computer network for pediatricians. Now in its tenth year, the organization looks forward to upcoming challenges in the medical field.

Another NASA outreach success helps brain-injured patients to explore the stars with the click of a mouse. Through a new interactive hands-on program, patients at the Delta Rehabilitation Facility for the Severely Head-Injured, in Snohomish, Washington, were able to view and download celestial images through Telescopes in Education, a program sponsored by NASA's Jet Propulsion Laboratory. The program allows both educators and students around the globe to remotely control research-grade telescopes and charge-coupled device cameras at the Mount Wilson Observatory, Mount Wilson, California. All that is needed is a computer modem and the special astronomy software. As the Director of Internet Services for the Brain Injury Association of Washington, Paul Walsh, and his wife, Valarie, teach basic astronomy to the Delta residents. Mr. Walsh was inspired by the enthusiasm of the students and sensed that astronomy could help with the rehabilitation process, which involves surrounding patients with community and bringing life stimulation to them. Both Mr. Walsh and the patients are truly grateful for the program. "It's one of the best down-to-earth ideas they've ever come up with. The program is all about tying people to the stars; the young, the disabled, the city bound, and the imagination bound."

While NASA research is always helping to spark new technologies, some of that research helped battle the blazes of wildfires that seized the West in the summer of 2000. NASA



scientists provided fire officials with observations of the fires, courtesy of the Moderate-resolution Imaging Spectroradiometer (MODIS) instrument, onboard NASA's Terra satellite. NASA's Goddard Space Flight Center and the National Oceanic and Atmospheric Administration provided fire officials with daily images of fires in Montana and Idaho, the two states that ultimately suffered the most damage. These images provided a brief overview as to where the fires were most active, allowing firefighters to plan each day's strategy and allocate resources for monitoring and battling the flames. Terra Project Scientist, Yoram Kaufman explains that "...new satellite technology, as manifest in the MODIS instrument on Terra, can be used not only to do new Earth system science, but it can also be used to help monitor wildfires, save lives and property, and monitor air quality."

Developed with the assistance of Johnson Space Center, the DeBaKey Ventricular Assistance Device (VAD) is bringing hope to patients awaiting heart transplants. Dr. Michael DeBaKey led a team of Johnson scientists and medical specialists to develop the miniature heart assist pump, which is based partly on technology used in Space Shuttle fuel pumps. The VAD helps patients whose hearts cannot pump sufficient blood to maintain adequate blood flow while recovering from heart surgery, waiting for a heart transplant, or for a variety of other medical reasons. It is estimated that more than 35,000 patients a year could benefit from this pump. Presently, over 2 million people suffer from congestive heart failure and a pump such as the VAD could also assist a large portion of these patients. While still in clinical trials, the pump has been implanted in as many as 100 people for as long as four months. The pump gives patients an extension on hope as they wait for a heart donor. MicroMed Technology, Inc. of Houston, Texas, is the exclusive licensee and manufacturer of the DeBaKey VAD.

A young Texas boy was finally able to enjoy the outdoors thanks to NASA technology. Cardi Hicks of Magnolia, Texas, suffers from four rare skin diseases that cause a severe reaction to the Sun and even bright indoor lights, which can raise his body temperature to fatal levels. With the help of NASA technology from Johnson Space Center and the Hypohidrotic Ectodermal Dysplasia (HED) Foundation, Cardi received an ultra-violet (UV)-protection suit that allows him to go outside and remain protected from harmful light. HED is a disease where the victim lacks sweat glands, which can lead to heat stroke, heat exhaustion, and even death. The suit consists of a white jacket, pants, gloves, headgear, and goggles, and protects the skin from more than 99.9 percent of the Sun's UV rays. NASA and HED have worked together since 1997 to provide the special suits to children who need them.

More than 15 million Americans are afflicted with diabetes. Thanks to NASA's virtual reality technology, many of these sufferers may experience a new treatment in the self-management of the disease. NASA's artificial-vision technol-

ogy can help patients at risk for nerve damage associated with diabetes to visualize and control blood flow to their arms and legs. This new application of virtual reality results from several years of research aimed at enhancing aviation safety and combines two technologies: sensors to measure the body's reactions, and powerful computer graphics to turn those measurements into a 3-D virtual environment. Researchers hope this use of self-management, or biofeedback, will help diabetes patients learn to eventually control their blood flow without the use of the virtual reality device.

An ingestible capsule is becoming a valuable tool in the diagnosis of diseases in the small intestine. Invented at NASA's Jet Propulsion Laboratory, the capsule uses image sensors and high-performance image-capture technology, incorporated into pill form. Photobit Corporation, of Pasadena, California owns the rights to the NASA-developed technology, which is still undergoing clinical trials. The pill obtains color video of the gastrointestinal track as it makes it way through the body. The images are transmitted to a computer workstation, where they are viewed by medical professionals who use them to diagnose gastrointestinal diseases. It is hoped that this development will lessen the need for x-rays and invasive endoscopic exploration, both of which can cause patient discomfort.

NASA is continuously making significant strides to provide for the well-being of the Earth and its residents. By using its resources to create revolutionary technologies, NASA is bettering the lives of people everywhere. ❖



EDUCATIONAL FRONTIER

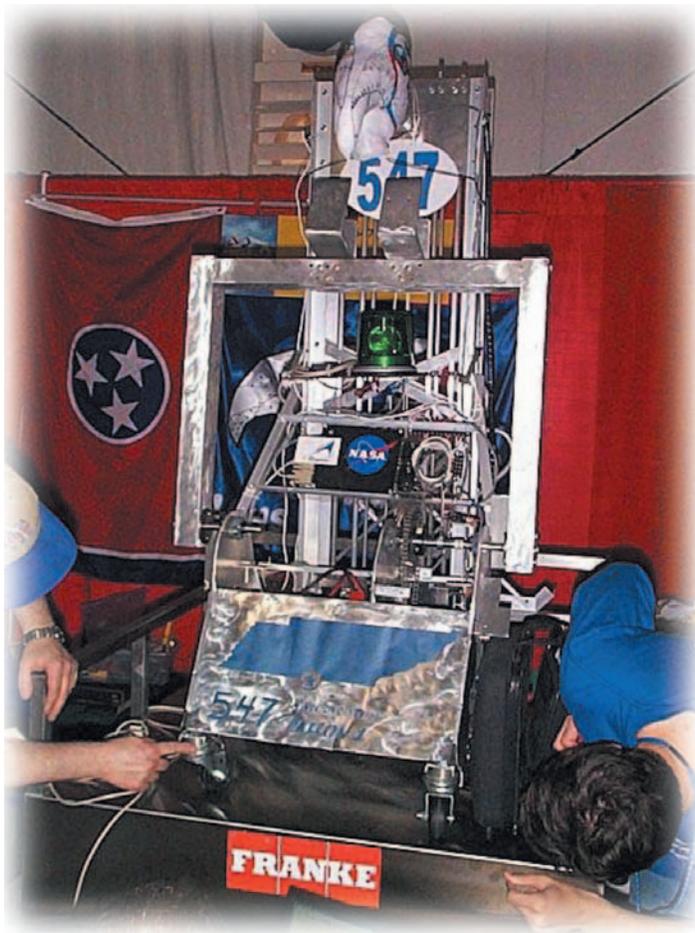
Since the inception of the Space Program, NASA has made a substantial commitment to education. A highly skilled workforce, competent in mathematics, science, engineering, and technology, is crucial to the success of the Agency. NASA has been an active participant in elementary, secondary, and higher level education for decades. This section features NASA's efforts to motivate teachers, educators, and the community, and to highlight other NASA educational activities and programs.

NASA places great value on hands-on education and encourages programs that offer real-world experience. The NASA Student Involvement Program (NSIP) is a national program that links students directly with NASA's various research, exploration, and discovery missions, and gives them the opportunity to learn science by participating in real missions. This year, high school students from across the country participated in the NSIP flight opportunities competition. Four student teams, their teachers, and advisors traveled to NASA Goddard Space Flight Center's Wallops Flight Facility, Wallops Island, Virginia, where they launched their experiments aboard a single-stage NASA Orion sounding rocket to an altitude of more than 28 miles. The experiments parachuted into the Atlantic Ocean where they were

recovered and returned to the students that same day for analysis. The students investigated materials for future space flight vehicles, studied the efficiency of electric motors during rocket flight, measured atmospheric constituents, and gathered data on the sounding rocket flight environment for a musical composition. Four additional student teams met at Wallops to integrate their experiments in a Space Experiment Module (SEM) for flight on a future Space Shuttle mission. The students worked with Wallops personnel in the Space Shuttle Small Payloads Office to test their experiments before integrating the projects with the carrier for flight. "The purpose of the competition is to provide high school students an opportunity to take what they have learned in the classroom and apply it to the real-world environment," said Lynn Marra, NSIP Officer at NASA Headquarters, Washington, DC. "We hope that the students involved in the flights see it as a positive experience and pursue careers in science and engineering."

A workshop hosted by NASA's Jet Propulsion Laboratory (JPL), Pasadena, California, brought together two worlds that view the stars differently. A group of 17 elementary and secondary education teachers from Native American reservations in New Mexico and Arizona participated in the two-week workshop held at JPL's Educator Resource Center, in Pomona, California. NASA scientists, engineers, and researchers served as guest speakers at the workshop, which was designed to help the educators develop an action plan that supports standards-based teaching and learning in mathematics, science, technology, and geography, while preserving and celebrating their rich Native American traditions.

Inviting the public on a space odyssey is an annual event for JPL. Once a year, the Center takes education beyond the classroom and invites thousands of people of all ages from around the country to tour the facility for a behind-the-scenes look at NASA's lead center for robotic space exploration. Structured around the themes of technology, Earth, Mars, the solar system, and stars and galaxies, the tour showcases everything from virtual flying lessons, to building your own spacecraft, to having your picture taken with an infrared light, as well as the latest in technological advancements. Those who cannot physically attend the Open House, have the opportunity to share in a virtual tour via webcast. Thousands of people from around the country had the chance to view the webcast, which featured a diverse lineup of scientists and engineers, cutting-edge researchers, and even kids who built their own robots through a NASA program.



Another NASA program is the Solar System Ambassadors Program. Coordinated by the Jet Propulsion Laboratory, one of this year's events by ambassador volunteers from Victoria, Texas, was a parking lot solar telescope viewing event. The ambassadors invited curious members of the community to come to an area parking lot on Space Day to view sunspots through telescopes equipped with special filters. Space Day is a day devoted to the advancement of science, mathematics, and technology education. Because the Sun is not viewable without the special filters, the event gave the public a unique opportunity to look at it safely and learn more about this mysterious star. The Solar System Ambassadors Program currently consists of 206 ambassadors in 48 states and one U.S. military base in South Korea. Ambassador Program events are held year-round and reach more than 500,000 people annually.

Another event sponsored by NASA proves that learning is fun. Two thousand high school students and 49 student-built robots took over the Los Angeles Sports Arena for the FIRST (For Inspiration and Recognition of Science and Technology) Southern California Regional Competition. Complete with referees and cheering crowds, the robots duked it out and put on a show demonstrating their ability. FIRST is a non-profit organization whose mission is to generate an interest in science and technology through robotics competitions that include hands-on activities and teamwork.

A new summer program takes a novel approach to out-of-classroom research. This year, NASA introduced its Undergraduate Student Research Program (USRP). USRP was designed to increase the nation's science, engineering, mathematics, and technology skill base in undergraduate and graduate programs. The program aims to provide students with challenging goal-oriented research experience designed to stimulate academic interest in these fields. USRP attracted over 1100 applicants from across the country. Some 100 students representing 70 of the nation's colleges and universities participated in the program.

One of the most exciting education initiatives is the new NASAexplores program. Operated by the Marshall Space Flight Center Education Programs Department on behalf of NASA's Aerospace Technology Enterprise and the Human Exploration and Development of Space Enterprise, the program provides free educational materials to educators on a weekly basis. Offered online at <http://www.nasaexplores.com>, the materials are printable and downloadable. The initiative was founded to generate further interest and understanding in current NASA research within these enterprises by disseminating learning materials via the Internet.

As NASA continues its commitment to space exploration and cutting-edge technological advances that benefit the American people, it will also continue offering programs that serve to inspire, motivate, educate, and prepare generations for an optimistic future. ❖



COMMERCIAL TECHNOLOGY NETWORK AND AFFILIATIONS

The NASA Commercial Technology Program sponsors a number of organizations around the country that are designed to assist U.S. businesses in accessing, utilizing, and commercializing NASA-funded research and technology. These organizations work closely with the Commercial Technology Offices, located at each of the 10 NASA field centers, providing a full range of technology transfer and commercialization services and assistance.

Technology Transfer Network

The **National Technology Transfer Center** <<http://www.nttc.edu>>, located on the campus of Wheeling Jesuit University in Wheeling, West Virginia, was established by Congress in 1989 to strengthen American industry by providing access to more than \$70 billion worth of federally-funded research. By helping American companies use federal technologies, NTTC helps them manufacture products, create jobs, and foster partnerships between federal laboratories and the private sector, universities, innovators, and economic development organizations. From that mission, NTTC has grown into a full-service technology commercialization center. In addition to providing access to federal technology information, NTTC provides technology commercialization training; technology assessment services that help guide industries in making key decisions regarding intellectual property and licensing; and assistance in finding strategic business partners and electronic business development services.

NTTC developed a *leads management system* for NASA that is the formal reporting and tracking system for partnerships being developed between NASA and U.S. industry. The leads system allows all members of the NASA Technology Commercialization Team to have an easy-to-use and effective tool to create and track leads in order to bring them to partnerships. NTTC also utilizes the expertise of nationally recognized technology management experts to create and offer technology commercialization training. Course topics range from the basics of technology transfer to hands-on valuation, negotiation, and licensing. Courses are developed at NTTC and around the country. In addition, on-line courses, supporting publications, comprehensive software applications, and videotapes are also available.

NASA TechTracS <<http://technology.nasa.gov>> provides access to NASA's technology inventory and numerous examples of the successful transfer of NASA-sponsored technology for commercialization. TechFinder, the main feature of the Internet site, allows users to search technologies and success stories, as well as submit requests for additional information. All NASA field centers submit information to the TechTracS database as a means of tracking technologies that have potential for commercial development.

Since their inception in January 1992, the six NASA-sponsored Regional Technology Transfer Centers (RTTCs) have helped U.S. businesses investigate and utilize NASA and other federally-funded technologies for companies seeking new products, improvements to existing products, or solutions to technical problems. The RTTCs provide technical and business assistance to several thousand customers every year.

The network of RTTCs is divided as follows:

Far West (AK, AZ, CA, HI, ID, NV, OR, WA):

The **Far West Regional Technology Transfer Center (FWRTTC)** <<http://www.usc.edu/dept/engineering/TTC/NASA>> is an engineering research center within the School of Engineering at the University of Southern California in Los Angeles. Using the Remote Information Service to generate information from hundreds of federal databases, FWRTTC staff work closely with businesses and entrepreneurs to identify opportunities, expertise, and other necessary resources. The FWRTTC enhances the relationships between NASA and the private sector by offering many unique



The National Technology Transfer Center is located on the campus of Wheeling Jesuit University in Wheeling, West Virginia.

services, such as the NASA On-line Resource Workshop, NASA Tech Opps, and links to funding and conference updates.

Mid-Atlantic (DC, DE, MD, PA, VA, WV):

The **Technology Commercialization Center (TeCC)** <<http://www.teccenter.org>>, located in Newport News, Virginia, coordinates and assists in the transfer of marketable technologies, primarily from Langley Research Center, to private industry interested in developing and commercializing new products.

Mid-Continent (AR, CO, IA, KS, MO, MT, ND, NE, NM, OK, SD, TX, UT, WY):

The **Mid-Continent Technology Transfer Center (MCTTC)** <<http://www.mcttc.com/>>, under the direction of the Technology and Economic Development Division of the Texas Engineering Service, is located in College Station, Texas. The MCTTC, which provides a link between private companies and federal laboratories, reports directly to the Johnson Space Center. The assistance focuses on high-tech and manufacturing companies that need to acquire and commercialize new technology.

Mid-West (IL, IN, MI, MN, OH, WI):

The **Great Lakes Industrial Technology Center (GLITeC)** <<http://www.battelle.org/glitec>>, managed by Battelle Memorial Institute, is located in Cleveland, Ohio. GLITeC works with industries primarily within its six-state region to acquire and use NASA technology and expertise, especially at the Glenn Research Center. Each year, over 500 companies work with GLITeC and its affiliates to identify new market and product opportunities. Technology-based problem solving, product planning and development, and technology commercialization assistance are among the services provided.

Northeast (CT, MA, ME, NH, NJ, NY, RI, VT):

The **Center for Technology Commercialization (CTC)** <<http://www.ctc.org>> is a non-profit organization, based in Westborough, Massachusetts. Covering New England, New York, and New Jersey, the CTC currently has eight satellite offices that form strong relationships with Northeast industry. Operated by the CTC, the NASA Business Outreach Office stimulates business among regional contractors, NASA field centers, and NASA prime contractors.

Southeast (AL, FL, GA, KY, LA, MS, NC, SC, TN):

The **Southeast Regional Technology Transfer Center (SERTTC)** <<http://www.edi.gatech.edu/nasa>> at the Georgia Institute of Technology facilitates and coordinates private industry interests in the transfer and commercialization of technologies resulting from NASA's space and Earth

science research. Assistance is also provided in SBIR and STTR applications, as well as the establishment of connections to specialized research needs within NASA R&D centers nationwide.

NASA Incubator Programs

Ten NASA incubators are included within this network of programs. They are designed to nurture new and emerging businesses with the potential to incorporate technology developed by NASA. They offer a wide variety of business and technical support services to increase the success of participating companies.

The **Ames Technology Commercialization Center (ATCC)** <<http://ctoserver.arc.nasa.gov/incubator.html>>, located in San Jose, California, provides opportunities for start-up companies to utilize NASA technologies. The center uses a lab-to-market approach that takes the technological output of Ames' labs and pairs that technology with appropriate markets to create and foster new industry and jobs. The incubator helps businesses and entrepreneurs find NASA technology with commercial potential, then provides access to a network of business experts in marketing, sales, high-tech management and operations, financing, and patent and corporate law. The ATCC also offers low-cost office space and other start-up services.

BizTech <<http://www.biztech.org>>, of Huntsville, Alabama, is a small business incubator, offering participating companies access to services at Marshall Space Flight Center laboratories for feasibility testing, prototype fabrication, and advice on technology usage and transfer. BizTech is sponsored by the Huntsville-Madison County Chamber of Commerce.

The **Emerging Technology Centers (ETC)** <<http://www.etcbbaltimore.com>>, located in Baltimore, Maryland, is one of the newest NASA-affiliated incubators. Partnering institutions include the Goddard Space Flight Center and area universities and colleges.

The **Florida/NASA Business Incubator Center (FNBIC)** <<http://www.trda.org/fnbic/>> is a joint partnership of NASA's Kennedy Space Center, Brevard Community College, and the Technological Research and Development Authority. The mission of FNBIC is to increase the number of successful technology-based small businesses originating in, developing in, or relocating to Brevard County. FNBIC offers support facilities and programs to train and nurture new entrepreneurs in the establishment and operation of developing ventures based on NASA technology.

COMMERCIAL TECHNOLOGY NETWORK AND AFFILIATIONS

(Continued)

The **Hampton Roads Technology Incubator (HRTI)** <<http://www.hr-incubator.org>> identifies and licenses NASA Langley Research Center technologies for commercial use. HRTI's mission is to increase the number of successful technology-based companies originating in, developing in, or relocating to the Hampton Roads area.

The **Lewis Incubator For Technology (LIFT)** <<http://www.liftinc.org>>, managed by Enterprise Development, Inc., provides outstanding resources for technology and support to businesses in the Ohio region. Its primary objectives are to create businesses and jobs in Ohio and to increase the commercial value of NASA knowledge, technology, and expertise. LIFT offers a wide range of services and facilities to the entrepreneur to increase the probability of business success.

The **Mississippi Enterprise for Technology** <<http://www.mset.org>> is sponsored by NASA and the Mississippi University Consortium and Department of Economic and Community Development, as well as the private sector. The mission of the Enterprise is to help small businesses utilize the scientific knowledge and technical expertise at the Stennis Space Center. A significant part of this effort is Stennis' Commercial Remote Sensing Program (CRSP), which was formed to commercialize remote sensing, geographic information systems, and related imaging technologies.

The **NASA Commercialization Center (NCC)** <<http://www.nasaincubator.csupomona.edu/home.htm>>, run by California State Polytechnic University, Pomona, is a business incubator dedicated to helping small businesses access and commercialize Jet Propulsion Laboratory (JPL) and Dryden Flight Research technologies.

The **NASA Illinois Commercialization Center (NICC)** <<http://www.nasa-illinois.org>> serves the Chicago region. The NICC is a partner of the Glenn Research Center and GLITeC, and is aimed at assisting companies with the use of NASA technology, as well as establishing new companies in Illinois built from NASA technology.

The **UH-NASA Technology Commercialization Incubator** <http://www.research.uh.edu/otm/inc/UH_inc_home.html> is a partnership between NASA's Johnson Space Center and the University of Houston. The incubator is designed to help local small and mid-sized businesses commercialize space technology. The University of Houston houses the program and provides the commercialization and research expertise of its business and engineering faculties.

Other organizations devoted to the transfer of NASA technology are the **Research Triangle Institute (RTI)** and the **MSU TechLink Center**.

RTI <<http://www.rti.org>>, located in Research Triangle Park, North Carolina, provides a range of technology



The Hampton Roads Technology Incubator promotes the economic development of the Hampton, Virginia area through the commercialization of technologies developed at NASA's Langley Research Center, universities, and other regional government and industrial research and development laboratories.

management services to NASA. RTI performs technology assessments to determine applications and commercial potential of NASA technology, as well as market analysis, and commercialization and partnership development. RTI works closely with all of NASA's Commercial Technology Offices.

The **MSU TechLink Center** <<http://techlink.msu.montana.edu/>>, located at Montana State University-Bozeman, was established in 1997 to match the technology needs of client companies with resources throughout NASA and the federal laboratory system. TechLink focuses on a five-state region that includes Idaho, Montana, North Dakota, South Dakota, and Wyoming. Working closely with public, private, and university programs, TechLink provides ongoing support in the process of adapting, integrating, and commercializing NASA technology.

Affiliated Organizations, Services, and Products

To compliment the specialized centers and programs sponsored by the NASA Commercial Technology Program, affiliated organizations and services have been formed to strengthen NASA's commitment to U.S. businesses. Private and public sector enterprises build upon NASA's experience in technology transfer in order to help with the channeling of NASA technology into the commercial marketplace.

The **NASA Small Business Innovation Research (SBIR) Program** <<http://www.sbir.nasa.gov/>> provides seed money to U.S. small businesses for developing innovative concepts that meet NASA mission requirements. Each year, NASA invites small businesses to offer proposals in response to technical topics listed in the annual SBIR Program Solicitation. The NASA field centers negotiate and award the contracts, and monitor the work.

NASA's SBIR Program is implemented in three phases:

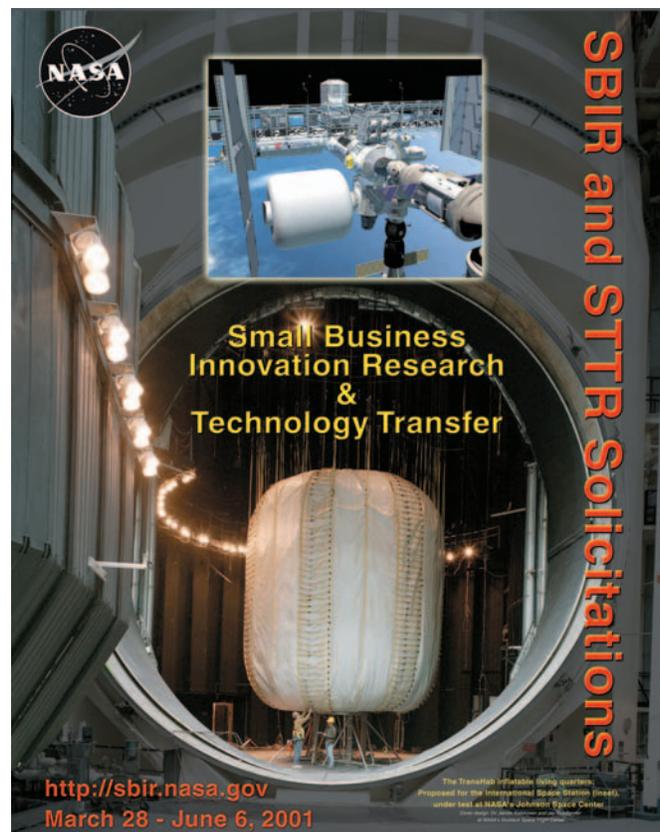
- **Phase I** is the opportunity to establish the feasibility and technical merit of a proposed innovation. Selected competitively, NASA Phase I contracts last six months and must remain under specific monetary limits.
- **Phase II** is the major research and development effort, which continues the most promising of the Phase I projects based on scientific and technical merit, results of Phase I, expected value to NASA, company capability, and commercial potential. Phase II places greater emphasis on the commercial value of the innovation. The contracts are usually for a period of 24 months and again must not exceed specified monetary limits.
- **Phase III** is the process of completing the development of a product to make it commercially available. While the financial resources needed must be obtained from sources other than the funding set aside for the SBIR, NASA may fund Phase III activities for follow-on development or for production of an innovation for its own use.

The SBIR Management Office, located at the Goddard Space Flight Center, provides overall management and direction of the SBIR Program.

The **NASA Small Business Technology Transfer (STTR) Program** <<http://www.sbir.nasa.gov/>> awards contracts to small businesses for cooperative research and development with a research institution through a uniform, three-phase process. The goal of Congress in establishing the STTR Program was to transfer technology developed by universities and federal laboratories to the marketplace through the entrepreneurship of a small business.

Although modeled after the SBIR Program, STTR is a separate activity and is separately funded. The STTR Program differs from the SBIR Program in that the funding and technical scope is limited and participants must be teams of small businesses and research institutions that will conduct joint research.

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COMMERCIAL TECHNOLOGY NETWORK AND AFFILIATIONS

(Continued)

The **Federal Laboratory Consortium (FLC) for Technology Transfer** <<http://www.fedlabs.org>> was organized in 1974 to promote and strengthen technology transfer nationwide. More than 600 major federal laboratories and centers, including NASA, are currently members. The mission of the FLC is twofold:

- To promote and facilitate the rapid movement of federal laboratory research results and technologies into the mainstream of the U.S. economy.
- To use a coordinated program that meets the technology transfer support needs of FLC member laboratories, agencies, and their potential partners in the transfer process.

The **National Robotics Engineering Consortium (NREC)** <<http://www.rec.ri.cmu.edu>> is a cooperative venture among NASA, the City of Pittsburgh, the State of Pennsylvania, and Carnegie Mellon's Robotics Institute. Its mission is to move NASA-funded robotics technology to industry. Industrial partners join the NREC with the goal of using technology to gain a greater market share, develop new niche markets, or create entirely new markets within their area of expertise.

The road to technology commercialization begins with the basic and applied research results from the work of scientists, engineers, and other technical and management personnel. The **NASA Scientific and Technical Information (STI) Program** <<http://www.sti.nasa.gov>> provides the widest appropriate dissemination of NASA's research results. The STI Program acquires, processes, archives, announces, and disseminates NASA's internal, as well as worldwide, STI.

The NASA STI Program offers users such things as Internet access to its database of over three million abstracts, on-line ordering of documents, and the NASA STI Help Desk for assistance in accessing STI resources and information. Free registration with the program is available through the NASA Center for AeroSpace Information (CASI).

For more than three decades, reporting to industry on any new, commercially significant technologies developed in the course of NASA research and development efforts has been accomplished through the publication of *NASA Tech Briefs* <<http://www.nasatech.com>>.

The monthly magazine features innovations from NASA, industry partners, and contractors that can be applied to develop new or improved products and solve engineering or manufacturing problems. Authored by the engineers or scientists who performed the original work, the briefs cover a variety of disciplines, including computer software, mechanics, and life sciences. Most briefs offer a free supplemental Technical Support Package (TSP), which explains the technology in greater detail and provides contact points for questions or licensing discussions.

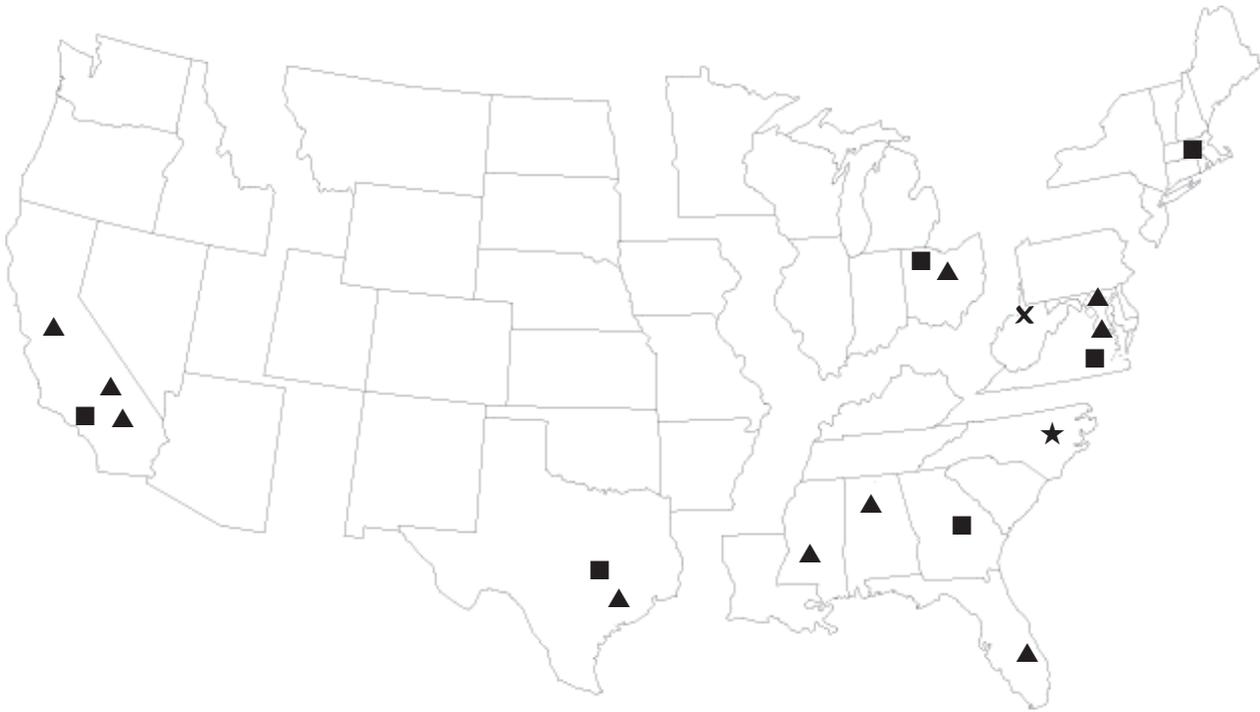
Aerospace Technology Innovation <<http://nctn.hq.nasa.gov/innovation/index.html>> is published bimonthly by the NASA Office of Aerospace Technology. Regular features include current news and opportunities in technology transfer and commercialization, aerospace technology and development, and innovative research.

NASA Spinoff <<http://www.sti.nasa.gov/tto/spinoff.html>> is an annual print and on-line publication featuring current research and development efforts, the NASA Commercial Technology Program, and successful commercial and industrial applications of NASA technology. ❖

The National Robotics Engineering Consortium (NREC) located in Pittsburgh, Pennsylvania develops and applies advanced automation technologies to create new opportunities for American businesses.



COMMERCIAL TECHNOLOGY NETWORK



The NASA Commercial Technology Network (NCTN) extends from coast to coast. For specific information concerning commercial technology activities described below, contact the appropriate personnel at the facilities listed or go to the Internet at: <http://nctn.hq.nasa.gov>. General inquiries may be forwarded to the National Technology Transfer Center.

To publish your success about a product/service you may have commercialized using NASA technology, assistance, or know-how, contact the NASA Center for AeroSpace Information or go to the Internet at:

<http://www.sti.nasa.gov/tto/contributor.html>.

- ▲ **Field Center Commercial Technology Offices**
Represent NASA's technology sources and manage center participation in technology transfer activities.
- X **National Technology Transfer Center (NTTC)**
Provides national information, referral, and commercialization services for NASA and other government laboratories.
- **Regional Technology Transfer Centers (RTTC)**
Provide rapid access to information, as well as technical and commercialization services.
- ★ **Research Triangle Institute**
Provides a range of technology management services including technology assessment, valuation and marketing; market analysis; intellectual property audits; commercialization planning; and the development of partnerships.

▲ **FIELD CENTERS**

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National Aeronautics and Space Administration
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John F. Kennedy Space Center

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John C. Stennis Space Center

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■ REGIONAL TECHNOLOGY TRANSFER
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