

Spinoff

National Aeronautics and
Space Administration



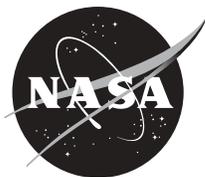
Fortieth Anniversary
Technology Utilization Program

2002

Spinoff 2002

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

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Foreword

Two hundred years after President Jefferson chose Lewis and Clark to explore the vast Louisiana Purchase lands extending to the Pacific, and 100 years after the Wright brothers conducted the first powered flight on a strip of Atlantic beach, the spirit of exploration, discovery, and invention is reaching ever farther into the new ocean of space.

And the United States of America, through NASA, proudly leads the way.

I am honored at this time in our country's history to lead America's civil aeronautics and space research efforts. Building on an extraordinary record of accomplishment, the people of NASA continue to develop revolutionary technologies needed to understand and protect our home planet and explore the universe. These technologies are helping NASA pioneer the future on a daily basis as we improve aviation safety and efficiency, probe more deeply into the mysteries of the universe, learn how to propel robotic emissaries more swiftly throughout the solar system, and work to better understand the dynamics of Earth's climatic system.

Our showcase project is the International Space Station, a permanently crewed research outpost in near-Earth orbit. Based on promising experiments already underway, Space Station research will significantly advance basic science, enable applications beneficial to millions of people, and enhance our ability to send explorers to other planets. Further, the drama of seeing astronauts living and working 24/7 on the Space Station will no doubt capture the imagination of students of all ages and motivate them to excel in subjects that will help them to become the next generation of explorers.

I am similarly proud of NASA's longstanding role as an agent of invention and technological progress in our society.

In 2002, NASA marks the 40th anniversary of the Technology Utilization Program, established under congressional mandate to promote the transfer of aerospace technology to the private sector. The program has been highly successful. Through NASA's efforts and those of innovative entrepreneurs, thousands of "spinoff" products and processes have been derived from NASA-developed technology. Collectively, they represent an immense contribution to the Nation's economy.

As NASA's research and development activities expand to meet the demands of our ambitious aeronautical and space research goals, the possibilities of applying technology to improve people's lives continue to grow. In one key area, medical research, NASA is teaming up with the National Cancer Institute to develop new biomedical technologies for cancer detection, diagnosis, and treatment, and with the Biotechnology Industry Organization to expand space-based biotechnology research and development activities. Millions of people promise to benefit from these important partnerships.

With compelling research like this, and with each scientific discovery, telescope image, launch, patent, and newly inspired child, the pursuit of NASA's new vision for the future—to improve life here, to extend life to there, and to find life beyond—will continue, I trust, to engage the public in an adventure without end.



Sean O'Keefe
Administrator
National Aeronautics and Space Administration



Introduction

Since its inception 40 years ago, NASA's Technology Transfer Program has led the way for our Nation to benefit from cutting-edge aerospace technologies. In addition to contributing to U.S. economic growth, these technologies are improving the quality of life on Earth while finding new ways to protect and preserve it. NASA's research and development efforts have advanced areas in medicine, communications, manufacturing, computer technology, and homeland security. These breakthroughs, translated into commercial products, are enhancing the lives of Americans everywhere.

When a congressional mandate led NASA to develop the Scientific and Technical Information (STI) Program, the Agency began a wide dissemination of its research and development results. In doing so, NASA recognized that many of its technologies were transferable to industry for the development of commercial products. As a result, the Technology Utilization Program was born in 1962. The successful program went through several changes over the years, as its philosophy, mission, and goals adapted into the Technology Transfer Program we know today. The program strives to make the latest technologies available to industry as soon as they are developed.

Each year, NASA's *Spinoff* publication showcases new products and services resulting from commercial partnerships between NASA and private industry. In the 2002 issue, the NASA field centers reflect upon the growth that has

made these innovations available to the public. The **Research and Development** section examines past achievements, current successes, and future goals for each of the 10 centers. The **Commercial Benefits** section proudly highlights 51 new spinoff products, including a heart pump for patients needing a heart transplant, as well as an air purifier that destroys anthrax spores. The **Technology Transfer and Outreach** section describes the outreach achievements and educational successes made possible through the NASA Commercial Technology Network. Each section of *Spinoff 2002* provides compelling evidence of the Technology Transfer Program's success and value.

With commercial products and successes spanning from work on the Apollo missions to the International Space Station, the 40th anniversary of the Technology Transfer Program invites us to celebrate our history while planning the future. I am proud to present the *Spinoff 2002* commemorative issue as a testament to the benefits of NASA's partnerships with U.S. industry.



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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Forty Years of Research and Development

The research and development efforts initiated by NASA's Strategic Plan ensure NASA's ongoing success and leadership in providing scientific and technical advances.

These advances not only impact the scientific and engineering communities, but also provide countless opportunities for private industry to develop innovative commercial products and services.

NASA's network of 10 field centers, empowered with the resources for developing cutting-edge technologies and advancing scientific research, strives to further expand our knowledge of Earth and the universe. Breakthroughs in remote sensing technologies, propulsion mechanisms, robotics, next-generation aircraft and spacecraft, advanced life support, and yet to be discovered areas will open the door to new possibilities on Earth and beyond.

NASA's Technology Transfer Program turns 40 this year, leading NASA Headquarters and the 10 field centers to explore the origin, growth, and potential of their technology transfer efforts. Inspired and guided by achievements that have made NASA a leader in aerospace research and development, the field centers are building tomorrow's technologies today. As the history of NASA technology transfer proudly demonstrates, the work of each field center serves to maintain the U.S. economy's global leadership while benefiting the lives of people around the world.

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 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 is the Nation's leading Government agency for providing technological leadership and advancements for the aerospace industry and the traveling public. To address the major needs for our future air and space transportation systems, the Aerospace Technology Enterprise has formulated 10- and 25-year objectives in 10 areas. Achieving these objectives would not only create a future system characterized by many new capabilities, but would also continue to contribute toward strengthening national security and improving the quality of life for all Americans. In addition to its role in advancing air and space transportation, the Enterprise has a role in developing basic technology for a



Advanced modeling, simulation, new materials and structural concepts, and other technologies will enable quieter, more efficient aircraft and more robust and affordable spacecraft.

broad range of space applications, such as aerospace communications, power and propulsion systems, microdevices and instruments, information technology, nanotechnology, and biotechnology. These advances will allow space missions to expand our knowledge of the Earth and the universe.

As we begin the 21st century, the Space Program seeks to forge a "Highway to Space" that will enable its citizens to travel, work, and live in space as a matter of routine. NASA research will make it possible for industry and 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 main challenges for the space industry continue to be reliability and cost. Space launch is prohibitively expensive and risky for all but missions of national importance and the most lucrative commercial efforts, such as worldwide broadcasting satellites. Whether doing business in Earth orbit or exploring distant worlds, the first few hundred kilometers of the "Highway to Space" are the toughest part of the journey. Half of the energy needed to go to the farthest planets in our solar system is devoted to escaping Earth's gravity and getting into low-Earth orbit.

Technology has a significant role in meeting these challenges. Advanced physics-based modeling, simulation, new materials and structural concepts, and other bold new technologies will enable quieter, more efficient aircraft and more robust and affordable spacecraft. A new information network for a modernized National Airspace System will allow greater flight efficiency and capacity. As the space transportation system grows, it will be increasingly linked with the aviation system. In the future, a single aerospace system will serve both air and space transportation.

NASA has always been a leader in applying advanced technologies. New technology will drive the next wave of innovation, enabling missions to be performed in completely new ways and creating missions that were never before possible. 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. 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. Safe, low-cost transportation will make space commercially accessible for both passenger and cargo operations. It will also allow the continued expansion of human and robotic exploration throughout our solar system.

Biological and Physical Research

The Biological and Physical Research Enterprise was established in 2000 to affirm NASA's commitment to the essential role biology plays in the 21st century, to establish the core of biological and physical sciences research needed to support Agency strategic objectives, to foster commercial development in space, and to ensure an effective management structure to optimize implementation of the Agency's scientific and technological goals.

Revolutionary solutions to science and technology problems are likely to emerge from scientists and engineers who are working at the frontiers of their respective disciplines and are also engaged in dynamic interdisciplinary interactions. The Enterprise fosters and enhances rigorous interdisciplinary research, closely linking fundamental biological and physical sciences. It is dedicated to using the unique characteristics of the International Space Station (ISS) environment to understand biological, physical, and chemical processes, conduct science and technology research required to enable humans to safely and effectively live and work in space, transfer knowledge and technologies for Earth benefits, and support investment in space research by the private sector.

Advances in biology, medicine, physics, and chemistry; associated analytical tools; and information systems have opened an era of unprecedented opportunities for bringing space-

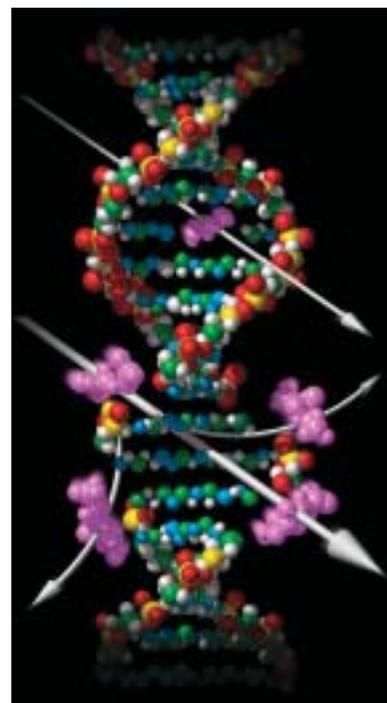
based knowledge to benefit human life on Earth. This increased understanding will transform the technological foundations not only of the space program, but also of our society. NASA researchers stand on the brink of using this knowledge to develop "smart" materials and "intelligent" spacecraft systems that are programmed to sense changes and adapt to them, a capability that will enable widespread advances for commercialization in Earth-based technology, engineering, biomedicine.

Earth Science

Imagine lighting homes with solar energy at night or having several days to prepare for a hurricane developing out in the Atlantic Ocean. Much of the technology studied by NASA's Earth Science Enterprise is being used to make these scenarios possible, with the hope that ongoing research and future projects will continue to improve our way of life.

While many people are interested in the scientific elements of the research data being collected, many more are concerned with how these data will impact their lives. Generally, people are unaware of the benefits that satellite research has already yielded for them. While satellites have been in orbit studying weather patterns for some time now, scientists and

(Continued)



Representation of DNA struck by radiation, a key concern for long-duration space travel.



During a 6- to 18-month validation flight, the Geosynchronous Imaging Fourier Transform Spectrometer instrument will take seasonal measurements over the continental United States. The mission will first orbit over the Atlantic Ocean to monitor hurricane activity along the East Coast, and then move to the Midwest during what is known to be the region's tornado season.

NASA Headquarters (Continued)

researchers have used resulting data to create a detailed historical weather pattern, allowing them to make relatively accurate predictions about potential locations of inclement weather and pinpoint likely destruction patterns within a community not prepared for that weather.

NASA has contributed to this effort by providing vital observations from space. The Agency continues to improve their models and methodologies, in order to achieve the best space-based observations to improve prediction techniques for certain weather patterns.

NASA's advancement of satellite technology is also assisting countries in locating food sources. For example, in December 1999, NASA launched the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard its Terra satellite. Remote sensing instruments like the MODIS have enabled fishermen to pinpoint fish populations in the ocean based on clear patterns of temperature and chlorophyll concentrations observed at the surface.

Additionally, the progression of satellite technology spawned the invention of the laser. Once upon a time, lasers were only used in space to conduct delicate technical procedures on equipment; however, dentists are now using this technology to make visits far less painful for their patients. Instead of using the traditional dental drill, dentists and oral surgeons can perform a variety of procedures using laser technology. The laser has the ability to cut and remove soft tissue for the treatment of gum

disease, and can close off blood vessels to eliminate visible bleeding.

As NASA forges ahead into the new millennium, Earth science data will continue to be usefully applied to our lives. The prospects look hopeful with the scheduled 2005 launch of the Geosynchronous Imaging Fourier Transform Spectrometer-Indian Ocean METOC Imager mission, which partners NASA, the National Oceanic and Atmospheric Administration, and the U.S. Navy. Substantial improvements in current weather forecasting techniques are anticipated from this mission.

Human Exploration and Development of Space

The goal of the Human Exploration and Development of Space Enterprise is to open the space frontier by exploring, using, and enabling the development of space. The Enterprise's programs provide safe, assured transportation to and from space for people and payloads, and develop and operate habitable space facilities in order to enhance scientific knowledge, support technology development, and enable commercial activity.

NASA serves as a catalyst for space development. In exploring space, NASA brings people and machines together to overcome challenges of distance, time, and environment. Robotic science missions survey and characterize other bodies as precursors to eventual human missions. The Space Shuttle and the ISS serve as research platforms to pave the way for sustained

human presence in space through critical research on human adaptation. These programs also provide opportunities for research with applications on Earth. The Enterprise employs breakthrough technologies to revolutionize human space flight.

Utmost in the commercialization plans is the ISS, which opened new frontiers in human space exploration, technology, and business. The ISS is an unparalleled international scientific and technological cooperative venture that has ushered in a new era of human space flight with the promise of economic benefits to people on Earth. The ISS



An artist's conception of what the final configuration of the International Space Station (ISS) will look like when it is fully built and deployed. The ISS is a multidisciplinary laboratory, technology test bed, and observatory that will provide an unprecedented undertaking in scientific, technological, and international experimentation.

provides more space for research, with greater resources and flexibility than any spacecraft ever built. It provides unprecedented, long-term access to the microgravity and ultra-vacuum environment of space, a flexible vantage point for observational research, and a test bed for new technologies.

The commercial development of the space frontier is one of the greatest opportunities facing America. It is the growth of business into space that will bring the benefits of space down to Earth and enrich the everyday lives of all Americans. The Enterprise also is encouraging businesses to seize this opportunity through the Space Product Development Program and its Commercial Space Centers, to help ensure continued U.S. economic growth and to bring the opportunities for new advances, technological understanding, products, and jobs to the public.

Space Science

The Space Science Enterprise offers 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 the following questions: 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 probe deeper into the mysteries of the universe and life on Earth and beyond; to pursue space science programs that enable, and are enabled by, 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.

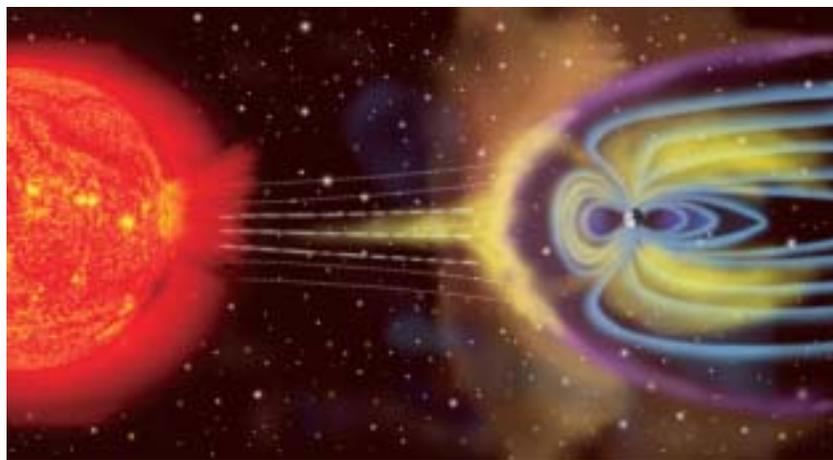
To better study solar variability and understand its effects on humanity, NASA started a program called “Living With a Star,” a set of missions and enhancements to current programs

which will eventually encompass a number of spacecraft and systems. “Living With a Star” also will pursue partnerships with other Federal agencies that are concerned with the effects of the Sun on the 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 micro-satellites 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 that will use the energy in sunlight rather than wind to get to 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 that will probe the Earth’s upper atmosphere and space environment and their response to solar storms.

The program’s goal is to provide an exciting new capability for understanding, and ultimately predicting “solar weather” which affects Earth. ❖



The “Living With a Star” program will pursue partnerships with other Federal agencies that are concerned with the effects of the Sun on the Earth.

Ames Research Center

Testifying before the Senate Committee on Aeronautical and Space Sciences in 1972, Daniel J. Harnett, head of NASA's Office of Industry Affairs and Technology Utilization, mentioned a Denver Research Institute study that investigated NASA contributions to industrial technology and identified examples of successful technology transfer throughout the Agency. In many instances, Ames research and development (R&D) was cited as the basis for the advances, with much of it contributing to spinoff technology. The Center's contributions ranged from the exotic to the mundane, but the very assortment underlines the wealth of applications Ames research embraces as a basic R&D center.

Today, Ames' R&D focus includes advances coming from information technology, biotechnology, and nanotechnology, lending to a strong technology transfer and commercialization mission. Throughout the 1970s and 1980s, the Technology Utilization Office at Ames maintained an active program, assisting both the internal researcher and outside organizations

with technology transfer. In 1994, NASA Headquarters released the "Agenda for Change" program, announcing a new way of accomplishing technology transfer with emphasis on commercialization. Priorities shifted from providing technology assistance programs for businesses to providing outreach for licensing patented technologies. Currently, the Ames Commercial Technology Office actively supports the traditional activities of fostering NASA/industry technology development partnerships, executing licenses, and administering a **Small Business Innovation Research (SBIR)** program. In addition, it is tapping into the new NASA Research Park at Moffett Field—a growing initiative co-located with Ames. The Office has partnered with the Girvan Institute of Technology, a non-profit organization chartered to foster research, technology development, and technology commercialization for NASA. Girvan will also provide services for companies pursuing new relationships with Ames and will manage the small business incubator activities.



An artist's rendering of the new NASA Research Park at Moffett Field depicts the bold new vision proposed for Ames.

Over the last 40 years, one example of a far-reaching technology transfer story dates back to 1966 when Ames awarded Stencel Aero Engineering Corporation a contract to develop a safer seating system for commercial aircraft. This project produced temper foam—a new foam for aircraft seat cushions that would absorb great shocks. Throughout the 1970s and 1980s, the foam found additional uses from hospital beds to improving sports equipment. In the 1990s, temper foam became the basis for a new material for bed mattresses and pillows commercialized under the name “Tempur-Pedic” by the company with the same name.

In 1998, NASA’s temper foam was inducted into the U.S. Space Foundation’s Space Technology Hall of Fame. Following this event, Robert Trussell, chief executive officer of Tempur-Pedic, Inc., presented former NASA Administrator, Daniel Goldin, with the company’s one millionth pillow. Other businesses are still making temper foam-based products, such as Dynamic Systems, Inc. The company’s owner, Charles Yost, collaborated on temper foam’s final formulation and was honored as one of the original innovators. Temper foam remains a leading Ames success story, having commanded a spot in the marketplace for over 30 years.



Seats in the cockpit of the Wing Derringer twin-engine lightplane have temper foam padding to reduce pilot and passenger fatigue on long flights.

The Ground Processing Scheduling System (GPSS) software, originated at Ames, is another successful transfer from aerospace to commercial markets. Mr. Monte Zweben, a former deputy branch chief, designed and developed several planning and scheduling systems, including a software system for complex, multifaceted operations known as the Gerry scheduling engine. Since Space Shuttle flow managers at Kennedy Space Center needed a more efficient scheduling system, Kennedy brought Ames, Lockheed Space Operations Company, and Lockheed Missiles and Space Company together to transfer the technology of the Gerry scheduling engine to the Space Shuttle program. The GPSS successfully became the accepted general purpose scheduling tool for operations. The system was also adopted for scheduling Space Shuttle orbiter refurbishing, saving NASA about \$4 million annually.

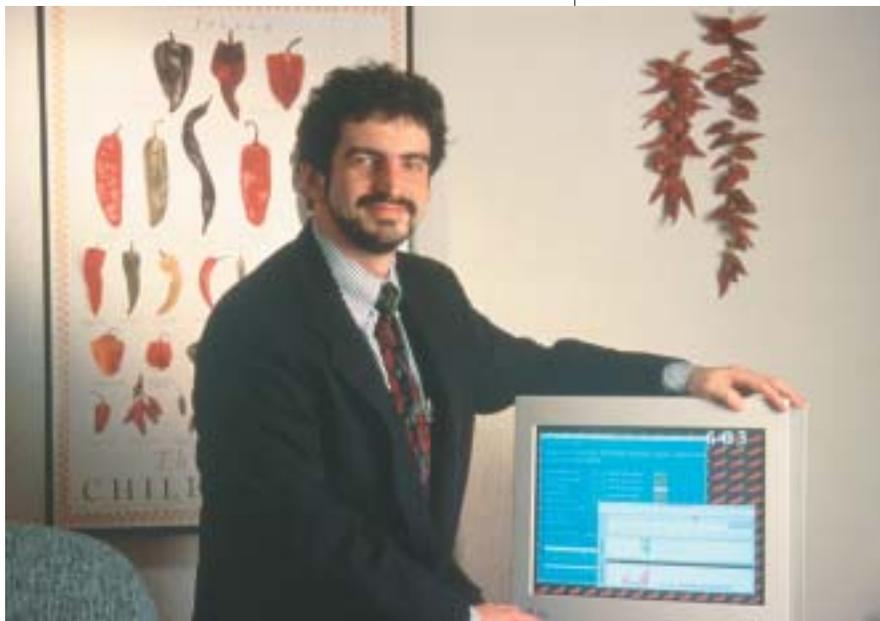
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Temper foam’s applications have spanned from wheelchairs to sporting equipment.

Ames Research Center (Continued)

Zweben left NASA in 1993 and applied for and received the copyright license to commercialize the GPSS. He then founded Red Pepper Software Company (RPS) in 1994 with Daniel T. Doles. RPS emphasized the real-time responsiveness in the modern manufacturing environment as a primary benefit of its product. In 1995, RPS was one of five winners of *Industry Week* magazine's Technologies of the Year Award. RPS, with a rapidly growing list of customers that included Sun Microsystems, Inc., Hewlett-Packard, Coors Brewing Company, and Cheseborough-Ponds, was purchased in 1996 by PeopleSoft Inc., for \$225 million. Building RPS was only the beginning for Zweben, who started a new venture, Blue Martini Software, aimed at providing companies with software to personalize their products for customers. The story of Monte Zweben and the NASA scheduling software illustrates the positive economic impact that can result from spinning off space-based applications for industry solutions.

A look at Ames' technology transfer history would not be complete without recognizing the value remote sensing technology has brought to government entities and the business community. Remote sensing yields unique data benefiting public safety, conservation, disease prevention, and improving agricultural methods and crop yields. *Spinoff 1983* published a story on the Airborne Thematic Mapper (ATM) that Daedalus Enterprises developed for Ames for agricultural studies and data validation from the Landsat 4 Thematic Mapper. Daedalus then commercialized both systems for sale, lease, or data collection services. One data collection program, sponsored by 13 energy and mining companies, used ATM data to map exposures of clay minerals and to segregate iron oxides; such exposures are associated with deposits of gold, silver, uranium, copper, lead, and zinc.



Red Pepper Software Company, founded by former NASA employee Monte Zweben, commercialized Ames' Ground Processing Scheduling System software.



The Ames C-130 took photographs of the 1988 Yellowstone fires in a composite of visible and thermal channels.

Although remote sensing data determine the extent of disasters like fires and hurricanes, and map the spread of diseases like malaria, some of the greatest benefits are found in agriculture. In the 1980s, Ames partnered with CROPIX, Inc., to make crop acreage estimates and to calculate a field-by-field vegetative index number. In 1993, the Ames Research Center Ecosystem Science and Technology Branch collaborated with industry and university partners to use remote sensing and associated computerized technologies as a tool for vineyard managers to address the phylloxera infestation and to improve crop uniformity in the winegrape harvest. Robert Mondavi Winery produced high quality reserve wines from the studied vineyard for the first time.

In May 2002, Ames signed a Memorandum of Understanding to embark on a remote sensing project for the U.S.'s largest coffee

plantation, and to explore the establishment of an "Unmanned Aerial Vehicle (UAV) Applications Center" in the NASA Research Park. The new center's charter is to conduct collaborative R&D to enhance scientific and commercial utilization of UAVs as high-resolution imaging platforms in national airspace. The Ames-based research team is currently conducting a \$3.76 million project for NASA's UAV Science Demonstration Program. The effort will provide the first-ever test of the commercial use of a solar-powered UAV operating in national airspace.

Looking forward, Ames' Commercial Technology Office has many exciting prospects underway. Looking to the future with anticipation, but without forgetting the past, Ames remembers its rich history of contributions to the mission of technology transfer by celebrating the successes of the past 40 years. ❖

Dryden Flight Research Center

The Dryden Flight Research Center, located at Edwards Air Force Base, California, is NASA's primary installation for flight research. Projects at Dryden over the past 50 years have led to major advancements in the design and capabilities of many civilian and military aircraft.

The history of the Dryden Flight Research Center is the story of modern flight research in this country. Since the pioneering days after World War II, when a small, intensely dedicated band of pilots, engineers, and technicians dared to challenge the sound barrier in the X-1, Dryden has been on the leading edge in aeronautics, and more recently, in space technology. The newest, the fastest, the highest—all have made their debut in the vast, clear desert skies over Dryden.

Although NASA is celebrating 40 years of technology utilization, Dryden's foray into the world of spinoffs did not officially start until 1995, after NASA's "Agenda for Change" placed new emphasis on technology transfer. While Dryden is known primarily for its flight test

capabilities, closer inspection of these technologies led to the development of an office devoted to the full-time protection and dissemination of these valuable assets.

Dryden's successes are far-reaching and supported by customers from industry, universities, and other government organizations. New research and technology directions are moving toward revolutionary aeronautics, intelligent systems, space access, and airborne sciences.

One of Dryden's earliest aeronautics success stories celebrates its 30th anniversary this year. Most modern aircraft utilize a digital flight control system (DFCS). Dryden engineers pioneered this system in 1972, with the F-8 Digital Fly-By-Wire aircraft research project. The DFCS concept incorporated an electronic flight-control system coupled with a digital computer to replace conventional flight controls. Dryden's work paved the way for the DFCS now used in the Space Shuttle and today's military and civilian aircraft, making them safer, more maneuverable, and more efficient.



Most modern aircraft use digital flight control systems (DFCS). Dryden engineers pioneered DFCS, and the 30th anniversary of the first flight of Dryden's F-8 Digital Fly-By-Wire aircraft was May 25, 2002.

Digital systems make aircraft more maneuverable because computers command more frequent adjustments than human pilots. Aircraft designers are no longer confined to designing features that make the aircraft more stable, thus harder to maneuver. For commercial airliners, computerized flight controls ensure a smoother ride than a human pilot alone could provide.

Another Dryden success story involves an uninhabited aerial vehicle. The Center is rightly proud of its participation in the solar-powered aircraft Helios prototype, which recently set an altitude record at 96,863 feet and made a run as a candidate for one of aviation's greatest prizes, the Collier Trophy. The project team also has new plans to fly the Helios at night, without solar power in 2003. The aircraft, a solar wing that resembles a yardstick with a wing span of 247 feet, or larger than that of NASA's Boeing 747, will demonstrate a newly developed fuel-cell-based power system. The Helios spent about 7 hours above 50,000 feet

on its record-breaking, high-altitude flight August 13, 2001. This 2003 mission is expected to stay aloft for at least 14 hours above 50,000 feet, with different systems and procedures.

"Technically it's a very challenging mission. We fully expect to see some problems that require us to go back to the shop and test facilities and fix them and come back and fly," said John Del Frate, solar-powered aircraft project manager. "This is a whole new ballgame for us because we are trying to conquer the night."

AeroVironment, Inc., NASA's partner and the aircraft's builder, is developing the fuel-cell-based power system—a step toward "flying an eternal airplane that could be sent on missions spanning months," said Del Frate. These capabilities are developed as part of Dryden's Environmental Research Aircraft and Sensor Technology (ERAST) Program that began in 1994.

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The solar wing Helios aircraft spent about 7 hours above 50,000 feet on its record-breaking, high-altitude flight August 13, 2001.

Dryden Flight Research Center (Continued)

AeroVironment has commercial plans underway as well. The company is training people for work on another high flying solar wing, the Pathfinder Plus, in Kauai, Hawaii. Scheduled for two commercial demonstration missions outside of the ERAST program, the Pathfinder Plus will provide a flight platform for a Japanese agency that wants to test some of their communications payloads in the stratosphere. The aircraft also will carry a remote sensing instrument to monitor Hawaiian coffee crops, a project sponsored by Clark University of Worcester, Massachusetts.

“It’s gratifying to see commercial use of the solar flying wings. Ultimately the real commercialization of the airplane will blossom when it can routinely fly extreme duration flights because that’s how you get the costs down,” the project manager added. An aircraft with multi-week to multi-month flight capability opens the door to a new way of Earth monitoring. Helios could serve as a platform

for disaster relief and crop monitoring, or follow the eye of a hurricane.

Another important Dryden spinoff is improving communications systems on Earth and in space. In 1997, NASA needed help in talking with the orbiting Space Shuttle. Due to an ever increasingly congested radio spectrum, the ability to hear the orbiter’s radio signals required greater receiver sensitivity. Dryden partnered with Angle Linear, of Lomita, California, a manufacturer of linear radio frequency products and peripherals, to solve the problem. The solution was a receiving preamplifier specially crafted for NASA that made Shuttle communications more reliable. The company’s preamplifier line was greatly expanded to cover a broader range of frequencies, providing the same improvement to other communication markets in trucking, land mobile, broadcast media, and cellular telephones.



Originally developed for NASA Space Shuttle communications, Angle Linear’s receiving preamplifier has a very sensitive high dynamic range. The system is used in a variety of communications applications, including business, government, tracking, and cellular telephones.



NASA Dryden Flight Research Center will operate a highly modified NF-15B aircraft in a second series of flights in the Intelligent Flight Control System (IFCS) research project.

As always, Dryden's research produces cutting-edge technology in aviation. How about an airplane that can heal itself and land safely following a catastrophe? A special NASA airplane that can alter its own computerized flight software to meet in-flight emergencies is getting ready for research flights next year. Dryden will operate the highly modified NF-15B aircraft in a series of flights in the Intelligent Flight Control System (IFCS) research project. IFCS is designed to incorporate self-learning neural network concepts into flight control software to enable a pilot to maintain control and safely land an aircraft that has suffered a major systems failure or combat damage. Flight evaluation of first- and second-generation self-learning neural network

control software is expected to occur in 2003. Preliminary flight tests of an IFCS neural network that was pre-trained to the NF-15B's aerodynamic database were flown in spring 1999.

NASA and the Nation have seen the benefits on a daily basis of Dryden's contributions to aerospace research-derived technologies. Even though Dryden's Commercial Technology Office opened just 7 years ago, modern aviation—and the entire U.S. Space Program—could not have prospered without the Center's heroic efforts over the past 50 years. As one Dryden engineer said, "If you've been on an airplane, you've benefited from Dryden technology." ❖

Glenn Research Center

If a NASA technology improves the daily lives of people nationwide, and even worldwide, then commercialization has achieved its goal.

Over the last 40 years, technology developed at the Glenn Research Center has been commercialized to the extent that most people in the United States and in many other parts of the world come into contact with Glenn-developed technology every day.

Many serendipitous spinoffs resulted from NASA's work in the early 1960s. The Agency realized that industry could benefit from the vast amount of research performed at the Cleveland facility (then the Lewis Research Center) and began to proactively apply its efforts to assist industry with their technical needs. The Technology Utilization Office was

established at the Lewis Research Center in 1963 as a result of the National Aeronautics and Space Act of 1958, and also as an avenue for public access to NASA technologies.

Glenn has made significant contributions in the spinoff arena since the inception of the *Spinoff* publication in the early 1970s. During the Apollo era, before the publication was established, the Center's technology innovations included rechargeable batteries for small tools, such as cordless drills. In the late 1970s, technology for textured medical implants and a cataract removal tool were developed. More recent spinoffs include the Atomic Oxygen Art Restoration process, Moen's LifeShine® faucet finish, and the Tempest/Embedded Web technology, originally developed for Internet use on the International Space Station, but later



The NASA John H. Glenn Research Center at Lewis Field is located in Cleveland, Ohio.

transferred to industry with a variety of uses for remote monitoring.

Glenn's work in the 1990s with General Electric on the GE90 turbofan engine is considered to be one of its most significant spinoffs. The overwhelming majority of travelers using commercial transportation for long distance travel now fly in jet transports. Glenn has been NASA's lead center for gas turbine (jet) engines. In recent years, emphasis has been on quieting these engines, both to improve passenger comfort and reduce ground noise around airports. Thanks in no small part to quiet engine technology developed at Glenn, the aircraft flying today are much quieter than the aircraft flying in the 1960s. Beginning with the Energy Efficient Engine program in the 1970s, the Center developed fuel-efficient technology used in current jet engines, like the GE90 high-bypass turbofan. In addition, jet engine emissions, particularly nitrogen oxides (NOx), have been significantly reduced. This research resulted in commercial jet aircraft that are more environmentally friendly, and allow for lower costs for the flying consumer.

Air travel in bad weather is safer due to improvements in aircraft icing detection and



in-flight ice removal developed by Glenn's Aircraft Icing Research group. One of the Center's **Small Business Innovation Research (SBIR)** contractors, Cox & Company, worked with Glenn researchers to develop the first new aircraft ice protection system to be approved by the Federal Aviation Administration in 40 years.

General aviation has not been ignored. Glenn recently completed a program to help develop a new generation of general aviation aircraft engines. One of these is the Williams International EJ22, which will power the new "air taxi" currently being developed by Eclipse Aviation Corporation, of Albuquerque, New Mexico. The company developed the groundbreaking Eclipse 500 aircraft, creating a new class of twinjet light aircraft that could allow passengers to use smaller, less congested airports closer to their homes.

Glenn-developed technology in the area of satellite communications may affect the life of the average person more than anything else. The Commercial Technology Satellite (CTS) launched in 1976 increased the power of satellite-relayed signals by a factor of 20 over previous commercial satellites (COMSATS), and produced the technology that made possible the explosion in satellite television (TV) channels. For its efforts, Glenn was awarded an "Emmy" award by the television industry. Traveling-wave-tube technology developed for CTS was applied to "Klystron" power tubes used in ultra high frequency (UHF) TV transmitters, doubling their efficiency and making it possible for UHF stations to significantly increase their broadcast range with no additional power usage.

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The Multi-depressed Collector Klystron cuts the electric power consumption of UHF TV transmitters in half, allowing a UHF TV station to save 50 percent of its electricity cost.

Glenn Research Center (Continued)

This pioneering work was further developed by the Advanced Communications Technology Satellite (ACTS) Program. ACTS opened new communications frequency bands, greatly increasing the number of messages COMSATS could carry. This is particularly important for geosynchronous (stationary) satellites, because they all occupy a single orbit where there is limited space. The efficiency of COMSATS is increased by spot beam antenna technology pioneered on ACTS. Instead of blanketing an area, a spot beam antenna can concentrate its beams on more important areas, such as populated regions as opposed to lakes and desert lands.

A fact not normally appreciated by the general public is that the service life of a stationary satellite is limited more by the fuel supply needed for its attitude-adjusting rockets

than by the durability of its components. These satellites have to be kept in line with the millions of stationary satellite dish antennas in use. However, gravitational forces from the Moon, Sun, and other planets can skew the satellites out of line. Several times a year, small rocket engines are fired to realign them. The NASA Glenn Onboard Propulsion Branch has improved the efficiency of these small rockets and developed new types of small attitude rockets that have increased the useful lives of satellites by 50 percent. Considering that it costs between \$500 million and \$750 million to build and launch a communications satellite into geosynchronous orbit, this increase in service life results in a considerable cost savings to the COMSAT companies, and the savings are passed on to the consumer in the form of reduced rates.



The Advanced Communications Technology Satellite Program opened new frequency bands, allowing commercial satellites to greatly increase the number of messages they could carry.

Much new Glenn technology has spun off to the medical field. In the early 1970s, work on advanced rocket and gas turbine materials helped improve the biocompatibility of artificial hip and knee joints. Research on ion rocket engines led to pioneering the texturing of implants to encourage human tissue to grow into the implant. More recently, turbopump design technology originally developed for cryogenic fuel turbopumps in rocket engines was used to help develop a small turbopump that will be installed in humans to assist damaged hearts.

Several new biotechnology and biomedical applications are being developed at Glenn. One microgravity researcher is currently developing “space-vision goggles” to be used by astronauts and other future space travelers to allow physicians to remotely monitor their health. Glenn’s ACTS project has demonstrated the ability to transmit high-resolution mammograms and echocardiographic images from remote regions to major medical clinics. This has the potential to give people living in rural, low-population, and economically depressed areas direct access to the best medical teams in the world. Also, an atomic oxygen process developed at Glenn is being used in a partnership with the Cleveland Clinic Foundation, employing a polymer lattice for the growth of cellular tissue for reconstructive surgery.

Glenn’s spinoff applications are vast and delve into many technology areas. From aerospace, transportation, and biomedical applications to materials and sensor development, our technology transfer projects touch lives every day. ❖

LifeShine® is a registered trademark of Moen, Inc.



Glenn’s work on advanced rocket and gas turbine materials was translated to the medical field, where it helped improve the biocompatibility of artificial hip and knee joints.

Goddard Space Flight Center

Named after rocket research pioneer Dr. Robert H. Goddard, NASA Goddard Space Flight Center was established in 1959. Goddard employs hundreds of premier scientists and engineers who are devoted to research in Earth science, space science, and technology. The Technology Commercialization Office (TCO) at Goddard was established to encourage broader utilization of Goddard-developed technologies in the American industrial and academic communities.

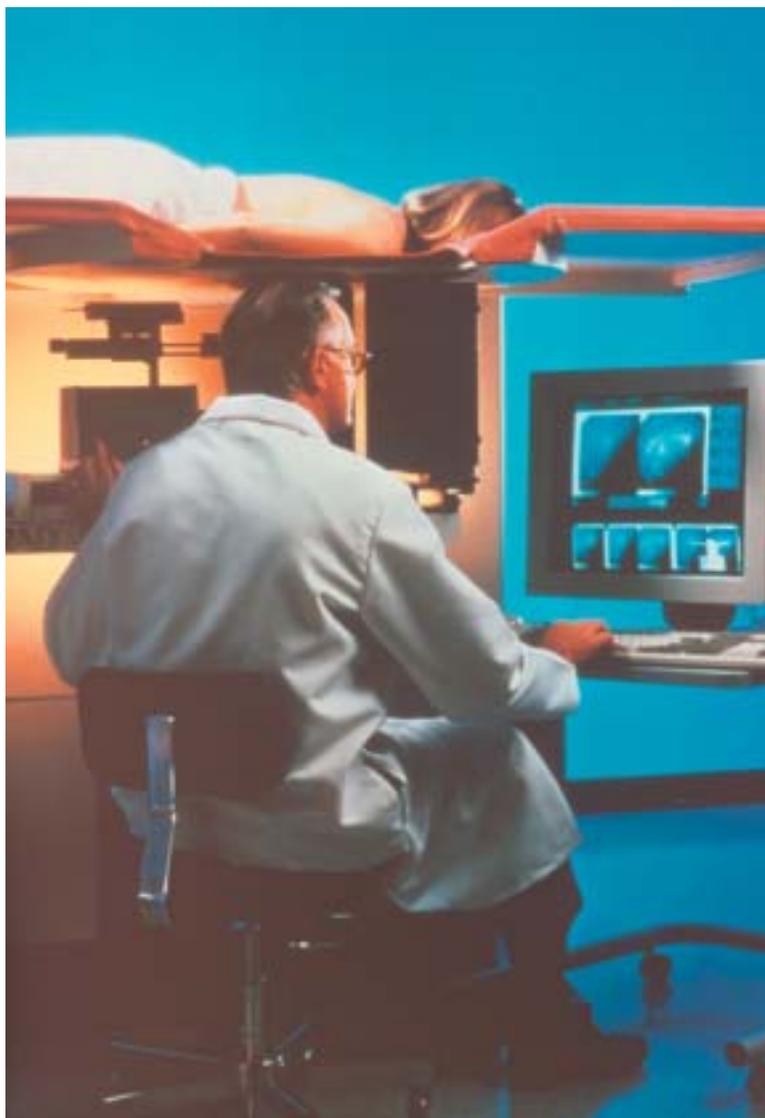
One of Goddard's most noteworthy examples is the NASTRAN® (NASA Structural Analysis) software application, written to help design more efficient space vehicles such as the Space Shuttle. NASTRAN was released to the public in 1971 by NASA's Office of Technology Utilization. The commercial use of NASTRAN has helped to analyze the behavior of elastic structures of any size, shape, or purpose. For example, the automotive industry uses the program to design front suspension systems and steering linkages. It is also used in designing railroad tracks and cars, bridges, power plants, skyscrapers, and aircraft. The program alone was estimated to have returned \$701 million in cost savings from 1971 to 1984. NASTRAN was inducted into the U.S. Space Foundation's Space Technology Hall of Fame in 1988, one of the first technologies to receive this prestigious honor.

Since the beginning of the technology transfer program at Goddard, several technologies have made significant contributions to the medical industry. The Implantable Cardioverter Defibrillator (ICD) was conceived in the mid-to-late 1960s, and tested at Sinai Hospital, of Baltimore, Maryland, in 1969. This heart assist system was derived from NASA's space circuitry technology. In 1985, after a number of years of pre-clinical testing, the device entered clinical trials and received U.S. Food and Drug Administration approval. The ICD is a fully implantable device, not much larger in size than the implantable pacemaker. The success of this therapy became regarded as the "gold standard" in the treatment of malignant arrhythmias.

Another spinoff application enabled by Goddard is the charge coupled device (CCD). This technology has made great strides in the area of non-invasive breast cancer detection. The stereotactic breast biopsy system incorporated the charge coupled technology as the key component of a digital camera that scans the breast structure with X-rays. The device images suspicious breast tissue more clearly and



The automotive industry uses NASTRAN® to design front suspension systems and steering linkages.



The LORAD Stereo Guide™ Breast Biopsy System incorporates Goddard's charge coupled device technology as part of a digital camera system that "sees" a breast structure with X-ray vision.

efficiently, saves women time and money, reduces pain and radiation exposure, and eliminates the scarring of more invasive techniques. With more than 500,000 women undergoing breast biopsies each year, the system has dramatically reduced annual health care costs. The system that first made possible this new technique is the LORAD Stereo Guide™ Breast Biopsy System, which incorporates Scientific Imaging Technologies, Inc.'s CCD as part of its digital camera system. The technology breakthrough that spawned the LORAD system originated at Goddard, where

scientists developed the Space Telescope Imaging Spectrograph for the Hubble in 1997.

Goddard is supported by the **Small Business Innovation Research (SBIR)** program in its commercialization efforts. This program, established by Congress in 1982, provides increased opportunities for small businesses to participate in R&D. Legislation enacted in 2000 extended and strengthened the SBIR program and increased its emphasis on pursuing commercial applications of SBIR project results.

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Goddard Space Flight Center (Continued)

The **Small Business Technology Transfer (STTR)** program awards contracts to small business concerns for cooperative R&D with a non-profit research institution, such as a university. Modeled after the SBIR program with the same basic requirements and phased funding structure, the STTR program is a separately funded activity.

Since its inception, the SBIR program at Goddard has made great strides in bringing small businesses and NASA innovation together. For example, Foster-Miller, Inc., a company that developed a high performance, low cost substrate for printed circuits under an SBIR contract, collaborated with NASA to develop better, more cost effective satellite- and land-based applications. The commercial product that resulted from the agreement led to the start of a spinoff company called Superex Polymer, Inc. The resulting product, called liquid crystal polymers, proved to be exceptionally strong and ideal for food and beverage packaging, high performance tubing, barrier layers for cryogenics, and high temperature electrical insulation.

Through a series of SBIR contracts with NASA, a company called Creare, Inc., has become a leader in advanced cryogenic systems. This collaboration at Goddard has

resulted in the development of a Miniature Cryogenic Turboalternator. This low temperature cooler for NASA was used in the Next Generation Space Telescope, Constellation-X. Long-term commercial applications include cryocoolers for low and high temperature superconducting medical and electronics instruments. This technology was also integrated with the Near Infrared Camera and Multi-Object Spectrometer instrument on the Hubble Space Telescope in 2001. Creare is currently developing components and systems for specialized cryogenic applications.

Goddard's fundamental mission is to expand our current knowledge of the Earth and its environment, the solar system, and the universe through observations from space. Goddard manages and implements flight programs and projects, including the Hubble Space Telescope and Next Generation Space Telescope, Geostationary and Polar Operational Satellites, "Living With a Star" and Solar Terrestrial Probes, the Earth Observing System, Explorers and Earth Explorers, Structure and Evolution of the Universe missions, and a portion of the New Millennium Program. Goddard also oversees the development and operation of the Tracking and Data Relay Satellites, and Space and Ground Networks.



Liquid crystal polymers proved to be exceptionally strong and ideal for food and beverage packaging. Their properties can prevent oxygen from deteriorating the taste of precooked and packaged food.

The Center also manages about two dozen Sun-Earth Connection and Structure and Evolution of the Universe missions currently in operation, including the Advanced Composition Explorer and the Microwave Anisotropy Probe. Goddard is currently building the Swift mission to determine the nature of gamma ray bursts, considered the largest explosions in space since the *Big Bang*. Additionally, it is building next-generation X-ray and gamma-ray detectors for future NASA missions.

Goddard plans, organizes, and evaluates a broad program of scientific research in the Earth sciences, ranging from basic research to flight experiment development, mission operations, and data analysis. The Center conducts missions that obtain highly accurate and frequent measurements of the Earth, as well as advanced computer networks that transmit data and the resulting information to a wide variety of global users. Scientific investigations include studying the internal structure, dynamics, and material variations of the Earth, as well as research to better understand the effects of climate change on ecosystems and the effects of land surface vegetation change on the climate.

Goddard is an important resource for observing, understanding, and modeling the global oceans and related research that focuses on the links between all aspects of the water cycle, as well as global weather and climate. Scientists develop and apply microwave and multispectral optical remote sensing to measure and define the abundance of water, ice, and snow on land surfaces; oceanic salinity; precipitation; the exchange of water between soil, biosphere, and atmosphere; and oceanic biological productivity.

In the next 10 years, Goddard will provide leadership in the systematic measurement and NASA/National Oceanic and Atmospheric Administration transition missions to understand how the Earth is changing and the primary causes for such change. ❖

NASTRAN® is a registered trademark of National Aeronautics and Space Administration.

LORAD Stereo Guide™ is a trademark of LORAD Corporation.



Peering into our stellar backyard, the Near Infrared Camera and Multi-Object Spectrometer peeled back the outer layers of the Cone Nebula to see the underlying dusty “bedrock” in this stellar “pillar of creation.”

Jet Propulsion Laboratory

For millions of Americans, 1963 began with the New Year's Day Tournament of Roses Parade broadcast from Pasadena, California, led by Grand Marshall Dr. William Pickering, the Jet Propulsion Laboratory's (JPL) director. Pickering was followed by a float honoring JPL's Mariner 2 space probe. Their prominent positions in the parade reflected the success of Mariner 2, the first spacecraft to encounter another planet, Venus, just 1 month earlier in December 1962. That success laid the groundwork for 40 more years of planetary exploration, from the 1960s manned lunar missions and the 1970s Mars Viking missions, to the Mars Odyssey mission's discovery of enormous subsurface frozen water deposits in May 2002.

Since the initial success in 1962, JPL spacecraft have visited every planet in our solar system, with the exception of Pluto. The laboratory also manages the worldwide Deep Space Network, which communicates with spacecraft and conducts research from its complexes in California's Mojave Desert, Spain, and Australia.

With every new space probe and discovery comes technology that leads to products with practical applications for industrial and commercial use on Earth. JPL's Commercial Technology Program, established in 1963 as the Office of Industrial Applications, was created to manage such developments. Since the program's inception, more than 200 U.S. companies have taken advantage of JPL's innovations. Some of the most significant technological contributions have been in communications, digital imaging, miniaturization, remote sensing, and robotics. From exploring the birth of the universe to mapping the interior of the human body, JPL instruments have achieved new breakthroughs.

JPL technology affects the lives of Americans every day. For example, the laboratory led the way in developing the capability to send and receive data within our solar system. This data transmission required a long-term series of technology developments of deep space antennas, precision timing systems, signal detection, and digital processing. Today, these technologies are widely used for wireless communication products.

Digital image processing was pioneered at JPL in the late 1960s, when analog signals from the Ranger spacecraft were converted to digital images with computer enhancement. The Ranger series was designed solely to take high-quality pictures of the Moon and transmit them back to Earth in real time. The images were used for scientific study, as well as for selecting landing sites for the Apollo Moon missions. The Mariner 4 probe, visiting Mars in 1965, was the first spacecraft to send digital images back to Earth. Today, digital imaging has a wide range of applications, with particular emphasis in medicine. Well-known uses include Computed Aided Tomography (CAT) scanning and ultrasounds.

Miniaturization is a crucial part of JPL's research and development efforts. Creation of ever smaller devices not only helps NASA



In the 1960s, JPL workers used teletypes to print out information for the Mariner 2 space probe, the world's first successful interplanetary spacecraft.



The Robot Assisted MicroSurgery workstation enables new procedures for the brain, eye, ear, nose, throat, face, and hand. The device uses computer compensated motion control to dramatically reduce the effects of operator muscle tremor.

miniaturize all aspects of its space systems, making space exploration more manageable and affordable, but also yields significant technology advances. JPL engineers have developed powerful sensors as small as a coin and computer chips no bigger than the period that ends this sentence. Doctors and patients already benefit from some of these technologies used in surgery and non-invasive procedures. A miniature sensor that images in the infrared and locates cancerous tumors is in clinical trials for non-invasive mammography. OmniCorder Technologies, Inc., has licensed JPL's Quantum Well Infrared Photodetector camera technology for detection of breast and skin cancer. The sensor, which helped JPL locate hot spots during fires and observe volcanoes, may potentially benefit other surgical or therapeutic procedures that require rapid and precise monitoring of blood perfusion changes.

JPL engineers assisted in developing a tiny camera chip placed in a pill. Once ingested, this camera-pill photographs the inside of the digestive system and provides doctors with

enhanced diagnostic information. The pill's Active Pixel Sensor expands on charge coupled device (CCD) technology (high-resolution imaging that revolutionized the field of astronomy and is now found on many scientific space vehicles, such as the Hubble Space Telescope) by consolidating functions and reading images more efficiently. The sensor requires one-hundredth the power of a CCD system and is less susceptible to radiation damage in space. Photobit Corporation, a spin-off company from JPL, obtained licensing rights to the technology and continues to develop and market it for use in camcorders and digital cameras.

Miniaturization is not the only way JPL technology has contributed to medical advances. Building on established NASA technology in telerobotics, JPL collaborated with MicroDexterity Systems, Inc., to develop a new robotic microsurgery device for delicate surgeries. Designed in cooperation with leading microsurgeons, this Robot Assisted

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Jet Propulsion Laboratory (Continued)

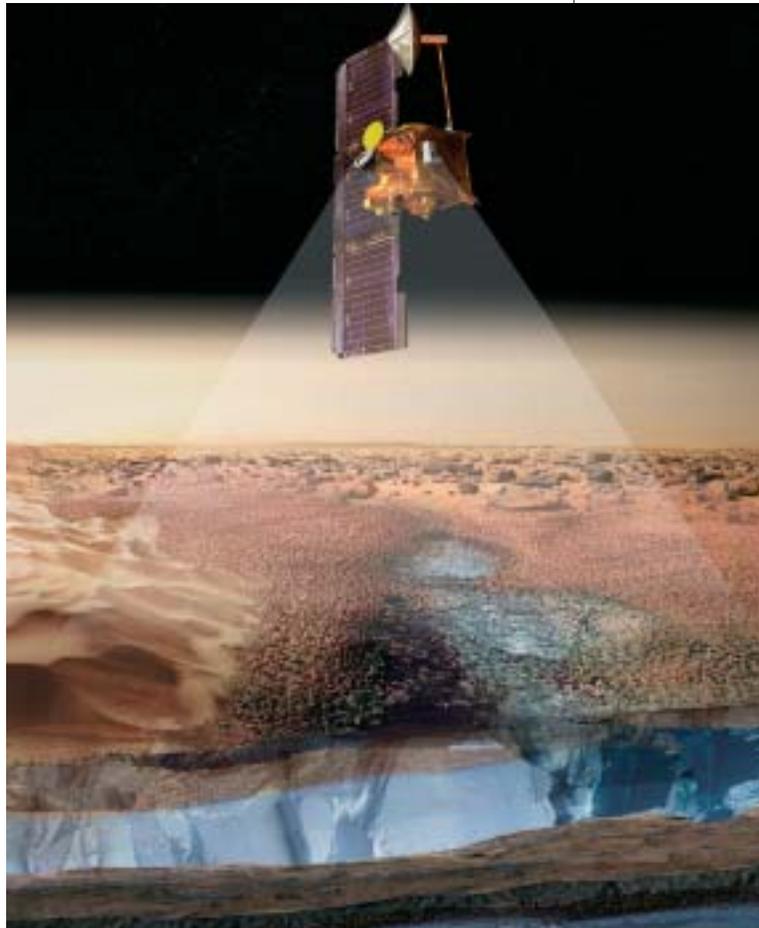
MicroSurgery workstation, or robot arm, will enable new procedures for the brain, eye, ear, nose, throat, face, and hand.

Another significant contribution from JPL is in the remote sensing field. JPL scientists and engineers have turned that knowledge Earthward to learn more about our own planet. In 1997, JPL gave the world an early warning of the El Niño phenomenon, saving thousands of lives and millions of dollars worth of property. Using the Global Positioning System (GPS) and altimeter data received from the JPL-managed Topex/Poseidon satellite, JPL scientists measured the height of the ocean and predicted the season of storms brought on by El Niño. GPS technology also monitors tiny slips along fault lines, and their strain in Southern California. Understanding this seismic activity will lead to better earthquake preparedness.

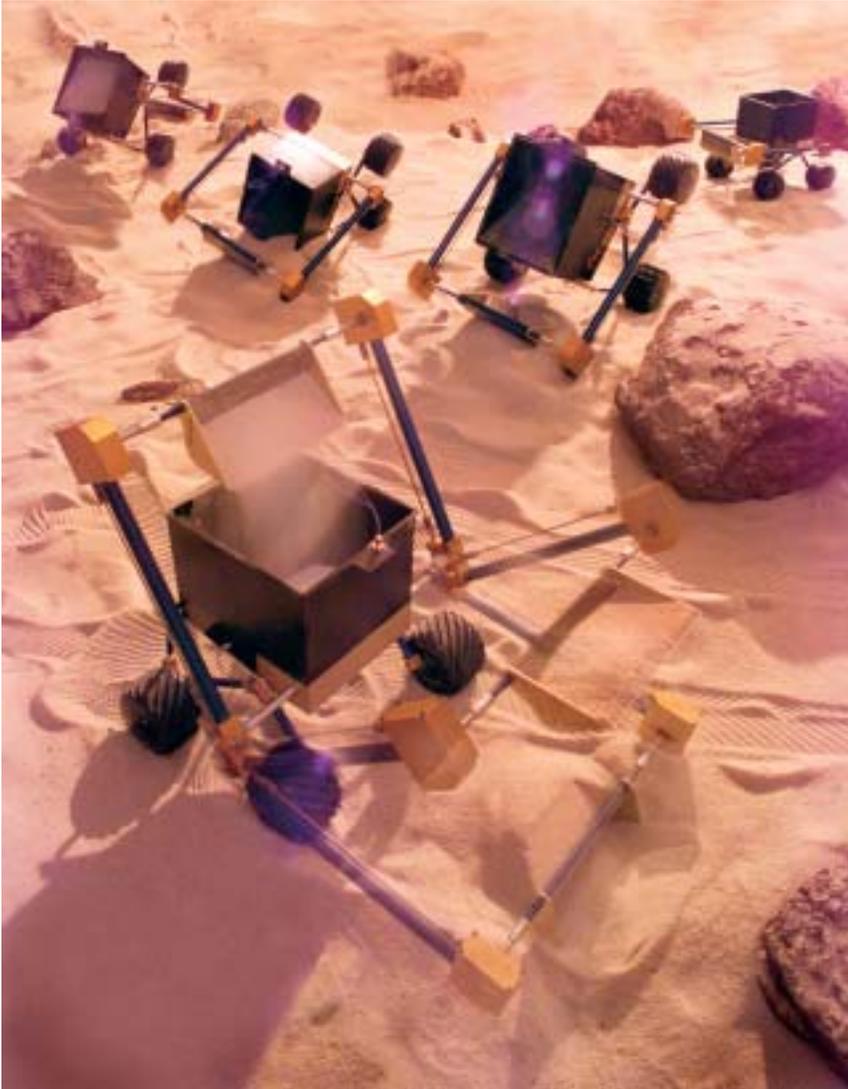
Last year, farmers put a new GPS system to the test. NavCom Technology Inc., a division of

the John Deere Company, licensed the technology and equipped tractors with receivers providing instant location information. The GPS allows farmers to navigate fields at night and during poor visibility. With soil sensors and other monitors, they can precisely map where fields may need more water, fertilizer, or weed control, saving both time and money.

Other advances from the exploration of Mars will be plentiful. In another sensing application, a landmark discovery by JPL's Mars Odyssey spacecraft revealed frozen water on the Red Planet. This year, scientists were surprised to find enormous quantities of buried ice lying just under the surface of Mars—enough frozen water to fill Lake Michigan twice. The detection technologies used on Odyssey may have applications for remote detection of materials on Earth.



A landmark discovery by JPL's Mars Odyssey spacecraft revealed frozen water on the Red Planet.



In the future, “bulldozer” rovers and other robotic explorers may be used to look for life and build a Mars outpost to sustain a human presence.

Future Mars explorers may include a giant “beach ball” rover rolling along the surface of the planet. Called the “tumbleweed rover,” the lightweight, two-story-tall ball may be used to traverse the tough, sloping Martian terrain. Other rovers may literally hang “on the edge” to give scientists a good look at the planet’s nooks and crannies. The new “cliff-bot” rover can do just that. Artificial intelligence software drives a team of rovers able to set up camp and work independently. “Bulldozing” rovers may scoop up the Martian soil. Basic research on these robotic explorers may support future Mars missions to look for life or to sustain a human presence and lead to new innovations in commercial technology. ❖

Johnson Space Center

For more than 4 decades, the Lyndon B. Johnson Space Center has been the leader in human spaceflight operations for NASA. Established as the Manned Spacecraft Center in 1961, the Center was renamed in honor of the late president in 1973. Located just outside of Houston, Texas, Johnson provides the planning and operation of the International Space Station (ISS) and Space Shuttle flights, and is the site of Mission Control. The operations at the Center include the development and integration of experiments for human spaceflight activities; the application of space technology and its supporting scientific engineering and medical research; the selection and training of astronauts; and the operations of human spaceflights.

Driven by the desire to expand the frontiers of space and knowledge and improve life here on Earth, Johnson set the pace for exploring, using, and enabling the development of space for human enterprise. As a result, Johnson achieved unprecedented accomplishments and delivered numerous benefits to America and the rest of the world through human exploration and development of space initiatives.

Johnson is the leading force of the ISS, which has grown from a 70-ton, efficiency apartment-sized foothold in orbit to a space laboratory of boundless capability. The assembled ISS provides the first laboratory complex where gravity, a fundamental force on Earth, can be controlled for extended periods. This ability to control gravity opens up unimaginable research possibilities that will enable discoveries that may benefit people around the globe.

Space-based technology has already enriched a wide range of human activities—how we communicate with one another, process information, travel, and study our planet's biosphere, to name a few. It has improved our quality of life by showing us new ways to treat our sick and injured, grow our food, and even correct our vision.

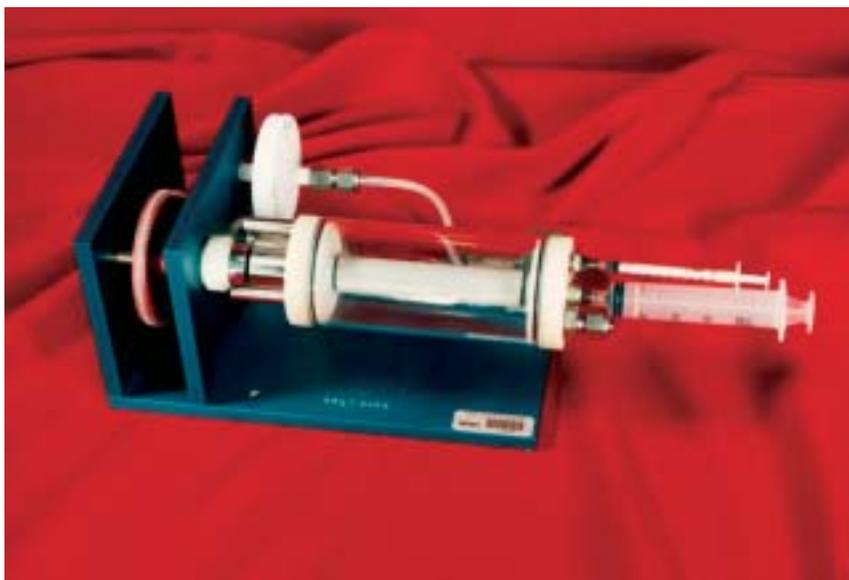
Johnson engineers collaborated with famed heart surgeon Dr. Michael DeBakey to develop the MicroMed DeBakey VAD.®

Johnson supports a wide range of responsibilities, including technology evaluation, intellectual property, commercialization, patent licensing, joint development partnerships, **Small Business Innovation Research (SBIR)** and **Small Business Technology Transfer (STTR)** programs, grants, and Space Act Agreements. These functions enable the Center to more closely align its way of doing business with that of the private sector, and help identify the Agency's technology needs and leverage its resources.

Johnson continually strives to research and develop technology with meaningful real-life applications here on Earth, as well as in space. Johnson has contributed to major medical advances, including the development of a ventricular assist device called the MicroMed DeBakey VAD,® which assists people with congestive heart failure awaiting heart transplants.

Other advancements in cardiology that resulted from NASA-developed technology include the Digital Cardiac Imaging (DCI) System and the Heart Rate Monitor. The DCI system, designed by Philips Medical Systems International, significantly improves angioplasty





The Rotary Cell Culture System™ grows accurate, three-dimensional cells which researchers use to test new medical treatments.

with better real-time imaging and the ability to employ image enhancement techniques to bring out added detail. The Heart Rate Monitor, developed under a NASA grant by researchers at Texas Technical University, incorporates a new type of electrocardiographic electrode. The dry, reusable electrode works upon contact with the skin and is not affected by heat, cold, light, perspiration, or rough and oily skin.

Johnson's unvarying force of discovery also led to the development of a bioreactor to study the impact of microgravity on cellular and tissue growth on Earth and in space. NASA granted biotech startup Synthecon,™ Inc., an exclusive license to develop a rotating bioreactor, called the Rotary Cell Culture System™ (RCCS), that allows researchers to grow more accurate, three-dimensional cells they can then use to test new medical treatments without risking harm to their patients.

Scientists and clinicians worldwide are using the RCCS bioreactors for a variety of applications, such as growing normal human tissue in vitro for testing of therapeutic drugs or for

growing replacement tissue such as liver, skin, and bone marrow. The RCCS bioreactor provides the research community with an excellent in vitro environment for culturing cells such as human tumor, viruses, and cells that produce valuable bio-products including proteins, enzymes, and hormones. Research

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Many firefighting tools, such as protective clothing, are spinoffs from NASA-based technologies that were first developed for astronauts.

Johnson Space Center

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centers currently using the RCCS bioreactor include the Cell & Gene Therapy Institute in San Antonio, Texas; the National Institutes of Health in Bethesda, Maryland; the U.S. Food and Drug Administration; and the U.S. Army Medical Research Institute of Infectious Diseases at Fort Detrick, Maryland.

At Johnson, the goal is to ensure that safety and health are inherent in all that is undertaken. Since human spaceflight is a primary focus at the Center, it has concentrated on technologies that prove to be safe and beneficial to astronauts during space exploration. Firefighters, like astronauts, often brave dangerous and hostile environments protected mainly by the technology on their backs. Numerous technologies first developed for space exploration

have proven beneficial for firefighting and prevention here on Earth, such as a portable firefighting module, protective clothing, flame-resistant fabrics, and the breathing apparatus worn by firefighters throughout the United States for protection from smoke inhalation injury.

Another Johnson-developed technology that has a meaningful real-life application here on Earth is the ultraviolet (UV) blocking suit and cooling vest. Developed for the Hypohidrotic Ectodermal Dysplasia (HED) Foundation, the suits and vests use spacesuit technology to help improve the quality of life for children suffering from HED, Sun and Light Reaction Syndrome, Xeroderma Pigmentosum, and related disorders that affect the body's ability to cool



Thousands of children with disorders that affect the body's ability to cool itself have benefited from cool suits developed for the Hypohidrotic Ectodermal Dysplasia (HED) Foundation.

itself. An 8-year-old boy from Magnolia, Texas, suffers from four skin diseases that kept him out of the sun and its potentially harmful UV radiation. However, that has all changed thanks to NASA and the HED Foundation. In April 2001, the boy received a special UV blocking suit that was developed from NASA space-based technology. The suit, which covers him from head to toe, allows him to go outside protected from harmful light. To date, thousands of children now enjoy their newfound outdoor freedom. More than 120 suits and about 3,000 cooling vest packs have been distributed through HED.

Taking technology a step further, Johnson collaborated with the Defense Advanced Research Projects Agency to create Robonaut—a humanoid robot. The Robonaut project seeks to develop and demonstrate a robotic system that can function as an Extra Vehicular Activity astronaut assistant. The dexterous manipulation technology used in the Robonaut's hands might some day be used in other applications such as human prosthetic development.

A key to Johnson's technology transfer success is the Mid-Continent Technology Transfer Center. The center helps market NASA/Johnson technologies and aids in identifying commercial opportunities. Johnson also participates with Clear Lake Area Economic Development Foundation to attract space-related business and industry or open operations in the local area. The Technology Outreach Program at Johnson helps small business access and utilize NASA technologies in beneficial commercial applications. The program provides up to 40 hours of engineering assistance at no cost to a business seeking technical assistance, which helps to accelerate the transfer of technology to the marketplace.

It has been another exciting year for technology development at Johnson Space Center. And, for the next 40 years, the Center will continue to focus on enhancing the quality of life in space, as well as on Earth through research partnerships and technical advancements. ❖

The MicroMed DeBakey VAD® is a registered trademark of MicroMed Technology, Inc.

Synthecon™ is a trademark of Synthecon, Inc.

The Rotary Cell Culture System™ is a trademark of Synthecon, Inc.



Robonaut is a humanoid robot being developed to function as an astronaut assistant. The dexterous manipulation technology in its hands might one day be used in applications such as human prosthetic development.

Kennedy Space Center

In 2002, NASA's John F. Kennedy Space Center, home to Space Shuttle launches and gateway to the universe, celebrates its 40-year anniversary—and 40 years of technology utilization. Because NASA believes that advancing space technology is vital to U.S. economic health, the Agency recently designated Kennedy as the Spaceport Technology Center, a world-class resource for the emerging space transportation industry. No other site in the world processes and launches as many different types of reusable and expendable space vehicles.

Kennedy is responsible for NASA's launch and payload processing systems. It is also the lead center for acquisition and management of expendable launch vehicle services and payload carriers. Kennedy and its neighbor, the U.S. Air Force's 45th Space Wing at Cape Canaveral Air Force Station, share a rich history of cooperation in perfecting space launch technologies. To recognize this partnership and to better serve the commercial space industry, the two organizations recently merged various support activities to establish the Cape Canaveral Spaceport. With so many space-related programs underway,

it is no wonder that Florida's Space Coast is now helping to set the standard for future spaceports around the globe.

This was not always the case. Prior to official establishment of the Center in 1962, NASA and numerous private contractors were fully occupied with developing the technology and equipment necessary to put the Project Mercury astronauts into space atop Redstone and Atlas rockets. Commercial transfer of new technologies was not a priority. Research grants and contracts were the primary means of sharing information on space-related innovations.

During the Gemini and Apollo Moon missions, a new era of innovation began. NASA soon realized the commercial benefits of these innovations and in 1962 established the Technology Utilization Program. In that same year, President Lyndon B. Johnson renamed the Cape Canaveral Launch Operations Center in honor of President John F. Kennedy, whose vision of space travel was realized in July 1969 when three Americans landed on the Moon. During this era, a noteworthy technology was developed: a rocket fuel tank gauging system that helped land the astronauts safely on the Moon. Its commercial application eventually earned it a place in history with a NASA Space Act Award.

Known as the Liquefied Natural Gas (LNG) Custody Transfer System, this Apollo-born technology is used by more than three-quarters of the world's LNG tankers and is manufactured by the Foxboro Company of Massachusetts (now Invensys Process Systems/Foxboro). The original technology, developed by Robert Blanchard and Arthur Sherburne of Trans-Sonics, Inc., provided precise capacitance liquid-level gauging, a capability required by NASA for real-time rocket fuel gauging on the Saturn V and lunar landing modules. The accurate readout of remaining fuel was critical to the performance of the rockets, as was shown in 1969 when Apollo 11 achieved the first manned



The Apollo 11 Lunar Module "Eagle," in a landing configuration is photographed in lunar orbit from the Command and Service Modules "Columbia."

lunar landing. Although recent technologies are now starting to replace this LNG system, the innovation is still used on 115 tankers worldwide with a trade valued at \$20 billion a year.

NASA's Advanced Technology Program was launched in 1976, which led to Kennedy's Technology Outreach Program and the creation of Regional Technology Transfer Centers, all aimed at more vigorously transferring space technologies to the public. The Space Shuttle era was here, and Americans became familiar with the concept of a Space Transportation System. As a result of the Technology Transfer Acts of the 1980s, even stronger transfer strategies began to emerge to publicize and disseminate Shuttle-related innovations.

The complexity of the Space Transportation System spawned the development of many new technologies related to fluid systems; launch pad structures and materials; process and human

factors engineering; range technologies; command, control, and monitoring technologies; and biological sciences. Kennedy innovators, with expertise in ground support equipment, contributed greatly to the effort, which in turn generated numerous commercial spinoffs.

The development of one important safety-related technology began in 1979, when engineers designed a Lightning Detection and Ranging (LDAR) system to protect Shuttle launch personnel and equipment during thunderstorms. Global Atmospheric, Inc., of Tucson, Arizona, later joined with NASA in a Space Act Agreement to upgrade and commercialize the LDAR. The three-dimensional system pinpoints the location and altitude of in-cloud and cloud-to-cloud lightning by measuring the exact arrival times of electromagnetic pulses. LDAR locates lightning in near real time. The data are then used to define the existence and

extent of the lightning hazard and to provide more accurate lightning warnings to Spaceport workers. The company focused its product on multiple markets, including electric utilities, the aviation community, commercial rocket launches, recreational facilities, construction, atmospheric research, and meteorology.

Another successful spinoff resulted from the development of a lubricant for the six-million-pound crawler/transporter used to move the Space Shuttle and Mobile

(Continued)



An electrical storm created a tapestry of light in the skies near Launch Complex 39A at the Kennedy Space Center prior to launch of the Space Shuttle Mission STS-8. In this view, a bolt of lightning appears to be striking the complex itself while the Orbiter sits on the pad, illuminated by flood lights.

Kennedy Space Center (Continued)

Launcher Platform from the Vehicle Assembly Building to the launch pad. Kennedy contacted Sun Coast Chemicals of Daytona, Inc., to help develop a more environmentally friendly lubricant. Working in cooperation with Kennedy, Sun Coast Chemicals developed the X-1R® Crawler Track Lubricant in just 8 months. Infrared thermography testing on the crawler revealed that the lubricant brought about the significant reduction in wear and heat that NASA was looking for. Sun Coast Chemicals went on to successfully market dozens of lubricating products and was chosen by the U.S. Space Foundation as a Space Technology Hall of Fame winner in 2000.

In 1994, NASA's *Agenda for Change* placed new emphasis on technology transfer. Responding to this new agenda, Kennedy's Technology Commercialization Office began using a wider range of resources to disseminate information to the public. The outsourcing of support functions, the development of Internet tools, and mission-related partnerships are some of the steps taking Kennedy-developed technologies in new directions. With new emphasis on the International Space Station (ISS), the Spaceport Technology Center, and next-generation manned spaceships, new technologies continue to appear in support of these plans, including advanced computer software tools.

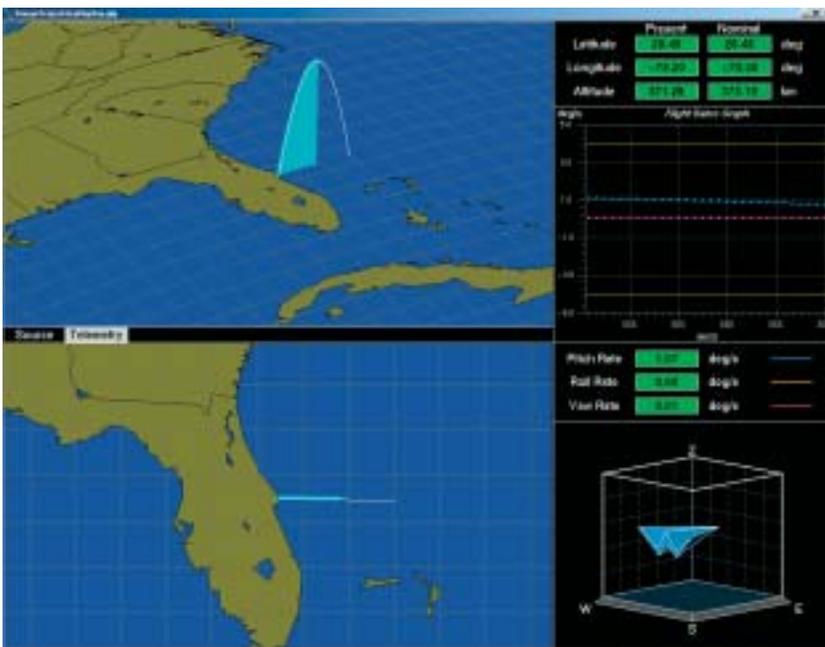


The X-1R® Reel Lube & Grease is an environmentally safe cleaner and lubricator, one of many lubricating products available from Sun Coast Chemicals of Daytona, Inc.

One tool, the Control Monitor Unit, provides a comprehensive array of capabilities for controlling and monitoring complex systems of equipment developed for the ISS. A Florida-based company, Command and Control Technologies (CCT) Corporation, licensed the technology and enhanced the software. The resulting product is now automating commercial, multivehicle spaceport launch control systems in four states. Three products are currently on the market: the Command and Control Toolkit™ (CCT's signature product), the T-Zero™ launch control software, and the Spaceport RangeNet™ software. The company, recognized as NASA-Kennedy's 1998 Small Business Subcontractor of the Year, was named one of the 100 fastest-growing Florida companies in 2000.

Also in 2000, the NASA Headquarters Inventions and Contributions Board bestowed

Spaceport RangeNet™ provides intuitive present position and instantaneous impact prediction displays to support flight operations.





The NOx Scrubber Liquor to Fertilizer system installed at Shuttle Pad 39A at Kennedy Space Center.

another Shuttle-based innovation the Commercial Invention of the Year Award, for a system that turns rocket fuel into fertilizer. The Nitrogen Oxide (NOx) Scrubber Liquor to Fertilizer system was installed at Shuttle Pad 39A. NASA's Dr. Clyde Parrish, Dr. Dale Lueck, and Andrew Kelly, and Dynacs Inc.'s Paul Gamble developed the new process in response to an Agency request to reduce the hazardous waste stream captured in a scrubber when a toxic oxidizer is transferred back and forth from storage tanks into the Shuttle's Orbital Maneuvering Subsystem and Reaction Control System. The innovation converts NOx into potassium nitrate, a primary fertilizer material. NASA licensed the technology to Phoenix Systems International Inc., of McDonald, Ohio, an engineering firm that develops utility and industrial fossil fuel technologies.

Launching ventures beyond our own planet has called forth the best efforts of America's scientists, engineers, and managers. Meeting this challenge has expanded knowledge and skills in virtually every field of science and technology. Kennedy's Technology Commercialization Office helps businesses avoid the costly process of

"reinventing the wheel" by making them aware that the technology they need may already be available.

The Center's research efforts are expanding to include the Space Experiment Research and Processing Laboratory, a research facility under construction at the new International Space Research Park. The laboratory will serve the ISS as the primary gateway for ground-based investigations in fundamental and applied biological science. The 400-acre park is cosponsored by NASA and the State of Florida to facilitate new opportunities emerging for expanded involvement by industry and academia.

For 40 years, Kennedy has successfully developed new technologies in support of the space program. Today, the Center stands ready to meet the challenges of the 21st century as a major partner in the construction and operation of spaceports on Earth, in orbit, and beyond. ❖

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

Command and Control Toolkit,™ T-Zero,™ and Spaceport RangeNet™ are trademarks of Command and Control Technologies Corporation.

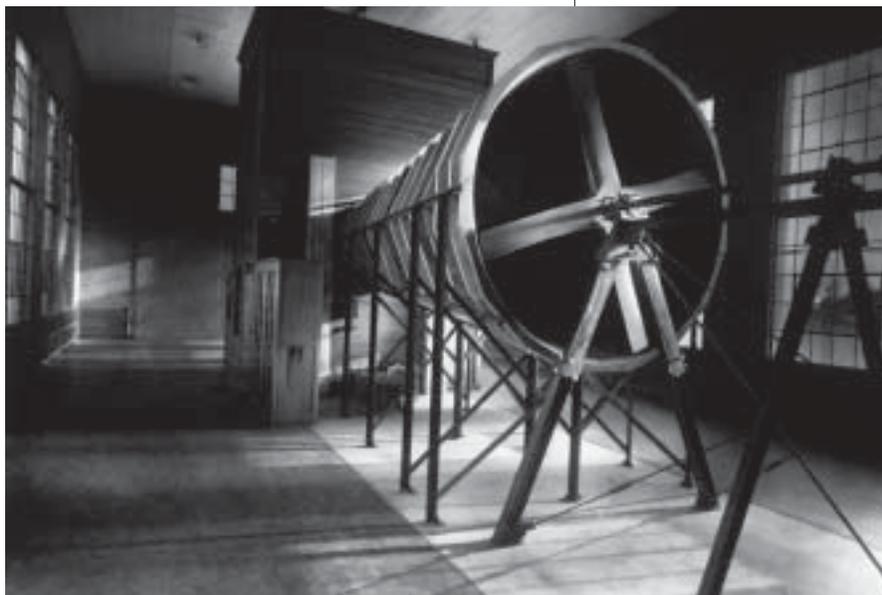
Langley Research Center

For over 40 years, Langley Research Center in Hampton, Virginia, has been leading the way to beneficial partnerships between industry, academia, and the Government. From the opening of the first National Advisory Committee on Aeronautics' wind tunnel at Langley Memorial Aeronautical Laboratory in 1922, the facility now known as Langley Research Center has been consistently involved in the dissemination of aerospace research-derived technologies to the Nation. While playing a pivotal role in the development of aircraft for defense and commercial uses through the 1930s, 40s, and 50s, the Center also was instrumental in the successful new assignments for the "Space Race" that the newly reorganized National Aeronautics and Space Administration (NASA) was tasked with in the 1960s and 1970s.

NASA's Industrial Applications Program, later renamed the Technology Utilization Program (TUP), was started in 1962 with the plan to foster greater utilization of beneficial, new innovations beyond their initial aerospace applications. The Langley Technology Utilization Office, formed in 1964, was the first organiza-

tion at the Center tasked with the transfer of aerospace technology to commercial industry. Increased emphasis on the importance of technology transfer and commercialization resulted in the formation of the Technology Application Group (TAG) in 1994. TAG was charged with proactively improving the effectiveness of the Langley Commercialization Program. This organization has been known as the Technology Commercialization Program Office since 1999, and has been instrumental in many successful transfers of technology to industry. Industries that have benefited from the transfers run the gamut from medical, transportation, construction, and manufacturing, to energy generation, and even recreation.

One of the TUP's most notable contributions was to the transportation safety industry. Most drivers are familiar with grooved highway surfaces, but few realize that these grooves were the result of Langley aeronautical research. This safety enhancement concept was developed through the hydroplaning program that began at Langley in 1962 with the goal of improving the control of aircraft touching down during wet weather. Surface grooves in concrete



The introduction of the National Advisory Committee on Aeronautics' wind tunnel in 1922 set the stage for the transfer of aerospace research-derived technologies to other industries.



From the runway to the roadway, grooved surfaces in concrete significantly improve wet weather traction for stopping and steering.

significantly improve wet weather traction for stopping and steering. It was easy for Langley engineers to see the need for the benefits of their research in public roadway systems. As a testament to the TUP's work, every state in the Nation today has miles of grooved pavement to enhance the safety of its roadways during wet weather. Also, research shows that the grooves increase the life of the pavement by 5 to 10 percent, decreasing the frequency of expensive repaving projects. Grooves on potentially slippery surfaces also benefit pedestrian areas, industrial factories, pools, and playgrounds. Grooved surfaces may affect people more than any other NASA spinoff application to date.

Another Langley technology that contributes to the safety of aircraft landing is the airborne wind shear detection system that was developed and refined at the Center. Wind shear occurs when invisible bodies of air are traveling in different directions to each other at different speeds. When an aircraft encounters this disturbance, the pilots can have severe difficulty in correcting the resulting changes in flight path, particularly when they are close to the ground for landing. This invisible aviation hazard is so dangerously unpredictable that about 26 aircraft crashed, resulting in over 500 fatalities between 1964 and 1985. After a Delta Airlines jetliner was brought down by wind shear near Dallas in August 1985, it was evident that something had to be done to provide pilots with greater advance warning of

wind shear situations. The Federal Aviation Administration and Langley combined forces to develop better wind shear detection capabilities for airlines and the military. The first challenge was to learn how to model and predict the phenomenon. Langley developed the F-factor metric that is now the standard for determining

(Continued)



Langley's 737 flying laboratory flew over 130 missions into extreme weather situations, learning how to hunt invisible wind shear elements 2 to 3 miles ahead of the aircraft.

Langley Research Center (Continued)

if the airflow ahead of an aircraft is dangerous wind shear. The next step was to determine what sort of detector was the most effective in detecting the wind shear 10 seconds to 1 minute ahead of a flying aircraft. Langley's 737 flying laboratory flew over 130 missions into extreme weather situations, learning how to hunt the invisible hazards 2 to 3 miles ahead of the aircraft. The resulting technological advances have enabled aircraft to read the speed and direction of invisible particles of water vapor or dust in the wind and provide pilots the necessary advance warning of wind shear conditions. Doppler radar-based systems were also developed based on the Langley research. This type of system has been commercially certified by several companies and was first flown on commercial aircraft by Continental Airlines less than 2 years after the Langley

Wind Shear Program declared "mission accomplished!" and concluded testing.

As a result of this pioneering work, aircraft manufacturers throughout the world today are mandated to supply new airliners with wind shear detection systems as standard safety equipment.

Not to be outdone, Langley materials researchers have been developing revolutionary materials over the past 40 years as well. Some materials, such as the colorless polyimide, have been qualified for use in space flight. Others, such as the rp-46 high-temperature (600 °F) polymer, are used in lightweight bearings for the Boeing 777. With new materials constantly entering commercial use, it is difficult to cull a single one for consideration. If sales figures are used as a measure of significance, a Langley-developed, flexible, high-temperature adhesive



Langley's Boeing 737 research aircraft is fitted with a Doppler radar wind shear detection system that sends a beam well ahead of the airplane to detect microbursts, evidenced by sudden large changes in raindrop velocities.

stands out from the pack. The polyimide adhesive is used on flexible circuit boards produced by one of the Nation's largest circuit board manufacturers, the Rogers Corporation. The flexible circuits are used in many applications, but primarily in high-speed computer disk drives. This advance in adhesive technology has resulted in cumulative sales of over \$135 million in less than 10 years and is expected to produce a total of over \$300 million prior to patent expiration.

As advances are made in the new fields of materials, such as shape memory materials, morphing technology, and nanotechnology, Langley plans to partner with companies much earlier than it had done so in the past. This

will ease the transition from government development to industry manufacture and speed up the prototype to manufacture cycle. It is expected that NASA will also benefit from the resulting acceleration in technology development and the reduced costs of technologies as they progress from exclusively high-tech applications to broad commercial uses. ❖



Langley's high-temperature, polyimide adhesive is used to bond film to copper foil conductor materials in flexible circuits produced by one of the Nation's largest circuit board manufacturers.

Marshall Space Flight Center

Since its inception, the Marshall Space Flight Center, in Huntsville, Alabama, has promoted an active program to transfer technology designed for the space program into products to improve life on Earth.

Early on, Marshall set the pace in the emerging field of technology transfer with specialized welding technology developed for giant rockets. Welding was the first NASA technology offered to private industry, marking the start of NASA's technology transfer efforts. Some of the welding techniques were developed at Marshall because existing methods were not adequate in meeting stringent specifications necessary in the building of large booster rockets.

In 1963, NASA produced a publication titled *Welding Tips*, dealing with the industrial applications of space research. *Welding Tips* became the first of a series of publications that NASA would issue periodically. The 26-page magazine was an instant hit with industry. By July 1964, NASA received 6,900 requests for the publication.

Throughout the 1960s and 1970s, the Marshall Technology Utilization team worked diligently to ensure proven technology was

offered to business and industry. The term "spinoff" became a common reference to the technologies and discoveries derived from NASA's Technology Utilization Program. For example, the "power factor controller" was invented by a Marshall engineer under NASA's Solar Heating and Cooling Program in the late 1970s and patented in the early 1980s. The device senses fluctuations in the amount of power needed by an alternating current electric motor and then varies the power supply to meet the need. Laboratory tests show 6- to 8-percent savings under normal demand conditions, and as much as 65 percent when a motor is idling.

These tests resulted in a flood of interest. More than 20 companies were granted non-exclusive licenses for commercial use of the power factor controller technology. In 1998, an exclusive agreement was reached with a licensee for the specific purpose of controlling motors not in existence when the device was first patented.

In the 1980s, the technology utilization mission at Marshall continued to evolve, focusing on consulting, while providing a think-tank atmosphere for solving difficult problems.



Two companies have successfully commercialized a specialized welding tool developed at Marshall for the friction stir welding process, marking another success for the Center's technology transfer program.

The Center developed working relationships with academia and industry in eight southeastern states.

At the same time, Marshall again led the way in transferring welding technology—this time with a special-purpose arc welding torch, designed to provide better quality welds with less room for human error. The torch was developed by Marshall engineers and B&B Precision Machine, Inc., for the difficult variable polarity plasma arc welding of the Space Shuttle External Tank. The company still sells this spinoff product today to aerospace and research organizations needing to weld complex aluminum alloys and titanium.

In 1994, Marshall's Technology Utilization Program changed its name to the Technology Transfer Department and continued its work to identify and transfer space innovations. In 1997, Marshall expanded its role to include management of NASA's **Small Business Innovation Research (SBIR)** program, working on commercialization and technology development collaborations based on Space Act Agreements, technology investment programs, and community investment programs. The Center's mission evolved from a consulting role to a formal commercialization and licensing role. Working closely with the Center's Patent Counsel and the Research Triangle Institute of Research Triangle Park, in Raleigh, North Carolina, Marshall's Technology Transfer Department now performs technical, business, and legal assessments to determine commercial potential, trends, and marketability of candidate technologies. The ultimate goal is to advance the technology readiness level of Marshall innovations into near-future and obtainable commercialization.

Today's approach results in a wide variety of benefits, from law enforcement to cancer treatment. One example, the Video Image Stabilization and Registration (VISAR) system, is a computer software invention that uses technology developed for enhancing images of the Sun to improve poor quality video. The Federal Bureau of Investigation was the first non-NASA beneficiary, using VISAR to analyze home video

footage of the deadly 1996 Olympic Summer Games bombing in Atlanta, Georgia. VISAR was inducted into the U.S. Space Foundation's Space Technology Hall of Fame in 2001, and won the Excellence in Technology Transfer award in 2002 from the Federal Laboratories Consortium. Intergraph Government Solutions and BARCO Inc. Display Systems have integrated VISAR into video enhancement system products for law enforcement, the military, and even home computers.

In another area, the need for a flexible tool to analyze rocket engine fluid flow prompted Marshall engineers to invent the Generalized Fluid System Simulation Program. Its flexibility,

(Continued)



Video made with a handheld camcorder from police cars chasing criminals can result in shaky footage, making license plates unreadable (bottom). When NASA scientists at Marshall Space Flight Center enhanced the video with the VISAR software, they produced a clear, sharp image, (top) allowing the license plate to be read.

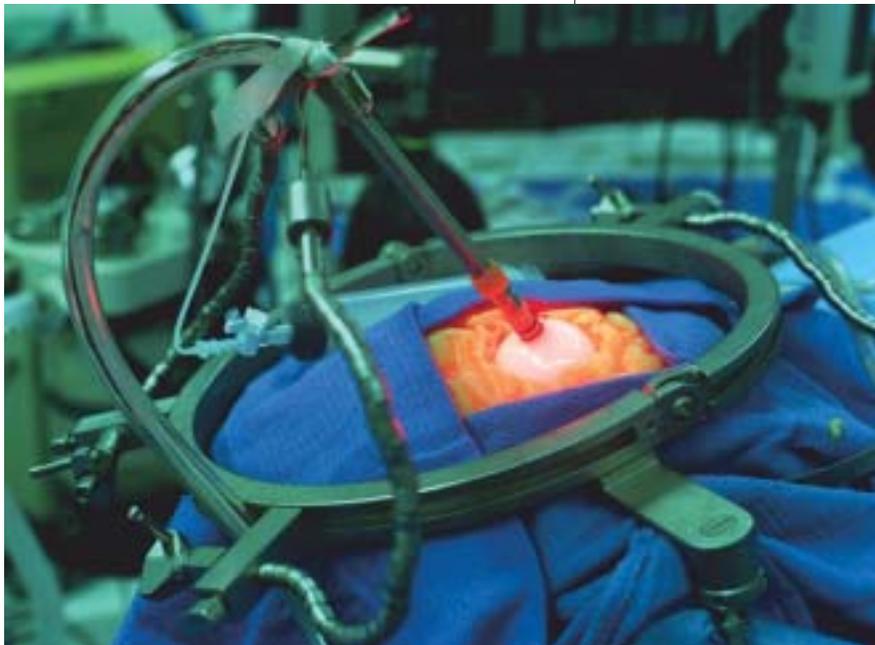
Marshall Space Flight Center (Continued)

ease of use, and applicability to a wide variety of commercial industries earned it NASA's Co-Software of the Year for 2001. Concepts ETI, Inc., holds an exclusive license agreement for the software.

Product identification technology, pioneered at Marshall to track Space Shuttle parts, is used by the private sector to mark items ranging from groceries to automobile parts. Capable of storing 100 times more information than a barcode, the two-dimensional Data Matrix symbol resembles a small checkerboard. Acuity CiMatrix and its parent company, Robotic Vision Systems, Inc., formed an alliance with Marshall to develop commercial applications. Data Matrix symbology was inducted into the Space Technology Hall of Fame in 2001,

and has been endorsed for NASA-wide application by the NASA Technical Standards Program Office.

Examples of Marshall's contributions to the medical field are abundant. Light emitting diode (LED) technology, originally developed for growing plants in space, has successfully treated cancer patients who have exhausted traditional therapies. Doctors at the Medical College of Wisconsin, Milwaukee, are applying this technology in photodynamic therapy, using pinhead-sized LEDs to illuminate or activate light-sensitive, tumor-treating drugs called photosensitizers. The process allows the drugs to find and destroy cancerous cells, leaving surrounding tissue undamaged. In another application of the same technology, Quantum Devices Inc., is



A simulation of the light emitting diode probe being surgically implanted into a patient at the Children's Hospital of Wisconsin, Medical College of Wisconsin, Milwaukee.

collaborating with physicians to use LEDs in treating hard-to-heal wounds such as diabetic skin ulcers, serious burns, and severe oral sores caused by chemotherapy and radiation.

Another Marshall-developed medical advance, ocular screening technology from space telescopes, is helping detect eyesight problems in school children. Vision Research Corporation integrated the technology into an ocular screening system used to test over 1.5 million children. The company placed these systems in pediatric offices and health clinics in more than half of the United States with mass screening operations in 10 states.

Activity in welding technology—the area where Marshall technology transfer first flourished nearly 40 years ago—continues today. The Retractable Pin Tool for Friction Stir Welding, developed at Marshall, virtually eliminates the pesky “keyhole” associated with this type of welding. The technique involves slowly plunging a rapidly rotating pin into the joint between two materials to be welded and moving it along the joint. At the end of the weld, the single-piece pin tool is retracted, which in the process would leave a “keyhole.”

MTS Systems Corporation integrated the pin tool into its advanced friction stir welding process for welding high-strength alloys for automotive, shipbuilding, and other industries. It uses a computer-controlled motor to automatically retract the pin into the shoulder of the tool at the end of the weld. MCE Technologies, Inc., also successfully commercialized the Stirwelder product incorporating the pin tool. It provides virtually flawless welds in nearly all applications using high-performance aluminum alloys, including those previously considered “unweldable.”

These are just a few of the hundreds of technologies that have come from Marshall in the past 40 years. Through its ongoing work in the Space Shuttle and International Space Station programs, as well as the cutting-edge Space Launch Initiative, Marshall will continue to play an important role in transferring NASA technology to improve the life of every citizen here on Earth. ❖



The probe, which is approximately 9 inches long and about one-half inch in diameter, was developed for photodynamic cancer therapy under a NASA Small Business Innovation Research program grant.

Stennis Space Center

Native Mississippian and Nobel laureate William Faulkner once described the Mississippi Gulf Coast as an area in which “The pines and moss-hung live oaks give way to grassy marshes so flat, low, and treeless that they seem less of Earth than water. More of a beginning to the sea than an end to the land.” Faulkner’s prose may not represent the heartiest of endorsements for the area selected as the future home of the John C. Stennis Space Center, but nonetheless, beginning in 1963, roads were built, buildings were constructed, and massive test facilities were erected, at an initial cost of \$200 million.

Today, Stennis has evolved into a multidisciplinary, multiagency Federal facility whose primary mission includes rocket engine testing and Earth science application activities integral to the Center’s Technology Transfer program. Traditionally, the Office of Technology Transfer provided support in the areas of intellectual property management, licensing activities, contracting or partnering efforts, and development of success stories. But just as

Stennis evolved from its humble beginnings, the Office of Technology Transfer’s focus was changed to meet the future needs and requirements of NASA.

Stennis implemented a technology development and integration initiative to support the specific new technology needs of its Propulsion Test and Earth Science Applications directorates. A Technology Development Pipeline was established to utilize Inreach program activities, Dual-Use partnerships, and the **Small Business Innovation Research (SBIR)** program to accomplish the task. Inreach establishes new lines of communication and strengthens existing ones to identify future NASA technological needs. Dual-Use and SBIR contracting activities yield products that meet the technological requirements identified by each directorate. Results include commercially available products meeting NASA mission needs, and an increase in partnerships, licenses, and success stories, demonstrating the Office of Technology Transfer’s relevance to Stennis’ directorates.

Work crews saw down one of the first trees on May 17, 1963, signaling the beginning of construction of the Mississippi Test Facility in Hancock County, Mississippi. The tree was cut in Devil’s Swamp near the site where the construction dock was built on the turn basin of Stennis’ man-made canal system.





A Space Shuttle Main Engine test lights up the night sky at Stennis. The Center implemented a technology development and integration initiative to support the specific new technology needs of such propulsion testing.

Inreach activities also provide the necessary communication process to identify future NASA technological needs or to fill the pipeline. Referred to as a “contact sport” by Kirk Sharp, Stennis’ Office of Technology Transfer manager, Inreach activities present an opportunity for interaction between the Technology Transfer Office, directorate personnel, and other researchers to identify future technology needs and requirements. This investment in time and energy provides the critical starting point from which new products are developed to support the Propulsion Test and Earth Science Applications directorates. Without these initial interactions, or filling of the pipeline, the Office of Technology Transfer’s new direction efforts would slowly sink into the proverbial swamps that surround the Center.

Actively pursued by Stennis for over a decade, the SBIR and **Small Business Technology Transfer (STTR)** programs were redirected toward more specific and higher priority Propulsion Test and Earth Science Applications technologies. These highly competitive

multiphase programs provide small U.S. businesses with Federal funds reserved for conducting innovative research and development. Through this new strategy of focus and relevance, the programs are now providing innovations matching specific NASA technology needs.

For example, a color hydrogen flame imaging system manufactured by Duncan Technologies, Inc., in response to NASA’s need for a hydrogen flame detection system, is being implemented in the E complex test facilities. Stennis uses the prototype system, developed to monitor hydrogen flame stacks invisible to the naked eye, during turbopump and other rocket component testing at its E-2 facility. Stennis also purchased six systems to conduct testing of hybrid rocket motors, turbomachinery, and small rocket engines at its E-1 facility. Bud Nail, NASA’s technical systems lead engineer at the time, stated that his job would be made safer by using the system. “There’s simply nothing else on the market that performs the way this system does,” Nail said. “It takes the guess work out of identifying a hydrogen fire.”

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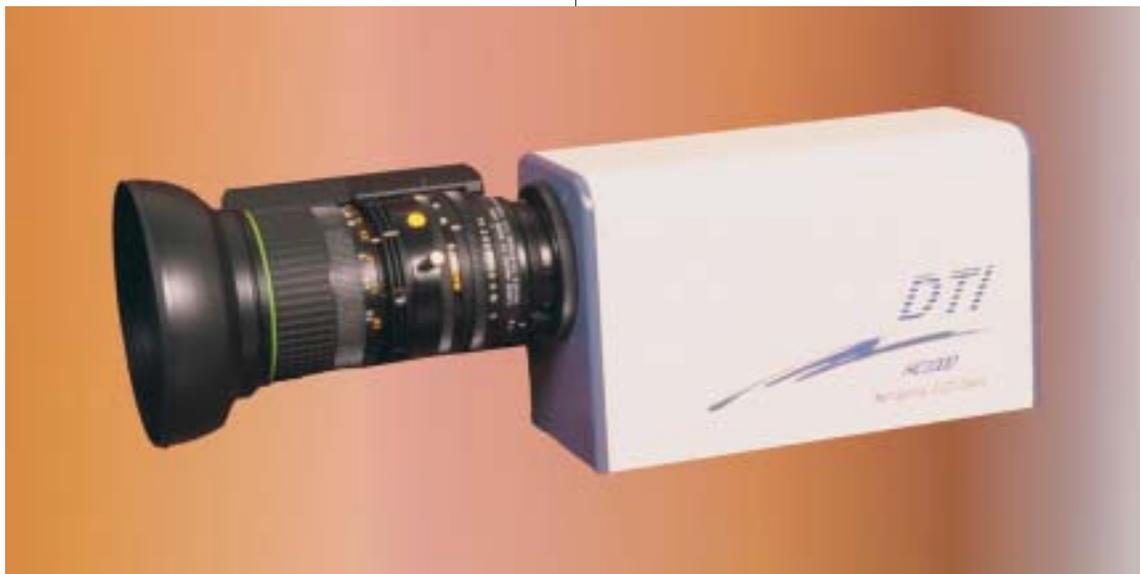
Stennis Space Center

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Though Stennis' Dual-Use program is relatively new with a history of only 2 years, new technology products are already available to directorate users. Product development partnerships are based on the sharing of costs, risks, and successes between the Government and its partner. In these projects, NASA contributes technology development, unique facilities and expertise, engineering resources, and in some cases, partial funding. In return, the commercial partner contributes its unique resources, facilities, manufacturing, and marketing capabilities. The result is a flexible approach that draws upon the capabilities of both parties. NASA maximizes benefit, reduces risks and costs, and receives a product with a specific NASA application, while the partner earns an opportunity to establish credibility, diversify its existing product line, and increase overall market visibility.

Recently, Earth science applications users benefited from a partnership with World Precision Instruments (WPI), Inc., that produced an innovative instrument to accurately measure color dissolved organic matter absorption while testing offshore. Stennis' Dr. Richard Miller of the Earth Science Applications Directorate partnered with WPI scientists Dr. Mathias Belz and Dr. Suyi Liu to develop an instrument that would meet the needs of both NASA and the general scientific community. This successful collaboration culminated in an exciting new device, UltraPath,™ now commercially available from the company.

The Propulsion Test Directorate also directly benefited through a critical redesign of a valve actuator. In partnership with BAFCO, Inc., an existing commercial product's size and weight were reworked, reducing cost and delivery time. The benefit to NASA on the 31 units already



During rocket component testing, Stennis uses a prototype of a color hydrogen flame imaging system developed by Duncan Technologies, Inc., to monitor flame stacks invisible to the naked eye.



Stennis realized a cost savings of over \$260 thousand from its partnership with BAFCO, Inc., which assisted the Center in the reengineering of a valve actuator.

purchased was a cost saving of over \$260 thousand. The redesigned product is commercially available, and the company is experiencing successful profit margins.

The Technology Development Pipeline provides Stennis' Office of Technology Transfer with the unique opportunity of fulfilling NASA's mandate by lending "mission critical" support through product and technology development. Maximum benefit at reduced cost and risk is being achieved through partnerships with the private sector in support of NASA mission needs. Working together, the Propulsion Test Directorate, the Earth Science Applications Directorate, and the Office of Technology Transfer are answering questions and solving problems critical to NASA's future. As the Agency moves forward to fulfill its mission, the challenges continue to grow, and Stennis is moving to meet those challenges. ❖

UltraPath™ is a trademark of World Precision Instruments, Inc.

Commercial Benefits—Spinoffs

Drawing upon research and development investments and other leading sources of technological innovation, NASA seeks to foster partnerships and cooperative activities with U.S. commercial enterprises to develop technology that is applicable to both NASA mission needs and commercial ventures in global markets. Also, as part of the Agency's mission, NASA facilitates the transfer and commercialization of NASA-sponsored research and technology, including the industrial use of unique capabilities and facilities.

Though NASA research and technology has been disseminated to the public in many different ways over the past 40 years, one transfer program has garnered significant recognition for its ability to provide small and socially disadvantaged U.S. businesses with the necessary resources to reach new heights. The **Small Business Innovation Research (SBIR)** program, established by the U.S. Congress in 1982, promotes commercialization of innovations derived from federally funded research. Each year, small businesses are encouraged to submit proposals in response to technical topics listed in the annual SBIR program solicitation.

Strong SBIR partnerships and other extensive outreach activities have translated into immeasurable benefits for humankind—from lifesaving medical devices to industrial machinery that complete jobs in minutes, rather than days. The following section highlights a vast assortment of commercial technologies shaped by the minds and hands of NASA scientists, engineers, experts, and their respective technology transfer collaborators. These products, known as spinoffs, strengthen the Nation's prosperity and quality of life.

Moving Ahead With Eye Power

Eye trackers have literally opened up the world to many disabled people who suffer with limited movement and speech. The sophisticated devices track eye movements—distinguishing the viewer’s precise gaze point at a computer screen—enabling communication and environmental control through an array of interface tools. For example, a man whose motor control is limited to his eyes can write a regular newspaper column, and a quadriplegic girl can attend school and participate in class with the help of an eye tracker.

While these systems have been available for more than a decade, their considerable size and weight have inhibited wider use. Recognizing the potential public benefit, Congress funded NASA in 1998 to help advance eye tracker technology to reduce size and increase portability, while preserving or improving its function. As a result, NASA’s Jet Propulsion Laboratory (JPL) collaborated with the eye tracker manufacturer LC Technologies (LCT), Inc., of Fairfax, Virginia, to complete phase one of the Eye Tracker Technology Development Task. This led to the development of LCT’s improved Eyegaze Communication System.

The collaboration aimed to advance eye tracker technology while fostering its commercialization for increased availability to the disabled. JPL’s team selected LCT’s existing Eyegaze System as a baseline for the work since it was both measurable and marketable. By completion of phase one, the team reduced the weight of

the original system by 6 times and its volume by nearly the same factor. The miniaturization not only increases portability, but improves energy efficiency by reducing the power requirements of the system by a factor of 4.

In the course of miniaturization, the Eyegaze System’s functionality also improved. For example, the JPL/LCT Pulser Board, a new illuminator drive, lights up the user’s eye in a series of tiny time intervals, enabling the system’s video camera to capture eye movements with very little blurring of the eye image. A new combination of the illuminator and light filter makes the camera more tolerant to ambient light, allowing the system’s use in a greater variety of lighting conditions.

The customized motion control unit, housing the enhanced illuminator and camera, provides real-time head tracking and more accurate eye tracking.

As a result of this joint effort, LCT commercialized the improved Eyegaze Communication System, providing customers with a more accurate, affordable, and portable product. To operate the Eyegaze System, the user sits approximately 24 inches from the computer monitor, while the camera, mounted below the monitor, focuses on one eye. A 15-second calibration procedure is all that is needed to get started. By looking at control keys on the monitor for a fraction of a second, the user can perform a broad variety of functions including speech synthesis, environmental



The Eyegaze System enables this boy to communicate using only the movement of his eyes. A video camera focuses on the pupil of the user’s eye, tracking its movement. To “press” a key on the screen, the user looks at the key for a specified time, prompting the computer to take the appropriate action.



LCT's collaboration with NASA's Jet Propulsion Laboratory reduced the size and weight of the Portable Eyegaze System, which can be conveniently mounted on a wheelchair.

control (controlling lights and appliances), typing, operating a telephone, accessing the Internet and e-mail, and running all Microsoft® Windows® software. The camera continually observes the eye movements, while specialized image-processing software determines where the user is looking on the screen. The system predicts the gaze point with an average accuracy of better than one-fourth inch, enabling the user to control entire on-screen computer keyboards. Nothing is attached to the user's head or body, and the improved size and portability allow the system to be mounted on a wheelchair.

Eyegaze Systems are enhancing the quality of life of people with disabilities all over the world. The system enables children with severe cerebral palsy, muscular dystrophy, and other motor disabilities to actively participate in their education by giving them a voice for the first time. Students who cannot talk or use a pencil are using their system to “speak” during class, as well as to research and write papers. With only their eye movements, these students can also chat with friends over e-mail and “talk” on the phone.

The Eyegaze System also enables adults with multiple sclerosis, strokes, brain injuries, spinal cord injuries, and ALS (amyotrophic lateral sclerosis, also known as Lou Gehrig's disease), to be productively employed. With the system, employees who are paralyzed and unable to speak are still able to do word processing, send and receive e-mails, and make telephone calls. Also, several books have been written and published by authors using only eye movement controls.

While phase one of the Eye Tracker Technology Development Task was successful, LCT continues to work with JPL on phase two, which concentrates on several other areas of improvement that have commercial add-on potential. With increased improvements in eye tracker technology, more people can get ahead using eye power. ❖

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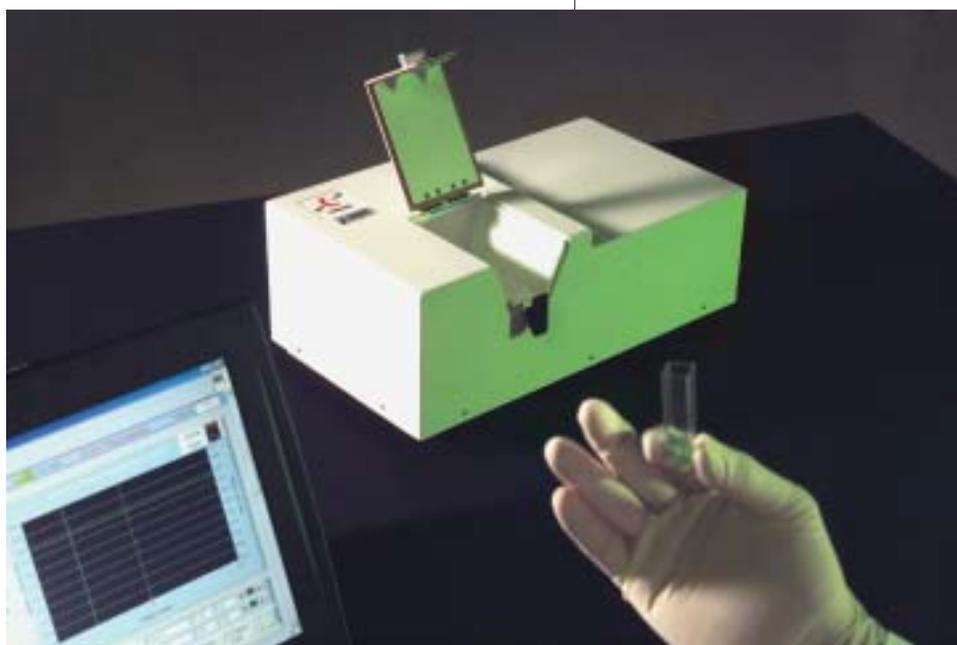
Illuminating Cell Biology

An instrument developed to help scientists study cell biology onboard the International Space Station (ISS) is also benefiting researchers here on Earth. The Cell Fluorescence Analysis System (CFAS), developed by Ciencia, Inc., of East Hartford, Connecticut, is a versatile, compact fluorometer designed to perform cellular functional assays and in vitro biochemical assays. The innovation will play an important role in studying biological specimens' long-term adaptation to microgravity.

With results from previous experimental studies showing that space flight has a significant impact on living cellular systems, NASA is preparing the Life Science Research Facility on the ISS to open a new era in gravitational biology. Researchers at the space-based laboratory will study cell development, signal transduc-

tion, cytoskeleton organization, gene expression, and many other cellular processes. To accomplish these goals, NASA recognized that fluorescence spectroscopy, one of the most powerful methods available for cell biology research, was a necessary technique within the facility, as well.

A major roadblock to incorporating this tool was the instrument's massive size prohibiting its deployment in the Space Station. With room requirements of 20-to-60 cubic feet and a weight of several hundred pounds, the typical fluorometer exceeded the available space to conduct experiments. Another problem was that the instrument's high power consumption might make it inoperable within the available power resources, and could cause power spikes leading to possible interferences in equipment operation.



The Cell Fluorescence Analysis System assists scientists conducting cell biology research on Earth and on the International Space Station.

To solve these problems, NASA's Ames Research Center awarded Ciencia a **Small Business Innovation Research (SBIR)** contract to develop a system that would address the size, mass, and power constraints of using fluorescence spectroscopy in the Life Science Research Facility. Ciencia, successful in creating the CFAS product to meet NASA's needs, recently delivered the product to Ames and is progressing with commercial sales. At Ames, researchers in the bone and signaling laboratories plan to use the CFAS to investigate the role of integrin and extracellular matrix protein interactions in the mechanotransduction of forces induced by hypergravity and hydrostatic pressure. "We are looking forward to using the CFAS to develop fluorescence resonance energy transfer and lifetime analysis assays for integrin clustering, an important step in cell adhesion and gravity mechanotransduction," stated Dr. Eduardo Almeida, research scientist in the Ames Gravitational Research Branch. "The CFAS represents an investment into future ISS analytical capabilities that should enable cutting-edge spaceflight cell biology consistent with NASA's vision to extend life into space," explained Donald Vandendriesche, ISS cell culture unit lead and contracting officer's technical representative for CFAS development.

Commercial applications for Ciencia's technology include diverse markets such as food safety, in situ environmental monitoring, online process analysis, genomics and DNA chips, and noninvasive diagnostics. Ciencia has a U.S. patent for its fluorescence lifetime sensing technology and has licensed the technology to HTS Biosystems, of Hopkinton, Massachusetts, for applications in high-throughput screening for drug discovery. Ciencia and HTS Biosystems are jointly developing commercial products based on the technology, including a fluorescence lifetime microwell plate reader.

Ciencia has already sold the system to the private sector for biosensor applications. Dr. Jerome Schultz, the director of the Center for Biotechnology and Bioengineering at the University of Pittsburgh, purchased Ciencia's fluorometer technology in the form of a minimally invasive fiber-optic glucose sensor. The center, which has approximately 100 researchers covering the fields of biosensors, molecular biology, gene therapy, and artificial organs, is using the system for clinical applications. ❖

Keeping Hearts Pumping

An estimated one million people worldwide have heart conditions that would benefit from a heart transplant. However, the number of donor hearts available is extremely limited, with less than 3,000 total transplants performed each year in the United States. Fortunately, for people with such heart problems, a unique collaboration between NASA, Dr. Michael DeBakey, Dr. George Noon, and MicroMed Technology, Inc., has resulted in a lifesaving heart pump for patients awaiting transplants. The MicroMed DeBakey VAD® is a ventricular assist device that functions as a “bridge to heart transplant” by pumping blood throughout the body to keep critically ill patients alive until a donor heart is available.

The concept for the tiny pump grew from conversations between Dave Saucier, an engineer at Johnson Space Center, and Drs. DeBakey and Noon, famed heart surgeons at Baylor College of Medicine. They discussed creating a heart pump that would benefit patients with

congestive heart failure. Saucier and a team of Johnson engineers joined with DeBakey, Noon, and colleagues at the DeBakey Heart Center at Baylor College to develop the initial design. The Johnson team built several versions of the device, based on the criteria and feedback supplied by DeBakey’s medical team.

During the initial development of the implantable axial rotary heart pump, engineers found two major concerns. Friction led to damaged blood cells, because the device created high shear flows through pump parts. Also, there were stagnant regions in the pump that caused blood clotting, a major problem with ventricular assist devices.

To solve these problems, help came from researchers Cetin Kiris and Dochan Kwak in the NASA Advanced Supercomputing (NAS) Division at Ames Research Center. Kwak, chief of the NAS Applications Branch, explained that they were asked to help because of their “experience with simulating fluid flow through rocket engines.” According to Kiris, “The speed of fluid flow through a rocket engine is faster than blood flow, but very similar in many ways.”

Using NASA supercomputers and computational fluid dynamics technology, which models the fuel and oxidizer flow through rocket engines such as the Space Shuttle main engine, the Ames researchers analyzed blood flow through the battery-powered heart pump. Based on the results, they suggested design improvements that reduced red blood cell damage to an amount well below acceptable limits. The improved blood flow pattern also reduced the tendency for blood clots to form by eliminating the stagnant regions. According to Kwak, “There are three groups who made this initial engineering effort successful—the medical team led by Dr. Michael DeBakey and Dr. George Noon, the systems engineers at Johnson Space Center, and the Ames computational team that



The MicroMed DeBakey VAD® functions as a “bridge to heart transplant” by pumping blood throughout the body to keep critically ill patients alive until a donor heart is available.

used NASA supercomputer know-how to help develop the VAD.”

The road to commercial success for the VAD began in 1996, when NASA patented the heart pump and licensed it exclusively to MicroMed Technology, Inc., of Houston, Texas. MicroMed, organized by President and Chief Executive Officer Dallas Anderson to further develop the pump for critically ill heart patients, faced the challenge of converting the engineering device into a medical appliance that could be implanted. Within 2 years, MicroMed obtained international quality and electronic standards certifications, developed the ancillary components of the system, and received regulatory permission to begin clinical trials in Europe. In November 1998, a 56-year-old male was the first patient implanted with the MicroMed DeBakey VAD. According to Anderson, the pump functioned normally and to design specifications.

After 135 implants in Europe, MicroMed’s product is commercially available at 12 European heart centers. In the United States, 25 patients successfully received the VAD as part of the 178 implants planned for clinical trials approved by the U.S. Food and Drug Administration (FDA).

The device presents several advantages for recipients. Weighing less than 4 ounces and measuring 1 inch by 3 inches, the MicroMed DeBakey VAD is approximately one-tenth the size of other currently marketed pulsatile VADs. This makes it less invasive and ideal for smaller adults and children. Because of the pump’s small size, less than 5 percent of the patients implanted developed device-related infections, compared to an approximate 25-percent infection rate for larger VADs. Additionally, MicroMed’s

These illustrations show a visual comparison of the original ventricular assist device, top, and the unit after modifications by NASA researchers, center and bottom. Adding an inducer to the MicroMed DeBakey VAD® eliminates the dangerous back flow of blood by increasing pressure and making flow more continuous. The device is subjected to the highest pressure around the blade tips, shown in magenta.

VAD can operate up to 8 hours on batteries, giving patients the mobility to do normal, everyday activities.

Currently, over 160 patients have received the MicroMed DeBakey VAD—with no incidence of pump failure. Having successfully implanted the device lasting for periods over 1 year in individual patients, MicroMed is planning to launch its DELTA ONE™ study to provide evidence of its VAD as a heart transplant alternative—which is also referred to as “destination therapy.” MicroMed is the first company to use a next-generation, miniaturized device to conduct a clinical trial to address the use of a VAD for long-term destination therapy. Upon FDA approval for its investigational device exemption application, MicroMed will begin its clinical study, which is projected to include 65 patients at up to 20 U.S. sites. With new advances broadening the scope of the life-saving VAD, which won the 2001 NASA Commercial Invention of the Year award, thousands of individuals with heart problems stand to reap enormous benefits. ❖

The MicroMed DeBakey VAD® is a registered trademark of MicroMed Technology, Inc.

DELTA ONE™ is a trademark of MicroMed Technology, Inc.

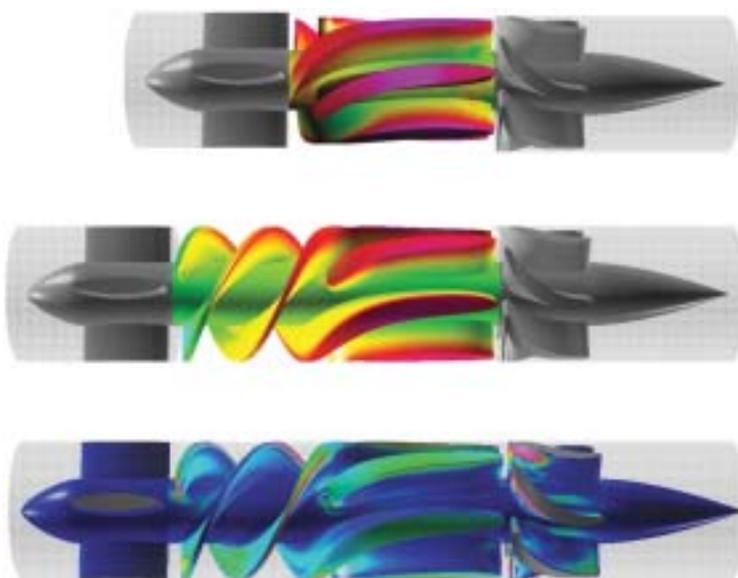


Image courtesy NASA/Cetin Kiris

A New Cure for Medical Errors

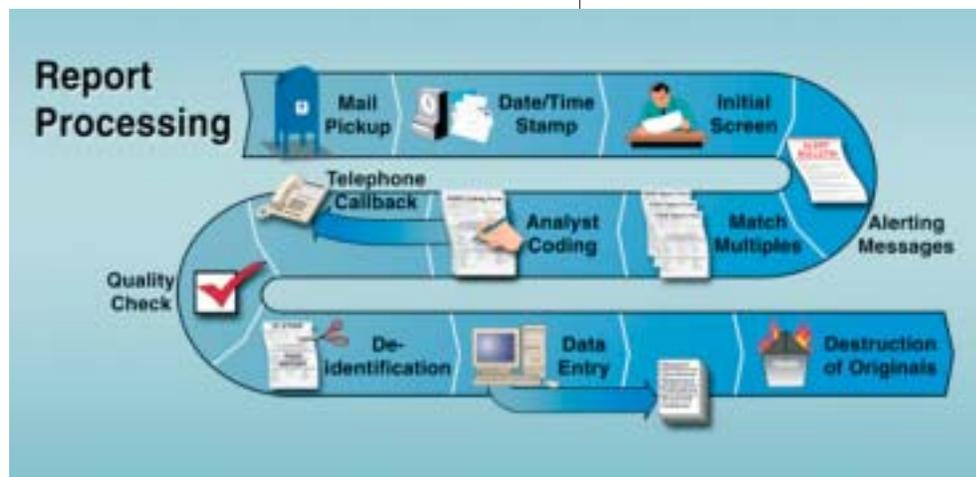
In 1999, the Institute of Medicine released a report indicating that as many as 98,000 people die per year due to medical errors in hospitals. This well-known report, titled “To Err is Human: Building a Safer Health System,” shook the American health care industry, and fueled momentum for improved patient safety measures across the country.

Even before the release of this report, the U.S. Department of Veterans Affairs (VA) was making strides to set new standards for patient safety and further enhance the quality of health care in the United States. The VA, which operates 163 medical facilities across the country, formed an expert advisory panel in 1997 to address patient safety. One year later, the Department established the National Center for Patient Safety in order to develop and maintain safe practices throughout the organization.

With these prevention measures in place, the VA was looking for a partner that could obtain completely confidential information and act as a “safety valve.” Therefore, it decided to call on its Federal sister agency, NASA, to assist in the development of such a punitive-free reporting system. As an “honest broker,” NASA would help the VA provide protections for health care professionals who voluntarily report adverse events or “close-calls.”

In May 2000, senior officials of the VA and NASA signed an agreement that would commit the two agencies to create the Patient Safety Reporting System (PSRS) to report: events or situations that could have resulted in accident, injury, or illness, but did not, either by chance or through timely intervention (close-calls); unexpected serious occurrences that involved a patient or employee’s death, physical injury, or psychological injury; lessons learned; and safety ideas. The VA provided NASA with funding for the initial development of the new system, which automatically removes all personal names, facility names and locations, and other potentially identifying information before entering reports into its database.

Designed to complement the VA’s current internal reporting systems, the PSRS is modeled after NASA’s Aviation Safety Reporting System (ASRS), which was established in 1975 under a Memorandum of Agreement between the Federal Aviation Administration (FAA) and NASA, and began operation in 1976. The ASRS, operated by NASA’s Ames Research Center, collects, analyzes, and responds to voluntarily submitted aviation safety incident reports in order to decrease the likelihood of aviation accidents. Pilots, air traffic controllers, flight attendants, mechanics, ground personnel,



A report processing illustration portrays the various steps taken when an adverse event or a “close call” is voluntarily and confidentially submitted for review. The new Patient Safety Reporting System automatically removes all personal names, facility names and locations, and other potentially identifying information before entering reports into its database.

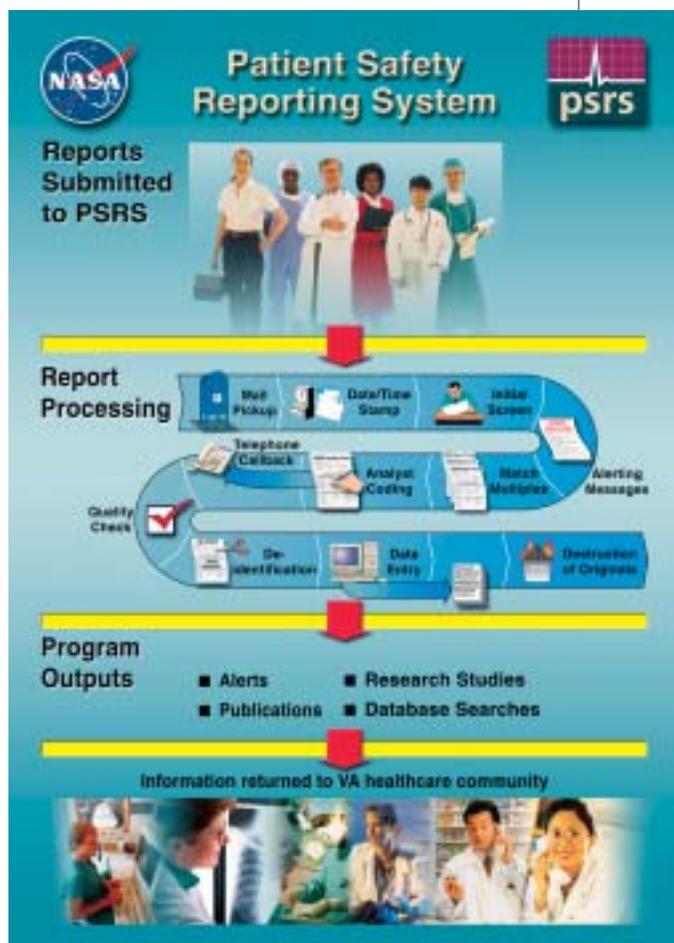
and others in aviation operations can submit reports to the ASRS when they are involved in, or observe, an incident or situation that compromises aviation safety. This system has been lauded for its strict confidentiality procedures, managed reports, easy retrieval of database information, creation of safety products, and distribution of safety information.

According to Linda Connell, NASA's ASRS/PSRS director, "the experience gained in operating the ASRS for 26 years will be invaluable in establishing the collection of voluntary, confidential data reported by health care providers on the front line of patient care in VA facilities." Connell also adds that the relationship between NASA and the VA represents a "good blend" of expertise for the purpose of learning about humans and safety. NASA will help to incorporate the highly successful aviation safety model and information technology developments within the VA medical

environment and the VA will identify vulnerabilities from the information provided by NASA.

After the joint agreement was signed, employees from Ames' Human Factors Research and Technology Division conducted intensive training sessions for VA patient safety coordinators who would be operating and maintaining the systems across the country. At the conclusion of the training, NASA and the VA launched a national roll-out for the PSRS in April 2002.

Presently, Ames is working on new mechanisms to disseminate PSRS results and data; nonconfidential reports and products are expected to be publicly released as the roll-out progresses. Ames officials anticipate that the accomplishments of the PSRS will provide VA hospitals with lessons learned and the fundamentals needed to eliminate errors and streamline overall health care operations. ❖



Designed to complement the U.S. Department of Veterans Affairs' current internal reporting methods, the Patient Safety Reporting System is modeled after NASA's Aviation Safety Reporting System, which Ames Research Center operates for the Federal Aviation Administration.

A Head Start to a Healthy Heart

Sudden cardiac death (SCD), or cardiac arrest, is a leading cause of death among Americans. The American Heart Association estimates that SCD kills over 300,000 adults in United States each year, 95 percent of whom die before they reach a hospital or another source of emergency aid, such as defibrillation.

Often mistaken as a heart attack, SCD is commonly triggered by an arrhythmic disorder called ventricular fibrillation, which disturbs the ventricles' blood-pumping action and causes them to contract in an irregular fashion. Sudden death can also result from ventricular tachycardia, which causes the ventricles to beat too fast, ultimately affecting their ability to pump blood; ventricular tachycardia may develop into ventricular fibrillation. As serious and as fatal as SCD is, cardiologists for years have lacked the proper diagnostic tools needed to gauge risk factors so that protective measures can be offered.

In response to the demanding need for an enhanced assessment test—and in order to offer reassurance to cardiologists and patients alike—Bedford, Massachusetts-based Cambridge Heart, Inc., has licensed the only U.S. Food and Drug Administration (FDA)-cleared tool to identify those at risk for SCD. The Microvolt T-Wave Alternans Test™ was invented by Dr. Richard J. Cohen, a professor at the Harvard-Massachusetts Institute of Technology (MIT) Division of Health Sciences and Technology, with developmental support and funding from NASA's Johnson Space Center and the National Space Biomedical Research Institute (NSBRI) in Houston, Texas. In 1993, MIT licensed the technology to Cambridge Heart, Inc., a start-up company that Dr. Cohen helped to establish.

Cambridge Heart's noninvasive technology measures T-wave alternans, a change from one heartbeat to the next that is too minute to be detected by a standard electrocardiogram. Cardiac patients with such a change in heartbeat regulation are faced with a much greater risk of ventricular arrhythmia and SCD than those without it. The company's ability to measure electrical alternans on a microvolt level has been clinically proven to be just as accurate as—and in some studies, more accurate than—more costly and somewhat risky, invasive procedures, such as electrophysiological testing that involves the insertion of a catheter into a patient's heart to deliberately induce ventricular arrhythmias.

While other noninvasive measurement tests are performed during rest or normal activity, the Microvolt T-Wave Alternans Test is administered while patients' heart rates are elevated, during exercise or pharmacological stress. Clinical studies have demonstrated that elevating the heart rate increases the sensitivity of



Unlike other noninvasive measurement technologies performed during rest or normal activity, the Microvolt T-Wave Alternans Test™ is conducted while the heart rate is elevated, generally during exercise or pharmacological stress.

Microvolt T-Wave Alternans testing in identifying patients at risk of SCD.

The predictive accuracy of Cambridge Heart's Microvolt T-Wave Alternans Test spawns from the company's Analytic Spectral Method,TM which determines precise microvolt measurements well below normal noise levels, and its unique, Micro-V AlternansTM Sensors, high-resolution electrodes that allow for the analysis to be performed in conjunction with noisy exercise activity, such as treadmill or bicycle use.

The Microvolt T-Wave Alternans Test is processed through Cambridge Heart's HearTwaveTM System, which is compatible with virtually all existing stress systems, electrophysiology monitoring devices, or electrocardiogram carts. The HearTwave simply collects and computes the alternans data, and then automatically prints out a real-time report.

The test has proved successful in multiple clinical trials conducted around the world in a wide variety of patient populations, including those who have experienced heart failure or myocardial infarction. It can also help physicians manage the most difficult cases, such as the analyses of young patients who appear to be in good health. For example, in a clinical study of 130 syncope patients (those who experience temporary impairment of blood circulation to a part of the body, which often leads to loss of consciousness), the Microvolt T-Wave Alternans Test predicted SCD-related events with a high relative-risk rate, whereas electro-physiologic testing of these patients failed to achieve statistical significance as a predictor of such events.

Cambridge Heart's original stress testing machine, the CH2000, served as the platform for the Microvolt T-Wave Alternans Test. The company advanced the original CH2000 model to detect T-wave alternans, and teamed up with Netherlands-based Philips Medical Systems International to market the technology exclusively throughout the United States and Canada.

Additionally, Spacelabs Medical, Inc., a leading provider of integrated healthcare information systems and instrumentation, was granted clearance from the FDA to incorporate Cambridge Heart's Microvolt T-Wave Alternans Test within its Burdick® Quest® exercise stress system. Used in conjunction with the test, the Burdick Quest system, which combines innova-

tive touchscreen technology with leading-edge diagnostic capabilities, will further help cardiologists in their efforts to predict the risk of life-threatening arrhythmias associated with SCD.

NASA and the NSBRI are currently supporting research involving the Microvolt T-Wave Alternans Test to determine whether space flight increases the risk of severe ventricular arrhythmias, and, if so, whether effective countermeasures can be developed. ❖

Microvolt T-Wave Alternans Test,TM Analytic Spectral Method,TM Micro-V Alternans,TM and HearTwaveTM are trademarks of Cambridge Heart, Inc.

Burdick® and Quest® are registered trademarks of Spacelabs Medical, Inc.



The HearTwaveTM System computes microvolt T-wave alternans and provides trend reports with guided interpretation for quick, accurate analysis.

Battling Brittle Bones

Building strong bones with exercise and a balanced diet rich in calcium and Vitamin D may be the best defense against osteoporosis and low bone mass. While osteoporosis is largely preventable for most people, an estimated 44 million adults aged 50 years and older are considered to be at risk for the debilitating disease, according to the National Osteoporosis Foundation.

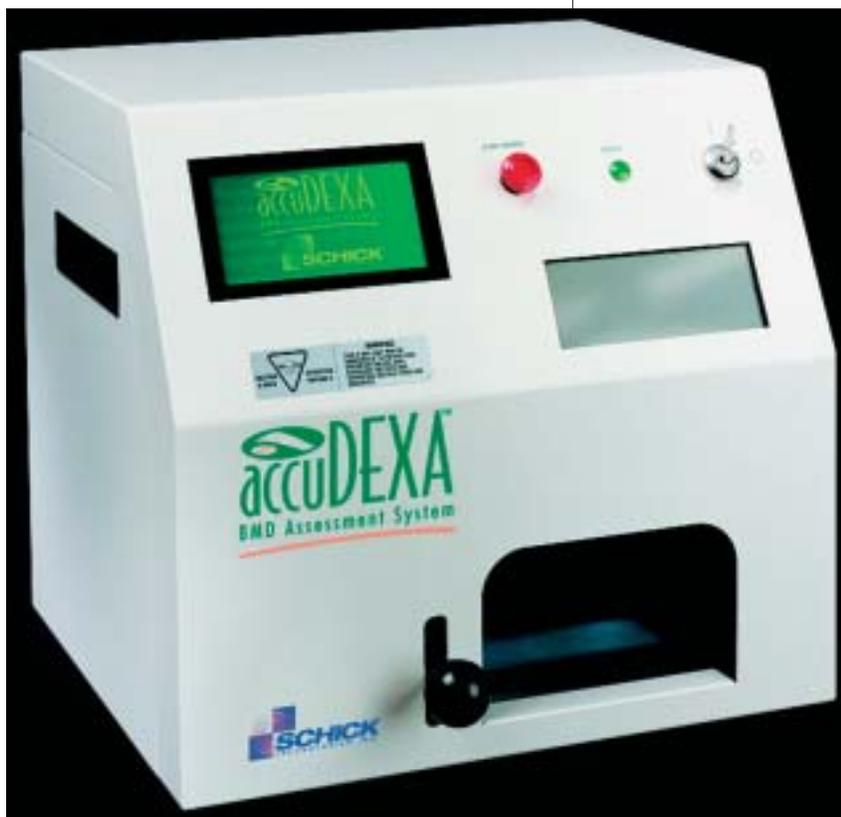
However, as a result of NASA know-how, millions of Americans under and above the age of 50 can rest assured with an early assessment system that provides a quick, convenient, and economical analysis to determine future fracture risk. The accuDEXA® Bone Mineral Density Assessment System, manufactured by Schick Technologies, Inc., utilizes “camera on a chip” sensor technology invented and developed by NASA’s Jet Propulsion Laboratory (JPL) that matches the abilities of costly, power-consuming charge coupled device (CCD) cameras that are considered the industry standard for high-quality imaging.

JPL’s Complementary Metal-Oxide Semiconductor Active Pixel Sensors (CMOS APS)

require one-hundredth the power of a CCD system, are lighter in weight, and are less vulnerable to radiation damage in space. These attributes helped NASA realize its goal of smaller, cheaper fabrications enabling affordable future space missions.

Photobit Corporation, a Pasadena, California-based spinoff company formed by JPL in 1995, gained intellectual property rights to the CMOS APS technology with the goal of developing and commercializing the second-generation, solid-state sensors. In 1997, Long Island City, New York-based Schick entered into an agreement with Photobit to create the new accuDEXA diagnostic tool using CMOS APS.

Schick’s accuDEXA system offers several advantages over traditional osteoporosis tests, which assess bone density loss in the hip and spine, and require specialized personnel to conduct. With accuDEXA, physicians can test the entire body’s bone density at a peripheral site, such as the finger, without applying gels or having patients remove garments. Using Dual Energy X-ray Absorptiometry (DEXA), the



Patients undergoing accuDEXA® tests are exposed to significantly less radiation than those submitted to traditional bone density testing methods.

results are achieved in 30 seconds and printed out in less than a minute, compared to the estimated examination time of 15 minutes for hip and spine density analyses.

Patients undergoing accuDEXA tests are exposed to significantly less radiation (.0003 μSv) than those submitted to traditional bone density testing methods (.1 μSv to 5.9 μSv). Effective radiation to the patient using accuDEXA is also just 1/150,000th of a chest X-ray, according to Schick. The system detects the smallest fluctuations in bone density with a precision that has a less than 1-percent margin of error. Additionally, accuDEXA's cost-effectiveness and compact size make it possible for physicians to offer the test to at-risk patients within the confines of their own offices, meaning that patients will not be inconvenienced by having to travel to an off-site radiology location.

Schick also applied the CMOS APS technology to a new software product that performs

dental radiography using up to 90-percent less radiation exposure than conventional X-rays. Called Computed Dental Radiography® (CDR), the new digital imaging product utilizes an electronic sensor in place of X-ray film to generate sharp and clear images that appear on a computer screen within 3 seconds, and can be enlarged and enhanced to identify problems. Because CDR saves and stores the images, it eliminates costs incurred by film, processing, and chemicals, and saves X-ray technicians and other medical staff from waiting for development and duplication. The product is compatible with virtually all X-ray tubes, seamlessly integrates with existing practice management systems, and allows for the correction of underexposed radiographs. ❖

accuDEXA® and Computed Dental Radiography® are registered trademarks of Schick Technologies, Inc.



Utilizing an electronic sensor, Computed Dental Radiography® delivers superior images instantly with no chemicals to handle, no hassles with duplicating images, and exposes patients to far less radiation than with film methods.

Air Taxi at Your Service

In the past, only the rich and famous may have had access to personal jets designed to whisk travelers from city to city without the inconvenience of crowded major airports. Now, however, with NASA's support and the work of several companies determined to redefine personal air transport, flying direct to nearly any city from the closest local airport may soon become a viable option for everyone.

In 1996, NASA initiated a program designed to revitalize the U.S. light aircraft industry through the development and commercialization of more affordable propulsion systems, including turbofan engines. Enlisted through this initiative, known as NASA's General Aviation Propulsion (GAP) program, Glenn Research Center conducted a small turbofan development competition among major U.S. engine builders. As a result, Williams International of Walled Lake, Michigan, won a cooperative research and development program with NASA, and work on the new NASA/Williams GAP engine began.

A year later, Vern Raburn, a successful entrepreneur in high technology, sought to apply digital technology; efficient lightweight engines, such as those being designed through the GAP program; high volume manufacturing;

and high technology business practices to a whole new type of general aviation company. Raburn met with Dr. Sam Williams, president and founder of Williams International, and created Eclipse Aviation Corporation of Albuquerque, New Mexico, to provide alternatives in air transportation.

NASA and Williams were then proceeding with the FJX-2 turbofan engine demonstrator. The FJX-2, the smallest commercial turbofan of its time and weighing less than 100 pounds, achieved a thrust-to-weight ratio that would enable the creation of a new, small, lightweight aircraft. The turbofan power would allow this new generation of aircraft to fly faster, have longer range, and provide more comfort, while setting new standards in general aviation safety.

The FJX-2 engine's low noise level, light weight, low emissions, low fuel consumption, and low cost in quantity production made it a perfect match for Eclipse. Under an exclusive agreement with Eclipse, Williams will manufacture the EJ22 engine, a commercial version of the FJX-2, for the Eclipse 500 aircraft. The new engine, which weighs approximately 85 pounds and delivers over 770 pounds of thrust, provides a higher thrust-to-weight ratio than any commercial turbofan ever produced. Being the smallest, quietest, and lightest commercial aircraft engine currently available, the EJ22 engine makes a whole new class of twinjet light aircraft feasible.

Eclipse is working closely with NASA and its Small Aircraft Transport System (SATS) program to reevaluate air transportation in the United States. The goal of the SATS program is to provide a safe travel alternative that will reduce public travel time by 50 percent in 10 years and by over two-thirds in 25 years at equivalent highway systems costs. The concept is an "air taxi" that will allow companies to provide fast "point-to-point" air travel. Enlisting the Eclipse 500 as an air taxi, passengers are free to use the small, uncrowded airports near their homes to reach their destinations.



The EJ22 engine, which has a low noise level, light weight, and low fuel consumption, delivers over 770 pounds of thrust while only weighing approximately 85 pounds.



Powered by the EJ22 engine, the Eclipse 500 aircraft is intended to provide “point-to-point” air taxi travel.

Eclipse’s vision of air passengers flying directly between cities in a fast and affordable way is quickly becoming a reality since The Nimbus Group, Inc., of Fort Lauderdale, Florida, has placed an order for 1,000 Eclipse 500 jet aircraft. The Nimbus Group will use the Eclipse 500 to operate air taxi services throughout North and South America. The aircraft is capable of using approximately 10,000 airports in the United States, leading the company to anticipate that the air taxi service will take commuters as close to their final

destination as possible. The Nimbus Group intends to make personal jet travel broadly affordable throughout the Americas. Pre-screened “Nimbus Jet Travel Card” members will have the convenience of traveling at the spur of the moment. The company is planning on-demand service to its clients, similar to calling a ground taxi service. With Eclipse’s vision and The Nimbus Group’s execution, perhaps catching that plane for a business trip will be more like hailing a cab. ❖

Intellectual Dummies

When NASA assisted in the development of a robotic vision system to determine the position and orientation of bar code targets back in 1987, little did anyone know that the innovation would eventually be used to evaluate lacerations and contusions in simulated car crashes.

The progression of this far-reaching application began during a **Small Business Innovation Research (SBIR)**-funded project involving NASA's Goddard Space Flight Center and Triangle Research & Development Corporation (Triangle R&D), of Research Triangle Park, North Carolina. The two entities collaborated to create "Smart Eyes," a charge coupled device (CCD) camera that, for the first time, could read and measure bar codes without the use of lasers.

The laser-free camera operated in conjunction with software and algorithms created by Goddard and Triangle R&D that could track bar code position and direction with speed and precision, as well as with software that could control robotic actions based on vision system input. This accomplishment was intended for robotic assembly of the International Space

Station, helping NASA to increase production while using less manpower.

After successfully completing the two-phase "Telerobotic Rendezvous and Docking Vision System Architecture" project with Goddard, Triangle R&D was awarded a separate SBIR contract from the U.S. Department of Transportation (DOT), which was interested in using the newly developed NASA camera technology to heighten automotive safety standards. In 1990, Triangle R&D and the DOT developed a mask made from a synthetic, plastic skin covering to measure facial lacerations resulting from automobile accidents. Traditionally, scientists tested for the severity of facial lacerations by tying materials such as chamois and leather around the heads of crash dummies. The strength and characteristics of these materials, however, were very questionable.

By pairing NASA's camera technology with Triangle R&D's and the DOT's newly developed mask, a system that could provide repeatable, computerized evaluations of laceration injury was born.

The Transparent Rigid Mask, Facial Laceration Mask, and Hybrid III-50th percentile Head and Neck simulate effects of kibbled windshield glass on a Laceration Mask.



The Soft Tissue Damage Assessment System underwent further testing at a University of Virginia crash laboratory, and was deemed ready for the commercial world. The new measurement device was licensed to First Technology Safety Systems, Inc., the world's largest creator of sophisticated crash test dummies and computer crash test models. The Plymouth, Michigan-based company, which developed research dummies for testing air and space craft ejection seats as far back as the 1950s, applied the new technology (now called the "Facial Laceration Measurement System") to its Hybrid III-50th percentile product line.

The Facial Laceration Measurement System encompasses a measurement cabinet with an adjustable mounting for the laceration mask, which fits over the head of a Hybrid III Dummy, an illumination system, an imaging camera with mirror, and electrical control. The system also includes a personal computer with one monitor for operation, and another high-resolution, large-format monitor for displaying the lacerated mask.

During a simulated car crash, the laceration mask is fitted over the Hybrid III head form. After the impact occurs, the mask is removed from the head and brought to the Facial Laceration Measurement System for analysis. Next, the mask is submitted to calibration testing, where it is assembled onto a rigid transparent head form. External illumination of the laceration mask in the cabinet is switched "on" in order to ensure that the imaging camera can obtain the best image. The area of interest on the mask and head form is then positioned in the camera's field of view with the adjustable mounting fixture. Next, the computer performs the menu-driven calibration procedure, and the area of interest on the head is delimited with a computerized window. Edge sensitivity of the laceration image is selected to

yield the best contrast at each defining corner of the window. This step determines the end-points of the measurement of each laceration.

Final analysis takes place after the calibration process. The illumination system is now switched to internal so that a bulb inside the rigid transparent head form lights up the laceration mask from within. Once again, the area is delimited and edge sensitivity is selected, so that the final data on size and number of lacerations are stored for examination.

With inspiration from the robotic vision system developed over a decade ago, First Technology Safety Systems' Facial Laceration Measurement System is presently being used by automobile and component manufacturers worldwide in vehicle testing, including General Motors, Fujijyu, and Autoliv. ♦



A Laceration Mask is placed over the head of a Hybrid III-50th percentile Crash Test Dummy in laceration test configurations.

A “Tread” Ahead of the Competition

Technology developed by NASA to evaluate and develop composite materials for jet engines has Goodyear Tire & Rubber Co., of Akron, Ohio, turning its wheels in high gear. Through a consortium formed by NASA's Glenn Research Center and the Great Lakes Industrial Technology Center (GLITeC), Goodyear acquired a software use agreement for NASA's Micromechanics Analysis Code (MAC), in an effort to design stronger and safer tires. Based on the Generalized Method of Cells (GMC) micromechanics methodology, the MAC technology has allowed Goodyear scientists and engineers to perform structural analysis of composite laminates for tires all in one step, rather than the several steps previously required.

Back in 1995, Goodyear's Akron Technical Center became interested in improving techniques used to model composites, fully aware that outside of the tire industry, soft composites and macro-micro analysis techniques were being developed. Soon after, Goodyear was introduced to Dr. Steven Arnold, a Glenn senior research engineer, who in return introduced the company to MAC software that dealt directly with the problem that Goodyear was looking to solve.

This leading-edge technology from NASA, which could simulate the proper relationship between the load and deflection (stress and strain) of an object, was not tailored for tire problems. At the time, the software code could

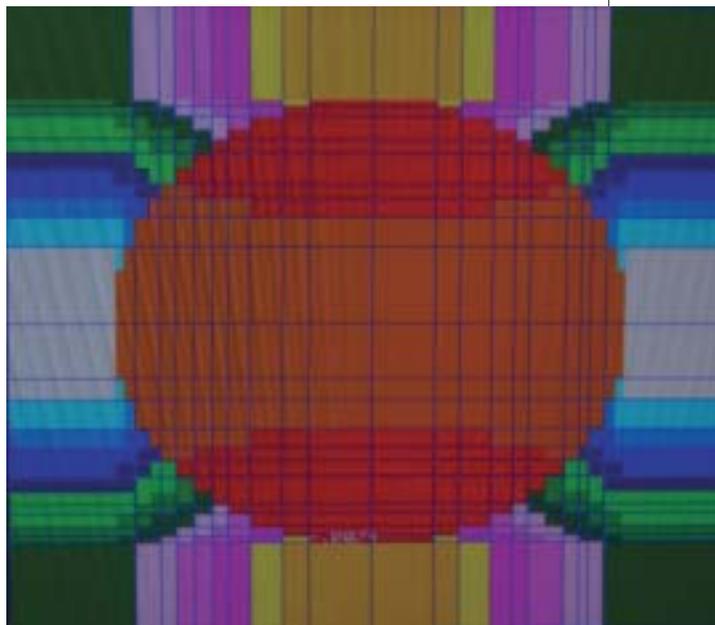
be applied to numerous materials, but not the soft materials used in tire construction. Recognizing the magnitude of the MAC technology and its potential to set new standards for the future of tire design, Goodyear joined Glenn and GLITeC as a member of the Consortium for the Design and Analysis of Composite Materials.

The MAC software code was in its infancy when first adopted by Goodyear, according to Dr. Mahmoud Assaad, a Goodyear research and development associate involved in modifying the NASA technology. Goodyear and NASA worked jointly to tailor the MAC code to the specific needs of the tire company, which at first used it for simple applications to learn its capabilities. In addition, NASA extended its knowledge and expertise by providing Goodyear with onsite training and education seminars. With this assistance from NASA, Goodyear transitioned from version 2.0 of the MAC technology to version 3.0, which is more sophisticated and better suited for pneumatic radial and truck tire analysis.

Currently, the MAC code can assess and optimize composite laminates; set cord-spacing guidelines (the diameter and distance between cords may impact the overall durability of a tire); explain structural impact of geometrical configurations; and compare the behavior of the different wire constructions that make up a tire. Furthermore, the MAC software contains a

built-in material database and several representative volume elements for a wider choice of composites to better represent the plies and belts in a tire. The end result of the process ultimately reduces the time spent on building, testing, and adjusting tires.

After successful implementation of the enhanced code, Goodyear scientists for the first time ever were able to better understand the behavior of each constituent at the local level,



Virtual simulation of tire performance is conducted regularly before actual laboratory testing.

and thus were able to provide the company's tire designers with opportunities to explore new applications to enhance overall tire performance. Further testing of the microanalysis code demonstrated that the MAC tires achieved a 22- and 35-percent improvement in high speed and low speed durability tests, respectively, compared with conventional tires. The MAC technology has been applied to composite laminate designs for several commercially available Goodyear models, including a Kelly-Springfield passenger tire, and a LT235/85R16 Safari tire.

Goodyear is currently advancing its analysis capabilities by utilizing the next level of MAC technology known as FEAMAC, a NASA-developed, seamless integration of MAC's micromechanics analysis capabilities, within the commercial, non-linear, finite element code called ABAQUS. The anticipated future applications for FEAMAC within Goodyear are vast, since tasks that required several hours to complete are now being accomplished within 45 minutes, on average. Goodyear scientists believe that FEAMAC will substantially improve the company's evaluation process for the structural behavior of tires, as well as the over-all longevity of its future line of commercial tires.

While NASA's MAC technology has been provided to other companies, Dr. Assaad proudly notes that Goodyear is driving the software application to "uncharted areas" regarding rubber composite materials. ❖



NASA's Dr. Steven Arnold (left) and Goodyear Tire & Rubber Co.'s Dr. Mahmoud Assaad inspect a MAC-manufactured tire for surface appearance, after it had been subjected to X-ray examination.

Deicing and Anti-Icing Unite

The Icing Branch at NASA's Glenn Research Center strives to increase aviation safety through the development of advanced ice protection and related technologies. Efforts began in 1944 with the opening of the Icing Research Tunnel, which was designated an International Historic Mechanical Engineering Landmark in 1987 for its leading role in making aviation safer for everyone. Taking advantage of this national asset and funding from Glenn's **Small Business Innovation Research (SBIR)** program, Cox & Company, Inc., of New York, New York, built an ice protection system that innovatively combines thermal anti-icing and mechanical deicing to keep airfoils (wings and other lifting surfaces) clear of ice.

In 1995, Cox proposed an ice protection system equivalent to hot air or electro-thermal anti-icing systems at a fraction of their costs. To accomplish this, the system would need to provide an effective means of protecting the leading, or front, edge of aerodynamic surfaces with limited use of power. Similar systems are known as "low power." Cox's concept was to combine an anti-icing system with a mechanical deicer developed by NASA called the Electro-Mechanical Expulsion Deicing System (EMEDS). The anti-icing element of this hybrid would reduce the aerodynamic losses associated with deicing systems.

Using this idea, the firm developed the Cox Low Power Ice Protection System. The anti-icing element of the system heats the leading edge of the airfoil, preventing ice from forming. Past the leading edge, EMEDS functions to break up

and remove ice. The system's two parts are well suited for airfoil leading edges where ice contamination can degrade aerodynamic abilities. Tested extensively at the Icing Research Tunnel, the system uses much less energy than other products that provide equivalent protection, thereby decreasing the operating cost.

The design of the deicing actuator, which is a rolled-up printed circuit, enables the system to function on substantially less energy. Starting out as a flat oval, the actuator's shape changes to a circle when electrical energy is applied. This change causes the actuator to impact the inside of the leading edge surface, which responds with a small but rapid flex movement that expels the accumulated ice from the surface of the aircraft's erosion shield.

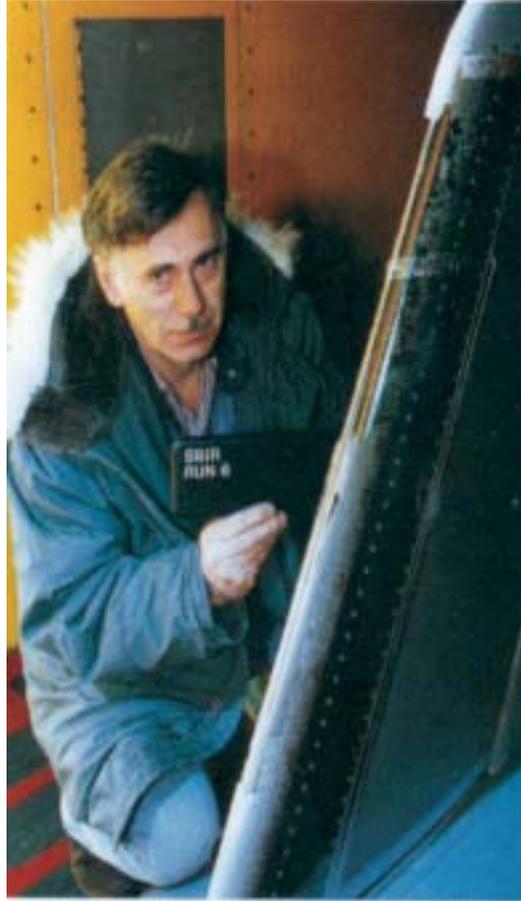
Although no deicer can remove all accumulated ice, EMEDS has shown to remove ice to within 0.030 inches thickness. As soon as the ice reaches a certain thickness, it is expelled. Another advantage of the system is its resistance to deterioration from sun exposure and the harsh icing environment. While systems with rubber leading edge surfaces require periodic replacement, EMEDS' metal leading edge surface enables it to last for the life of an airplane.



Tests conducted at the Cox & Company Icing Wind Tunnel at LaClerc Icing Research Laboratory helped solve the problem of removing ice from airfoils.

The Cox Low Power Ice Protection System is the first new aircraft ice protection system that has been approved by the Federal Aviation Administration (FAA) for use on a business jet in 40 years. According to Andrew Reehorst, an icing research engineer at Glenn, “the FAA approval culminates 20 years of NASA efforts to foster the development of a practical, low power ice-protection technology.” For Cox & Company, the FAA certification gives them credibility in the commercial marketplace.

The system is in production for Raytheon Aircraft’s Premier I six-passenger business jet, where it is used on the horizontal stabilizer. VisionAire has also selected the system for its Vantage business jet, and other companies are considering its use. While the system is currently sized for Premier class aircraft, there are no apparent constraints prohibiting its use on aircraft of any size. The company is investigating further applications, such as adapting the system for unmanned aerial vehicles and other military aircraft. EMEDS is also a viable candidate to replace pneumatic boots and other forms of ice protection. ❖



Cox’s innovation, which combines thermal anti-icing and mechanical deicing, was tested extensively by Cox Ice Protection Systems engineers at Glenn Research Center’s Icing Research Tunnel.

Parachuting to Safety

In 1995, NASA's Langley Research Center awarded Ballistic Recovery Systems (BRS), Inc., the first of three **Small Business Innovation Research (SBIR)** contracts to research and develop a new, low-cost, lightweight recovery system for aircraft that could be commercialized in both civilian and military markets. The company, based in South St. Paul, Minnesota, responded with a unique ballistic parachute system that lowers an entire aircraft to the ground in the event of an emergency.

BRS parachutes are designed to provide a safe landing for pilots and passengers while keeping them in their aircraft. They currently fit ultralights, kit-built aircraft, and certified small business aircraft. The parachutes are lifesavers in cases of engine failure, mid-air collisions, pilot disorientation or incapacitation, unrecovered spins, extreme icing, and fuel exhaustion. These situations typically

do not lead to injury while the aircraft is still in the air; fatalities occur upon impact with the ground. Since the parachute lowers the entire craft, passengers do not need to learn or deploy individual parachuting procedures. The pilot deploys the BRS parachute by turning off the engine and pulling an activating handle. According to the company, pulling the handle feels like slamming on the brakes of a car, only smoother. In less than a second after the handle is pulled, a rocket on the system accelerates to over 100 mph, extracting the parachute and tightly stretching its lines and airframe harness attachments. Shortly afterward, the parachute's canopy becomes fully inflated and begins decelerating the aircraft, which stabilizes quickly. Once stabilized, the aircraft has a design descent rate of 25 feet per second at 5,000-foot density altitude.



BRS parachutes are lifesavers in cases of engine failure, mid-air collisions, pilot disorientation or incapacitation, unrecovered spins, extreme icing, and fuel exhaustion.

Although originally designed for lighter weight aircraft, BRS gained the technological ability to adapt the parachute systems for conventional aircraft. This opened the door for BRS to install the parachute system on the Cessna 150/152 aircraft. Currently, the company's Cirrus Airframe Parachute System is included as standard equipment on Cirrus Design Corporation's four-seat SR20 and SR22 aircraft. With over 148 stories from pilots whose lives were saved as a result of a BRS parachute system, the aviation industry is taking notice. A leading aviation insurance underwriter grants a 10-percent discount on insurance premiums to pilots flying with the BRS parachute.

With its recent award of a new Phase I SBIR contract, BRS is investigating the possibility of installing emergency parachute systems to lower corporate jets carrying 4 to 12 people. In order to achieve this, the company is testing a new lightweight parachute design that was also funded by an SBIR contract from Langley. The new design will adapt a reinforced film technology that is used in the manufacturing of high performance sails, such as the ones on the America's Cup racing sailboats. With NASA's support to improve aviation safety, BRS continues to strive for softer landings. ❖



Since a BRS parachute lowers the entire aircraft, passengers do not need to learn or deploy individual parachuting procedures.

Fully “Eqwipped” to See the Heat

Commercial and government applications that require high performance, long wavelength infrared imaging are no longer being left in the dark, due to a unique technology that is capable of performing tasks that were previously too expensive to accomplish for most users.

Developed by NASA’s Jet Propulsion Laboratory (JPL) over the past decade with an excess of \$15 million of government research and development investment, quantum well infrared photodetectors (QWIPs) are infrared imaging sensors that can operate in the long wavelength portion of the electromagnetic spectrum, where objects at an ambient temperature emit the most energy. The QWIP technology is used to map planetary atmospheres, observe rocket launch plumes, and detect hot spots beneath the ground after a wildfire has been extinguished. The infrared technology also directly benefits various aspects of everyday life, including roadway safety, security and surveillance, medical imaging, anti-terrorism, fire fighting,

search and rescue, law enforcement, and predictive industrial maintenance. JPL’s sensors were even used to image and measure features of Hawaii’s Mount Kilauea volcano, where they portrayed a hot lava tube running underground, invisible to the naked eye.

QWIP Technologies (QWIPTECH) of Altadena, California, was formed in July 1998 to offer JPL’s QWIPs in a commercial format. The company currently holds an exclusive worldwide license to manufacture and sell the infrared photodetector sensors as part of a focal plane array (FPA) called a QWIP Chip.™ The QWIP Chip provides high thermal sensitivity (0.001 °C) and possesses a broad dynamic range, permitting precise observations over a wide range of temperatures. For instance, since the technology uses heat rather than light, it can “see” in complete darkness and through conditions such as dust, smoke, and light fog. QWIP Chips also contain lower noise characteristics than other multiple quantum well designs, according to QWIPTECH.



The JPL camera features a large-area, long wavelength QWIP focal plane array, which gives it greater sensitivity, resolution, and stability than previous infrared cameras.

Because image resolution is contingent upon the number of receptors (or pixels) applied to a FPA, QWIPTECH designed a series of QWIP Chip devices, the smallest one having a total of 81,900 pixels per unit, and larger units with more than 300,000 pixels. Although such a vast quantity of receptors usually increases the cost, QWIPTECH was able to develop a high-quality product without sacrificing price or performance, further expanding the capabilities of infrared technology and satisfying strong market demands for a multitude of new users.

The company currently offers a wide range of affordable commercial products, which includes a 320 x 256 FPA and a large format 640 x 512 FPA. Complementary sensor engines, camera modules, and full camera systems are also available.

QWIPTECH, along with its JPL team partners, are working under a current \$1.6 million contract with the U.S. Defense Advanced Research Projects Agency (DARPA) to develop the next generation QWIP multicolor FPA. This 2-year effort will lead to the production of FPAs for simultaneous visible and infrared measurements in the first year, and four-color integrated FPAs in the second year.

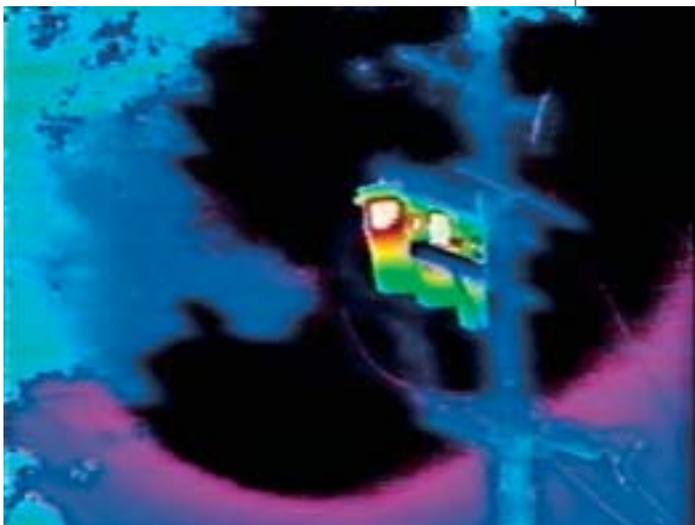
While the technology has already made a good impression on multiple industries, QWIPTECH and its sister company, InTransTech Corporation, recently teamed up

with the Insurance Corporation of British Columbia—one of the largest auto insurance firms in North America—in an effort to potentially save lives and increase road safety, using QWIP technology. In 2001, British Columbia motorists reported more than 10,000 accidents involving wildlife, resulting in costly insurance claims.

As a possible solution, a QWIPTECH prototype camera will be installed on the side of a highway where it will take continuous live video pictures of a stretch of road several kilometers long. The camera will be able to detect the presence of an animal such as a deer, moose, or bear, long before a motorist approaches. The QWIPTECH camera will then relay the animal's image to a computer that will convey information about the animal to a brightly lit digital sign that will act as a warning mechanism for oncoming drivers. Full-scale production and installation of more systems is expected to occur in 2003.

QWIPTECH's patented QWIP technology was inducted into the U.S. Space Foundation's Technology Hall of Fame on April 12, 2001, and was hailed as technology for the future by U.S. Senator John Glenn in an address to the President of the United States and the Senate around the time of the induction. ❖

QWIP Chip™ is a trademark of QWIP Technologies.



QWIP Technologies used the infrared imaging sensors to obtain a nighttime image for preventative maintenance of a transformer on a telephone pole.

Combining Sense and Intelligence for Smarter Structures

In an effort to keep pace with the demands of a continuously growing society and a new millennium, builders, engineers, and architects are constructing taller skyscrapers, longer bridges, and faster aircraft. But with these savvy technological advancements comes the need for a superior safety system that can provide real-time structural data to prevent the possibility of catastrophic failure. Intelligent Fiber Optic Systems (IFOS), Inc., a leading photonic company located in Sunnyvale, California, believes it has a viable solution: the company has positioned itself for rapid growth in the optical networking market with the development of the I*Sense™ 14000 Fiber-Optic Spectral Monitoring System, a high-speed, high-precision, modular measurement application.

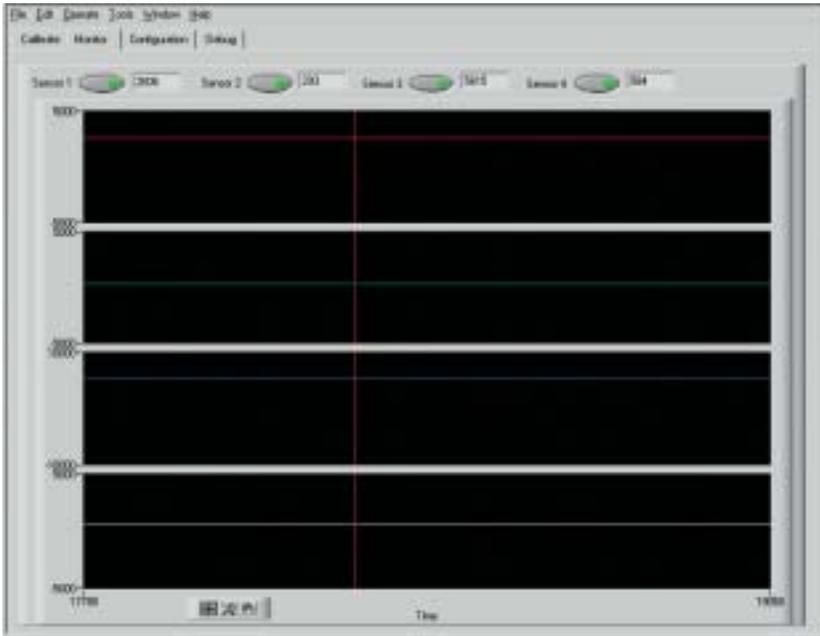
IFOS developed the I*Sense technology with assistance from a NASA Langley Research Center **Small Business Innovation Research (SBIR)** contract. NASA and IFOS collaborated to create sensing network designs that have high sensitivity, low power consumption, and significant potential for mass production. The joint-research effort led to the development of a

module that is rugged, compact and light-weight, and immune to electromagnetic interference. These features make the I*Sense multisensor arrays favorable for smart structure applications, including smart buildings, bridges, highways, dams, power plants, ships, and oil tankers, as well as space vehicles, space stations, and other space structures. For instance, the system can be used as an early warning and detection device, with alarms being set to monitor the maximum allowable strain and stress values at various points of a given structure.

IFOS continued to enhance the product design even further by adding multiple sensors on a single fiber. The I*Sense 14000 model makes parallel, high-bandwidth measurement of signals within an array of multiplexed optical sensors technically possible and economical. The technology has the capability to monitor optical systems that are up to several kilometers from the unit on a single 250-micrometer diameter optical fiber. Moreover, the system's data acquisition software and hardware permit the monitoring of four wavelengths per fiber module, and are expandable to accommodate



*The I*Sense™ 14000 detects strain and stress values of smart structures, such as bridges, buildings, and dams.*



*The acquisition software for the I*Sense™ 14000 returns real-time sensor feedback to a personal computer.*

monitoring systems with multiple module configurations; all units are compatible with personal computers equipped with Microsoft® Windows® operating systems. The company is also pressing ahead with its latest commercial model, the I*Sense 18000, which allows for parallel, high-bandwidth measurement of eight multiplexed optical sensors.

The aerospace industry has expressed considerable interest in employing I*Sense systems to monitor operational parameters and structural integrity. More specifically, aerospace companies are considering utilization of the sensing systems with composite materials to reduce the cost and weight of airframes. According to IFOS, its fiber sensors offer distinct advantages over electrical sensors, ultimately making the I*Sense networks a perfect match for smart skins on both aircraft and space vehicles, as well as many other aerospace structural health monitoring applications, including supersonic transport.

While IFOS' focus to date has been on multiplexed strain sensing applications, it is

planning to advance the I*Sense technology even further with applications in temperature and pressure sensing. The company notes that the I*Sense system's fiber Bragg grating building-blocks (wavelength-selective reflectors embedded inside the fiber through a specialized fabrication process) could potentially be used with materials that are electrostrictive, magnetostrictive, and piezoelectric to act as transducers for measurement of electric and magnetic fields, voltages, acceleration, velocity, displacement, and vibration frequency. Temperature-sensitive environments, such as greenhouses, arctic and marine regions, and space, may also benefit greatly from the monitoring capabilities of I*Sense. ❖

I*Sense™ is a trademark of Intelligent Fiber Optic Systems, Inc.

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Proceeding With Caution

It took a near-fatal experience for Jim Davidson to realize that traffic signals do not necessarily dictate traffic control. In 1978, Davidson was behind the wheel of a car that was almost struck by a fire truck that sped through a red light on its way to an emergency. Twenty-four years later, Davidson is at the helm of a company that is seeking to make a difference in transportation safety and efficiency with an advanced traffic safety system aimed at curtailing collisions involving emergency vehicles.

As the founder and chief executive officer of Agoura Hills, California-based E-ViEWS Safety Systems, Inc., Davidson has recruited a management team with more than 60 years of traffic control and safety experience to launch the Emergency Vehicle Early Warning Safety System (E-ViEWS), a first-of-its-kind preemption and warning mechanism.

E-ViEWS was developed with assistance from the Technology Affiliates Program at NASA's Jet Propulsion Laboratory (JPL). The system incorporates JPL expertise in the areas of systems engineering, transportation systems, antennas,

controls, optical displays, and mechanical systems. It consists of three modules that streamline traffic flow in the presence of emergency vehicles. The first module (E-COMM) alerts motorists and pedestrians that emergency vehicles are approaching an intersection. This is accomplished through traffic signal preemption, a process that utilizes microwave transmissions from an approaching emergency vehicle to immediately change three signal lights to red to halt traffic, and one to green to give emergency vehicles right-of-way passage.

Traffic signal preemption is capable of safely clearing intersections for ambulances transporting emergency patients, fire trucks making their way to a burning blaze, and police cruisers involved in a high-speed pursuit of another vehicle. Secondly, emergency vehicles take advantage of the microwave transmission component to establish an intelligent two-way communication network (E-MITT) with user agencies such as police and fire departments, transit authorities, and street maintenance units.

The third module (E-ViEWS) initiates visual, high-intensity light-emitting diode displays that are positioned above the centers of intersections to inform motorists from which directions emergency vehicles are approaching. The visual displays can be designed to portray changeable messages, street names, detour directions, and maintenance and traffic safety information. E-ViEWS' modular technology can also be applied to non-signalized intersections that incorporate stop signs to direct traffic flow.

The E-ViEWS system acts as a guardrail to protect today's motorists from distractions that could result in serious accidents. Although emergency vehicles use sirens and flashing lights to warn others as they rapidly pass through intersections, some drivers may be oblivious to the emergency situation at hand, due to factors such as car radios, cellular phones, air conditioning, rolled-up windows, vehicle sound proofing, hearing impairment, and many others.

According to the National Highway Traffic Safety Administration, 52 people died in accidents involving emergency vehicles in 1999, the most recent year for which statistics are available. In 1997, an astounding 15,000 emergency vehicle-associated accidents occurred in the U.S. alone. Moreover, National Safety Board metrics indicate that 40 percent of firemen killed in the line of



High-intensity light-emitting diode displays are positioned above the centers of intersections to inform motorists from which directions emergency vehicles are approaching.

duty die on their way to an incident, mostly from intersection collisions. Knowing this is a worldwide problem, E-VIEWS Safety Systems, Inc., has secured patents in six other countries, with plans for expansion in these major global markets.

Beyond reducing accidents and saving lives, E-VIEWS reduces emergency response times, lessens stress for vehicle operators, cuts back on property loss and equipment damage, lowers municipal insurance premiums, diminishes crime rates, and saves millions of dollars spent on vehicle repairs and costly lawsuits, including liability claims associated with city-owned vehicles.

In spring of 2001, the city of Monrovia, California—located just 7 miles from JPL and 28 miles east of Los Angeles—decided to implement the E-VIEWS system at 10 signalized intersections, following a series of bad accidents involving police and fire vehicles in 1999. Transponders that activate the visual warning displays via microwave transmission were installed in 20 police cars and 10 fire vehicles.

Shortly after installation, E-VIEWS faced its first challenge when the Monrovia Fire Department responded to an emergency call from a resident who had experienced severe bleeding after being attacked by a vicious dog. The fire department's emergency route crossed through all 10 intersections that employed the vehicle preemption and visual warning technology. As a result, the fire rescuers reduced their response time by several minutes, which, according to the fire department, later proved to be the difference between life and death for the dog-attack victim.

Although emergency vehicles use sirens and flashing lights to warn others as they rapidly pass through intersections, some drivers may be oblivious to the emergency situation at hand.

While E-VIEWS Safety Systems, Inc., continues to forge ahead with its intersection safety system, the company is fully aware that railroad crossings also pose great danger to motor vehicles and pedestrians. According to the Federal Railroad Administration, more than 130,000 public railroad crossings are virtually unprotected, and 97 percent do not have advanced warning devices. Even so, the railroad crossings that are considered as “protected” still experience accidents for numerous reasons, according to E-VIEWS Safety Systems, Inc.

In response, the company has launched testing efforts for Intellirail, a highly intelligent locomotive warning system that is based on the JPL/E-VIEWS preemption emergency vehicle platform. With Intellirail, E-VIEWS Safety Systems, Inc., hopes the system will not only increase crossing safety at highway-rail intersections, but that it will improve traffic flow and relieve congestion by directing drivers to alternative routes that have already been vacated by an oncoming train, and help mitigate locomotive horn blowing in order to establish whistle-free “quiet zones” all across the country. ❖



Speaking Volumes About 3-D

Genex Technologies, Inc., of Kensington, Maryland, has joined forces with NASA to develop a volumetric display system that does more than just capture a “moment.” The state-of-the-art technology is capable of depicting the true, three-dimensional (3-D) essence of the world, unlike most existing cameras and electronic image displays that are limited to portraying two-dimensional (2-D), flat images that lack physical depth cues.

In 1999, Genex submitted a proposal to NASA’s Stennis Space Center for a volumetric 3-D display technique that would provide multiple users with a 360-degree perspective to simultaneously view and analyze 3-D data. Genex, which has specialized in 3-D imaging and viewing since 1995, claimed that such a technique could significantly enhance the

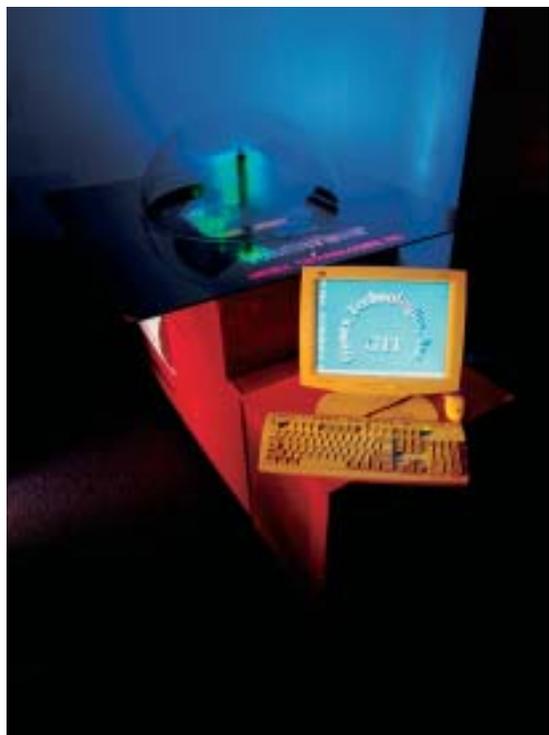
efficiency and accuracy of decision-making and validation. That same year, Stennis awarded Genex with a **Small Business Innovation Research (SBIR)** contract to develop the prototype version of the technology, now known as the **VolumeViewer®** to enable the real-time processing and visualization of 3-D data collected by the Space Center. Currently, the VolumeViewer allows NASA to better analyze and assess the various data collected by its satellite and spacecraft sensors, such as hyper-spectral

pixels in a 2-D image) of data, enabling a user to view a complex 3-D shape or image from multiple perspectives, without the need for special viewing aids or goggles. This 3-D display system provides both physiological and psychological depth cues required by the human visual system to perceive 3-D objects, literally adding a new dimension to the dynamic interaction between mankind and the surrounding world. Furthermore, Genex notes that the unique, walk-around viewing perspective and the direct interaction with the system’s “fish tank-like” volumetric images could greatly simplify human understanding of the intricacies of 3-D objects and the spatial relationships among them.

The futuristic capabilities of the VolumeViewer have offered tremendous benefits to commercial users in the fields of medicine and surgery, air traffic control, pilot training and education, computer-aided design/manufacturing, and military/battlefield management. Possible future applications include 3-D television, video games, sport stadium displays, and homeland defense. Genex capitalized on its success with Stennis by introducing two separate products to the commercial market that incorporate key elements of the 3-D display technology designed under the SBIR contract. The company’s patented Rainbow 3D® imaging camera is a novel, three-dimensional surface profile measurement system that can obtain a full-frame 3-D image in less than 1 second. The technology is based on a structured-light process that projects random colors on a given surface and captures over 440,000 data points of information. The resulting data model represents voxels for every visible point on the object surface, displayed in a single 3-D image.

Because the camera uses white-light technology rather than lasers, it is ideal for medical and research applications, where eye safety can be a major concern. Such applications include oncology and radiology, as a positioning device to precisely align patients during sensitive radiation treatments, and pre- and post-surgery analyses, to provide quantitative 3-D measurements. The technology is especially practicable for commercial manufacturing applications involving rapid prototyping and reverse engineering, due to its speed and cost-effectiveness.

Other applications include dentistry and orthodontics, plastic/cosmetic surgery, prostheses design, artifact archiving, and mass customization



The VolumeViewer® true 3-D display system provides both physiological and psychological depth cues required by the human visual system to perceive 3-D objects.

data sets, multi-variants geospatial data, and remote sensor data. Unlike hologram technologies, the VolumeViewer is not an illusion. The system’s true image capabilities stem from a Genex-developed technique that uses laser-light projection and a rotating “vortex” display screen to actually create a “viewing box.” The VolumeViewer displays nearly 34 million “voxels” (i.e., x, y, and z points, analogous to

of products. The most recent application of the technology involves 3-D facial recognition, dramatically enhancing the performance of traditional 2-D systems by addressing issues related to facial orientation and lighting/shadow effects. Genex also offers add-on software packages that allow users to perform customized post-processing functions, including image registration, editing, manipulation, and measurement calculations.

The third product to evolve from Genex's work with Stennis is the patented 360-degree OmniEye® video system. Ideal for intrusion detection, surveillance, and situation management, this unique camera system offers a continuous, panoramic view of a scene in real-time. In contrast to ordinary cameras that have relatively small viewing angles, the OmniEye's 360-degree, motion-capturing technology eliminates potential blind spots. Additionally, a single OmniEye unit can survey an area that previously required multiple cameras. Applications include banks, casinos, retail shops, airports, and industrial settings.

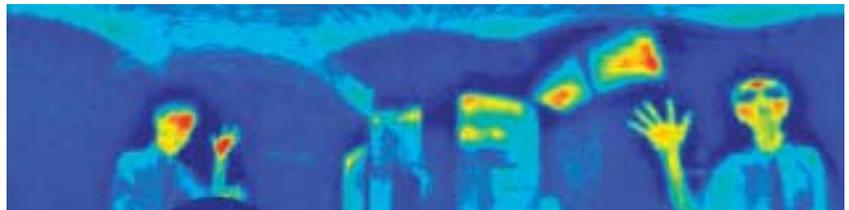
Genex recently introduced the OmniEye Infrared™ model for perimeter control, motion detection, and area surveillance in complete darkness and low-light environments. This camera offers unobtrusive monitoring for military and covert operations, and is used to uphold public safety measures and deter criminal activity.

In June of 2001, the company continued its working relationship with Stennis in an effort to further expand its knowledge of the third dimension. Given its recent track record, Genex may be on its way to opening a portal to a whole new dimension of commercial technology. ❖

VolumeViewer®, Rainbow 3D®, and OmniEye® are registered trademarks of Genex Technologies, Inc. OmniEye Infrared™ and EI Digitizer™ are trademarks of Genex Technologies, Inc.



The EI (Ear Impression) Digitizer™ integrates Genex's patented Rainbow 3D® camera technology to quickly and accurately capture and build a full 360-degree 3-D model in an automated process. The final model of the ear impression can then be used to streamline the process of creating a custom-fitting hearing aid.



The OmniEye Infrared™ marries the full functionality of panoramic video with the latest thermal infrared technology to enable 360-degree viewing and motion detection in complete darkness.

Space Rose Pleases the Senses

The flavors and fragrance industry is always seeking new ways to dazzle and delight consumers' senses. One company launched itself ahead of the competition by collaborating with NASA to create a new fragrance ingredient that is literally out of this world. International Flavors and Fragrances (IFF), Inc., of New York, New York, discovered this new scent, known as the "space rose" note, by flying a miniature rose plant, called the "Overnight Scentsation," aboard NASA's Space Shuttle Discovery Flight STS-95. IFF is the leading creator and manufacturer of flavors and fragrances used by others to impart or improve flavor or fragrance in a wide variety of consumer products.

The Wisconsin Center for Space Automation and Robotics (WCSAR) at the University of Wisconsin-Madison, a NASA Commercial Space Center (CSC), is managed by the Space Product Development Office at NASA's Marshall Space Flight Center. WCSAR is the leading NASA CSC for the development of space-based plant research technologies/facilities. IFF and WCSAR partnered to fly the rose plant in a commercial plant research facility for reduced-gravity environment research. The facility, known as ASTROCULTURE™, was developed in the mid-1990s by WCSAR, and was later modified to incorporate IFF's proprietary technology related to sampling and analyzing essential oils. Although it was understood that plant physiology/biology changes in microgravity, there was no research on gravity's effect on essential oils (or volatile compounds) produced by living flowers, which provide all flavor and fragrance. Therefore, IFF set out to use the rose plant to examine what would happen to the production of essential oils in microgravity.

The company expected the experiment to cause a shift in the scent of the rose, because gravity would no longer hold the plant oils in the stem. Even a slight shift would open up

thousands of possibilities through combinational chemistry. The end result, however, was much bigger than the company anticipated—the researchers discovered that the rose had produced an entirely new scent that was definitely not from Earth.

IFF has commercialized the unique space rose note, which is now a fragrance ingredient in a perfume developed by Shiseido Cosmetics (America), Ltd. The perfume, called Zen, combines three notes for a fragrance that the company describes as floral, woody, and spiritual. While this is the first commercial use of the space rose scent in a fine fragrance, further uses are anticipated. In addition to providing a light, crisp scent to the fragrance industry, the space rose oil can enhance food products flavors, offering new opportunities to the flavors industry.

The rose experiment demonstrates a successful collaboration between a commercial entity and a NASA-sponsored CSC—a strong illustration of how commerce can benefit from space-based research. Results from IFF and WCSAR collaborations during the summer 2002 Space Shuttle mission investigations are expected at a later date. ❖

ASTROCULTURE™ is a trademark of the Wisconsin Center for Space Automation and Robotics.



The unique space rose note is now a perfume fragrance ingredient.

Space-Age Shades

Since 1989, Dr. Keith Manuel has been recognized as the “official” optometrist overseeing the NASA Space Shuttle, the International Space Station, and various other vision-related space projects. In 1990, Dr. Manuel was selected by NASA’s Johnson Space Center to perform studies establishing the viability of contact lenses in space flight. Ever since this initial research effort, he has continued to provide vision care for the astronaut corps, while finding time to co-author the ophthalmic chapter in the book, “Principles of Clinical Medicine for Space Flight.”

Dr. Manuel’s contribution to the Space Program does not stop there, however. He and a company renowned for its stylish eyewear products are responsible for bringing a titanium alloy frame to NASA that can withstand the extreme conditions of space travel. After rigorous testing by NASA scientists, the Agency agreed that the Titan Minimal Art frame was best suited to protect the eyes of astronauts on their space missions.

The frame, produced by Silhouette International Schmied AG (Silhouette), is extremely light in weight and devoid of hinge screws, which reduces the danger potential for astronauts to a minimum. Because astronauts work in sensitive environments, tiny screws or eyeglass components that become loose or fall off could lead to a catastrophe. Such hazards could potentially come in to play during Extra Vehicular Activity (EVA), when astronauts spacewalk with only the protection of their spacesuits. A loose screw or component during an EVA could be nasally or orally ingested, causing choking; could be drawn into the coolant system impeller, causing mechanical suit failure; or could cause a tear in the suit bladder, resulting in a loss of suit pressure.

The already difficult-to-handle conditions of space are further exacerbated by the fact that astronauts can be on the job for up to 10 hours without pause, while wearing tight-fitting helmets. Long durations in spacesuits preclude astronauts from using their hands in the event that their eyeglasses slip out of place.

Silhouette’s Titan Minimal Art frames possess a super elasticity that ensures a slip-free fit for wearing comfort, without causing irritating pressure points. The titanium alloy used in the frames also prevents allergic

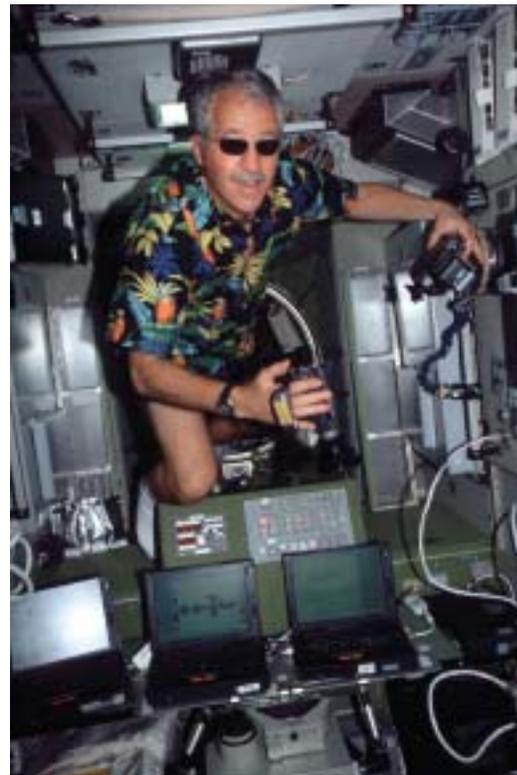
reactions. This technology is available to both NASA astronauts and public consumers in either corrective eyewear or sunglass models.

The only difference between the sunwear used by NASA astronauts and the commercial models is the lens. Dr. Manuel and Silhouette brought NASA a lens that is considerably darker (5.5-percent overall light transmittance), with a thin gold coating that offers total protection, not only against ultraviolet (UV) radiation, but also against the harmful infrared radiation in space.

Silhouette adapted the NASA lens to offer commercial users lasting comfort and protection against harmful infrared light exposure. The company’s Voyager™ lens uses the combination of a soft-brown tint and a scratch-resistant, bi-layer mirror to strike an ideal balance between the amount of short-wave blue light absorbed and allowed to reach the eye (like UV, blue light has been shown to cause irreversible damage to the eye). These features not only provide contrast enhancement and comfort from the fatigue of scattered blue light, but longer-term wearability and better color perception than many high-contrast lenses.

Silhouette International Schmied AG is based in Linz, Austria, with a U.S. office, Silhouette Optical Ltd., in Northvale, New Jersey. ❖

Voyager™ is a trademark of Silhouette International Schmied AG.



The sunglass lenses worn by NASA astronauts are considerably darker than the commercial lenses, with a thin gold coating that offers total protection, not only against ultraviolet radiation, but also against the harmful infrared radiation in space.

Foot Comfort for the Fashionable

Modellista Footwear's new shoe line takes comfort to a level that is out of this world. The company, headquartered in Wellesley Hills, Massachusetts, achieved this feat with Tempur® material, a special foam originating from NASA research that was later refined by Tempur-Pedic, Inc. Modellista uses the foam in their exclusive Tempur PRT insoles, which conform to each wearer's unique foot shape to absorb shock and cushion the foot. The foam's properties allow the shoe to change with the wearer's foot as it shrinks and swells throughout the day.

Scientists at NASA's Ames Research Center originally developed temper foam in the early 1970s to relieve the intense pressure of G-forces experienced by astronauts during rocket launches. In the following years, temper foam was used in wheelchairs, football helmets, airplane seats, and X-ray table pads. In the 1990s, the foam attracted increased attention when Tempur-Pedic, Inc., further developed it for their Tempur-Pedic Swedish Sleep System,[™] a line of mattresses and pillows.

Tempur material consists of billions of open, spherical-shaped cells that are viscoelastic, meaning solid with liquid properties. This viscoelastic property, in addition to the foam's temperature and weight sensitivity, enable the cells to shift position and reorganize to conform to body contours. The material softens in

warmer areas where the body makes the most contact with the surface, and remains firmer in cooler areas, where less contact is made. By absorbing and evenly distributing a body's weight over its surface, the material eliminates uncomfortable pressure points.

Modellista's David Froment, inspired by the comfort of Tempur-Pedic's mattresses, sought to bring Tempur material to footwear. After acquiring a license from Tempur-Pedic, Froment and his team conducted 22 months of research and development. During that time, they overcame a problem that other shoemakers interested in the Tempur material had failed to solve. Traditionally, steam is used to shape shoes. Since Tempur material's extreme sensitivity to heat and moisture causes it to deflate upon contact with steam, Froment's team needed to develop an entirely new process. They devised a way to form the shoes without steam that does not harm the material. Even with this new process, the challenge to protect the material from the effects of hot, sweaty feet remained. To solve that problem, an antibacterial lining was incorporated into the shoe, designed to wick away heat and moisture. Froment's research, which included having his teenage daughter walk around the house with different densities of Tempur material tied to her feet, ultimately paid off with a colorful line of shoes built on a clog platform.



Modellista's colorful line of shoes use NASA-originated foam to absorb shock and cushion feet.

Froment's main goal in developing the Modellista line was to design a shoe that provided exceptional comfort without sacrificing style. He noted that all too often, health care professionals and chefs who are on their feet all day resign themselves to less attractive shoes in exchange for comfort. While Modellista offers an industrial line of shoes for these workers, every Modellista shoe provides the same amount of Tempur material padding. The difference in the industrial line is a stain resistant leather upper to protect the shoes against betadine, blood, urine, and other damaging elements.

The Modellista collection is the first shoe design and construction to be certified by the Space Awareness Alliance. The shoes, with designs ranging from traditional clog shapes to sling backs and open-toe sandals, are currently available nationwide at select Nordstrom stores, specialty shoe stores, and through catalogs including Garnet Hill, Faith Mountain, Monterey Bay, Hanna Anderson, and Soft Surroundings. Modellista is looking to expand the line by introducing new and interesting fabrics in addition to its current offering of leather, suede, and nubuck. After introducing

Tempur foot pillow shoe inserts, Modellista is planning a full line of sandals. Future products may include women's pumps and men's dress shoes, which will surely bring relief to tired feet. ❖

Tempur® is a registered trademark of Tempur-Pedic, Inc.
Swedish Sleep System™ is a registered trademark of Tempur-Pedic, Inc.



The cells in Tempur® material are solid with liquid properties, allowing them to conform to body contours.

Hoof Comfort for Horses

Walking, racing, and jumping inflict a great deal of stress on a horse's legs and hooves. Linda Greenlaw, founder of Aquila Equine Enhancement Products, Inc., of Woburn, Massachusetts, developed magnetic hoof protector pads, called "Power Pads," which ease the discomfort caused by this stress. Similar to a person's sneakers, the company's power pads support and cushion the impact on the horse's hooves and legs to provide comfort and protection against injuries. Tested by NASA for strength and durability, the power pads are quickly gaining recognition in the field as a solution for sore hooves.

Aquila Equine Enhancement Products obtained NASA's help by taking advantage of the technology development assistance available to small businesses from NASA's Marshall Space Flight Center. The staff at Marshall's Technology Transfer Office introduced the company to Deborah Dianne Schmidt and Anthony J. Schaffer of the Center's Materials and Processing Laboratory, who agreed to analyze the power pads.

Schmidt conducted fatigue stress analysis of the magnetic pads. While these tests showed that the pads' composite material and magnetic insert material were satisfactory, Schmidt found that a modification in the placement of the magnet was necessary. Based on her analysis, she was able to recommend an optimal configuration for the durability of the entire pad design. Schmidt also suggested using an injection process to seal the magnet into the pad, rather than applying bonding agents.

Placing the pads on the horse's hooves does not interfere with the horse's natural movement or flexibility and can be compared to a person changing into athletic shoes for a sporting event. The pads are cut to a suitable size, and then mounted onto a horse's hooves using conventional shoeing methods. Once attached, the pads protect the hard and soft parts of the hoof by cushioning blows against the hard ground. The pad's design also protects the vulnerable "heel" of the hoof. They are a cost-effective way to protect a horse's hooves since they can be reused.

With magnetic inserts to increase blood circulation, power pads protect a horse's hooves and legs against injury while providing support and comfort.



The magnetic material presents several additional benefits. Research has shown that magnetic devices improve blood flow to damaged tissue by acting on the blood's iron. By stimulating the damaged tissue's fluids, the magnet helps to speed the elimination of waste products, reduce swelling, and restore normal function to the area. Since magnetic material inserted directly into the hoof wall can cause toxic poisoning, the non-invasive power pads are the best solution to provide the horses with magnetic therapy in their daily work routines.

Aquila Equine Enhancement Products has the support of several master farriers, professionals who shoe horses. Several New England farriers who used the pads on their horses in "field testing" reported that the pads cause hooves to grow more resinous, resulting in a stronger fiber. This makes the pads a

good option for correcting problems such as "brittle" or "cracked" hooves. Power pads have also proven helpful with navicular and arthritic horses.

The power pads are currently being tested at several veterinary schools, including Tufts University, Virginia Polytech Institute, the University of Tennessee, Miner Institute, and Cornell University. The Brotherhood of Working Farriers Research Center in LaFayette, Georgia, which offers service to the equine industry in solving difficult hoof problems, is also working with the pads. ❖



Power pads are fitted onto a horse's hooves using conventional horseshoe nails or glue. Metal horseshoes are then fitted over the pads.

The New Realm of 3-D Vision

People seeking 3-D special effects are usually forced to wear plastic shutter glasses. Now consumers can put those retro glasses away and still enjoy 3-D effects using their own home computers. Dimension Technologies Inc. (DTI), of Rochester, New York, developed a line of 2-D/3-D Liquid Crystal Display (LCD) screens, including a 15-inch model priced at consumer levels. DTI's family of flat panel LCD displays, called the Virtual Window,[™] provide real-time 3-D images without the use of glasses, head trackers, helmets, or other viewing aids.

Most of the company's initial 3-D display research was funded through NASA's **Small Business Innovation Research (SBIR)** program. NASA sought a way to enhance its understanding of great masses of data, like those for fluid flow around Space Shuttle launches. Believing that a 3-D presentation of this information would aid in its interpretation, NASA's Ames Research Center awarded DTI several SBIR contracts to develop its 3-D technology. As a result, the company succeeded in providing

specialty displays for NASA, in addition to developing a commercial product.

The images on DTI's displays appear to leap off the screen and hang in space. The display, which also comes in an 18.1-inch model, accepts input from computers or stereo video sources, and can be switched from 3-D to full-resolution 2-D viewing with the push of a button. The DTI displays are the only ones in the world with the ability to convert instantly from 3-D to 2-D. With the product's eyeQ[™] technology, users can position themselves correctly for the maximum 3-D effect. EyeQ works by placing a small red LED (light emitting diode) on the front panel. If the red is visible, the users reposition their heads until the LED appears dark. The cue is mostly used by new users of the display, much like training wheels on a bike. Experienced users position themselves automatically.

The DTI display achieves the 3-D effect by simulating the most powerful visual cue that the human visual system uses to construct internal three-dimensional models of what it is



The Virtual Window[™] system tricks the brain into seeing 3-D by creating two images of an object as seen from two slightly different angles. The image appears to leap off the screen as a result.

Image courtesy of Dimension Technologies Inc., www.dti3d.com

seeing. This cue, called binocular disparity, gives viewers the vivid sensation of depth that is only seen when looking at the real world or a 3-D movie. Binocular disparity is the slight difference between what the left eye sees and what the right eye sees. Because left and right eyes look at the world from two slightly different locations, about 2.5 inches apart on average, the shape of an object seen by each eye is slightly dissimilar, as is the way the two images of the object line up with one another. A person experiences this disparity by looking at an object with only one eye and then the other. The brain processes the differences in these two views to provide an accurate representation of the three-dimensional shape and position of the object, resulting in the real depth 3-D humans see in the real world.

The DTI system fools the brain into seeing real depth by creating two images of a scene as seen from two slightly different viewing angles. It then takes one image and displays it on the odd pixel columns of a LCD screen, while placing the other image on the even columns. Thin light sources behind the screen send light through the odd and even columns, which travels out at slightly different angles toward the viewer. Since the different light sources only reach the corresponding left or right eye, each eye only sees one of the images. The brain blends the two images into one, creating an image that appears to float in space in front of the flat panel screen. Adding real depth information to any presentation makes the information easier and faster to understand.

The Virtual Window displays have applications in data visualization, medicine, architecture, business, real estate, entertainment, and dozens of other research, design, military, and consumer applications. Displays are currently used for computer games, protein analysis, and surgical imaging, to name just a few. Hundreds of worldwide users include NASA, Goodyear,



DTI's flat panel LCD displays provide 3-D images without any special viewing aids.

Image courtesy of
Dimension Technologies
Inc., www.dti3d.com

Microsoft,[®] Northrop Grumman, Honeywell, Lockheed Martin, Kodak, all branches of the military, Massachusetts Institute of Technology (MIT), Stanford, Johns Hopkins, and about 40 other worldwide educational institutions. The technology greatly benefits the medical field, as surgical simulators, which allow virtually unlimited practice with open surgical techniques, are helping to increase the skills of surgical residents. DTI believes that the screens will gain increased use as new software, more powerful desktop PCs, and increased production quantities drive down costs. DTI is actively seeking licensing partners to incorporate the unique 3-D technology into their flat panel displays, thereby increasing production and decreasing costs. 3-D technology in everyday use may be closer than it looks! ❖

Virtual Window[™] is a trademark of Dimension Technologies Inc.

Microsoft[®] is a registered trademark of Microsoft Corporation.

Better Pictures in a Snap

With the help of new image enhancement technology, the casual photographer can now produce better quality pictures without upgrading to expensive camera equipment. Retinex Imaging Processing, which won NASA's Space Act Award as one of the Agency's top inventions for 1999, is commercially available through TruView Imaging Company of Hampton, Virginia. With this technology, amateur photographers use their personal computers to improve the brightness, scene contrast, detail, and overall sharpness of images with increased ease. The process was originally developed for remote sensing of the Earth by researchers at NASA's Langley Research Center and Science and Technology Corporation (STC).

STC, a high-tech Small and Disadvantaged Business, has been providing technical support services to NASA and other government agencies since 1979. In 1996, STC's Dr. Zia-ur Rahman joined with Daniel Jobson and Glenn Woodell, both from Langley, to invent a new method for enhancing digital images. The method, called Multi-scale Retinex with Color Restoration, was developed from Edwin Land's Retinex

(retina + cortex) theory of human color vision. An outgrowth of scientific research and its application to NASA's remote sensing mission, the method automatically enhances a digital image in terms of dynamic range compression, color independence from the spectral distribution of the scene illuminant, and color/lightness rendition. As a result, the enhanced digital image is much closer to the scene perceived by the human eye, under all kinds and levels of lighting variations, than if the digital image was enhanced by any other method. Woodell explains that "current technology like that found in Adobe's Photoshop software makes adjustments in gain, contrast, and other variables. The difference with ours is that we not only look at the pixel, but the pixels around a given pixel." Recognizing the technology's potential to provide color digital images of unprecedented clarity, presence, and quality, STC created TruView to commercialize the technology.

Through an exclusive license from NASA, TruView features the Retinex image technology in its first commercial product, PhotoFlair 1.0 for Windows,® which is available through the



The images show before and after versions of a photograph that was enhanced using Retinex Imaging Processing technology.



TruView's PhotoFlair software enables people to adjust their photographs to reflect what they saw with their own eyes.

company's web site. The software is distinguished from other existing image-enhancement technologies by its ability to automatically make corrections while still allowing the end-user to manipulate the image as desired. As a result, the average photographer is not only more likely to use the software, but is also more likely to use it successfully.

The realistic beauty and visual impact of photographs can be diminished, damaged, or lost by a variety of possible problems. For example, colors and details can be lost or suppressed in shadows or other low light level zones in a picture. These same scenes, when directly viewed by the human observer, are vivid by comparison to the recorded image. PhotoFlair enables users to adjust their photographs to reflect what they saw with their own eyes, capturing the memory more accurately.

TruView believes there are additional applications for the software in medical imaging,

forensics, security, recognizance, mining, assembly, and other industrial areas. The technology has been demonstrated in aerospace imaging applications such as Space Shuttle Operations, Shuttle Earth observations, and the Earth Knowledge Acquired by Middle School Students (EarthKAM) Project, which allows students to take images of selected areas of the Earth using a camera mounted in the Space Shuttle. TruView's next plan is to release a Macintosh version of PhotoFlair, as well as a plug-in version for Adobe's Photoshop series of image-editing programs. The technology is also being refined for video image enhancement, where the product's high-speed, automatic correcting features should make quick work of an otherwise tedious and extensive process. ❖

Microsoft® is a registered trademark of Microsoft Corporation.

Pest Control on the “Fly”

An accidental discovery that occurred during the 1976 Viking missions to Mars has led to the creation of a new, non-toxic, and environmentally safe pesticide that is wreaking havoc on fly populations at farms, stables, and households across the country. Although new to the commercial market, the 100-percent biodegradable substance appropriately tagged as FlyCracker® has quite a rich history, evolving over several decades.

Dating all the way back to 1959, NASA Headquarters provided research and development support to a company called Biospherics Inc. (now known as Spherix Inc.), under the Agency’s planetary science program. In 1969, the Beltsville, Maryland-based biotechnology company’s “Labeled Release (LR) Life Detection Experiment” was selected by NASA to fly aboard the Viking 1 and Viking 2 landers, which were both headed to Mars. Dr. Gilbert V. Levin, the current chief executive officer of Spherix and holder of more than 100 patents, was the principal investigator and experimenter for the tests conducted at the Martian landing sites.

The path leading to the development of FlyCracker began when Dr. Levin and his research team carried out the task of producing nutrients to feed hypothetical Martian microbes

in the LR microbial life detection test. During the course of developing the nutrients, the researchers synthesized various compounds that would act as candidate nutrients. The syntheses that took place involved the generation of intermediates that were subsequently reacted to form nutrient candidates for microbiological testing. One of the intermediates was produced on a Friday afternoon and left in an open vessel, awaiting the next step in making the candidate nutrient.

According to Dr. Levin, he and the research team returned to the open vessel the following Monday morning, only to find an abundance of dead flies on the floor around it. As it turned out, the Environmental Protection Agency (EPA) happened to be issuing warnings about the dangers linked to the harsh chemical pesticides that were available at the time that Dr. Levin and his team unexpectedly stumbled upon the intermediate and its deadly effect on the flies. The EPA’s desire to develop new pesticides that would be safe for the environment and all of its living inhabitants led Dr. Levin to believe that his discovery could result in an alternative solution to the hazardous substances on the market.

With this in mind, Dr. Levin and his company embarked on a small research effort, learning that the initial pesticide effect that killed the flies was produced by a compound that would require substantial testing in order to prove safe under EPA regulation guidelines. The company further experimented with related compounds that were already regarded as safe, and identified one that interrupted the life cycle of the fly, without poisoning the adult insects. Rather, the adult flies’ larvae never pupated when exposed to the compound, hence, no adult flies appeared.

This successful achievement led to the conception of Spherix’s FlyCracker and an entire new method for using pesticide to treat and control fly problems in closed environments such as milking sheds, cattle barns and hutches, equine stables, swine pens, poultry plants, food-packing plants, and even restaurants, as well as in some outdoor animal husbandry environments. The product can be applied safely in the presence of animals and humans, and was recently permitted for use on organic farms as livestock production aids. According to Spherix,



FlyCracker® is environmentally friendly, completely biodegradable, and does not harm animals or humans.



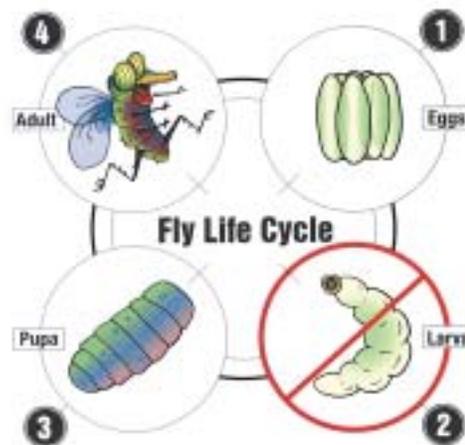
The pesticide is easy to apply around the inside perimeter of calf pens, milking sheds, livestock buildings, and other enclosed environments.

onsite treatment with FlyCracker eliminates labor costs tied to the relocation of animals during facility treatment. Other financial burdens attributed to fly infestations include milk production losses, exceeding \$90 million per year, and weight gain depression for cattle, costing cattle feeders more than \$100 million annually.

Used in areas that are conducive to fly egg deposition, FlyCracker's carbohydrate technology kills fly larvae within 24 hours. By killing larvae before they reach the adult stages, FlyCracker eradicates another potential breeding population. The Food and Drug Administration-approved product works through a physical process that dehydrates larvae as they ingest the granules in treated decomposing organic matter. Because the process is physical—not chemical—flies and other insects never develop resistance to the treatment, giving way to unlimited use of product, while still keeping the same powerful effect. Furthermore, FlyCracker has been proven effective and safe in multiple studies, including a University of Maryland trial which found that the product reduced the live fly larvae count in 10 pens containing 1-week-old dairy calves from 108 per 6-inch square sample to less than 1 per 6-inch sample. Moreover, no pupae were found in any of the samples, demonstrating complete control in preventing emergence of adult flies.

As sales of FlyCracker continue to climb for Spherix, the company is on the verge of making yet another impact on the commercial market with a revolutionary low-calorie sweetener called Tagatose. The natural sugar—also a result of Dr. Levin's experiment that flew aboard the 1976 Viking missions—is intended for use with food and beverages, but according to Spherix, the main market could be the pharmaceutical industry, where the company plans to use the substance to treat type-2 diabetes, sweeten bad-tasting prescription drugs, and preserve human organs during transplant procedures. ❖

FlyCracker® is a registered trademark of Spherix Inc.



FlyCracker® incorporates a compound that interrupts the life cycle of the fly, without poisoning the adult insects. By killing larvae before they reach the adult stages, the pesticide eradicates another potential breeding population.

Super Clean, Super Safe

Cleaning mechanical, electrical, and fluid components should not come at the cost of a protected environment. Unfortunately, traditional high-pressure cleaning systems for these components require the application of large quantities of solvents. The disposal of these solvents can cause environmental problems, especially Freon 113 and other chlorofluorocarbons (CFCs).

To address this problem, NASA's Kennedy Space Center developed an innovative system that makes cleaning super safe. Kennedy's Supersonic Gas/Liquid Cleaning System (SS-GLCS), which originated as a cleanliness verification tool for complex Space Shuttle mechanical and electronic parts, has commercial applications ranging from cleaning circuit boards to scouring building exteriors.

Kennedy's SS-GLCS has several advantages over other pressurized cleaning methods. The system does not abrade the surface of the hardware being cleaned, and it requires much lower levels of pressure while using very little water. These features enable the system to clean a wide variety of items. Developed as an alternative to CFC-based solvents, the system mixes air and water from separate pressurized tanks. It then ejects the gas-liquid mixture at supersonic speeds from a series of nozzles at the end of a hand-held wand. At these speeds, the water droplets have the kinetic energy to forcibly remove the contaminant material, dispersing it into a minimal waste stream. According

to NASA lead project engineer, Raoul Caimi, "During our testing programs, we found that the gas-liquid supersonic system actually does a better job of cleaning than the system that uses CFCs." Since the environmentally friendly system requires less than 3 ounces of water per minute, there is very little fluid left after cleaning that must be handled as contaminated waste.

Taking advantage of the SS-GLCS' unique design, Va-Tran Systems of Chula Vista, California, is one of several companies to license Kennedy's invention for commercial application. Va-Tran is marketing the system as a tool to eliminate heavy hydrocarbon contamination. The company conducted studies that showed the product can also remove adhesive, flux, and fingerprints. According to Va-Tran, test results indicate that oil and grease can be removed with a greater than 95-percent efficiency.

Va-Tran's SS-GLCS can be applied in the aerospace, automotive, and medical industries, as well as to circuit boards, electronics, machinery, metals, plastics, and optics. With a nozzle that can be oriented in any direction, the system is adjustable to allow all sides of a part to be cleaned without reorientation. Designed for operator safety and comfort, it requires minimal training and is easily moved on built-in casters, despite its 450-pound weight.

Other companies that have licensed SS-GLCS have suggested additional applications in the nuclear, pharmaceutical, semiconductor, and chemical industries. ♦



By injecting water mist into a supersonic stream of air, the Supersonic Gas/Liquid Cleaning System uses less pressure and water than other systems, decreasing leftover contaminated fluid as a result.

Analyzing Water's Optical Absorption

A cooperative agreement between World Precision Instruments (WPI), Inc., of Sarasota, Florida, and NASA's Stennis Space Center has led to a new innovation that benefits both NASA and the general scientific community. After a collaboration with Dr. Richard Miller, a NASA chief scientist and biological oceanographer, WPI is marketing its UltraPath™ device, which provides a more efficient method for analyzing the optical absorption of water samples at sea.

Dr. Miller, who conducts research aboard ships around the globe to support NASA's satellite programs, initiated the development of UltraPath. He collects water samples to verify observations from space by examining colored dissolved organic matter (CDOM), a major component of land runoff that affects ocean color in coastal waters. Since the presence of CDOM complicates the detection of other materials using ocean color sensors, measuring how much light CDOM absorbs helps scientists to evaluate the accuracy of products developed from satellite imagery. The standard method of measuring the absorption of water samples requires special handling and storage. According to Dr. Miller, the procedure involves freezing the seawater samples and shipping them to a laboratory for spectral analysis.

To avoid this time-consuming and costly process, Dr. Miller teamed with WPI, an international manufacturer of laboratory equipment, to develop a portable, yet robust, system. Dr. Miller gained financial support for the UltraPath project through a dual-use cooperative agreement between Stennis' Office of Technology Transfer and WPI. The company's recognized expertise in the field of liquid waveguide capillary cell technology (LWCC™) served as a platform for UltraPath's design. Dr. Mathias Belz, senior scientist for the company, stated, "The [Technology Transfer's] Dual-Use program has provided both partners with the opportunity to combine NASA's vast knowledge of oceanology with WPI's expertise in optical instrumentation, resulting in the successful design of UltraPath."

On a technical note, UltraPath is a unique, high-performance absorbance spectrophotometer with user-selectable light path lengths of 2, 10, 50, and 200 cm. It is an ideal tool for any study requiring precise and highly sensitive spectroscopic determination of analytes, either in the laboratory or in the field. The instrument operates in the wavelength range of 370 nanometers (nm) to 725 nm and has a dynamic range allowing reliable absorbance measurements between 5 micro absorbance units per centimeter (mAU/cm) to 1 absorbance unit per centimeter (AU/cm).

As a low-cost, rugged, and portable system capable of high-sensitivity measurements in widely divergent waters, UltraPath meets Dr. Miller's needs while providing commercial opportunities for WPI. Dr. Miller explained, "The flexibility of the system solves a critical problem for oceanographers and opens the door to numerous other applications." The product will help scientists examine the role that coastal ocean environments play in the global carbon cycle. ❖

UltraPath™ is a trademark of World Precision Instruments, Inc.

LWCC™ is a trademark of World Precision Instruments, Inc.



The innovative UltraPath™ is a "multiple pathlength" optical system.

Safety on Earth From MARSS

Quick detection and accurate monitoring can help prevent dangerous weather conditions and chemical spills from becoming lethal. ENSCO, Inc., of Springfield, Virginia, created a system that not only detects and monitors, but also provides mock scenarios to guide preparations for emergencies involving meteorological hazards and toxic substances.

ENSCO has been developing the Meteorological and Atmospheric Real-time Safety Support (MARSS) concept since the early 1980s, in partnership with NASA's Kennedy Space Center and the U.S. Air Force. Developed under a Phase III **Small Business Innovation Research (SBIR)** contract with Kennedy, MARSS is a full-color graphics system specifically designed for real-time assessment of meteorological data displays and toxic material spills. The system was originally designed to measure the safety of NASA and Air Force range safety personnel while performing weather sensitive operations around launch pads.

Severe weather can injure personnel, damage equipment, and possibly destroy space vehicles and payloads. Due to the weather's effect on most of Kennedy's operations, MARSS augments a ground operations safety plan that limits certain work operations and procedures to very specific weather conditions. For example, MARSS will notify personnel of occurring or

imminent lightning within 5 miles of operations, which would necessitate a halt to certain activities like outdoor crane hoisting.

In addition to monitoring severe weather conditions, MARSS provides toxic hazard prediction models to assist safety managers in planning for and reacting to releases of hazardous materials, such as those associated with launch vehicles. Prior to a launch, forecasting and modeling capabilities enable users to run mock scenarios to predict blast and toxic parameters. This allows managers to characterize the nature and scope of launch-related dangers, as well as to plan procedures in the event of a chemical accident.

MARSS works by acquiring real-time meteorological data from a network of surface, upper-air, and lightning sensors. This data, along with a database specifying which chemicals are stored at each location, is integrated into a single application environment for chemical hazard predictions and continuous atmospheric hazard monitoring. When atmospheric conditions violate user-specified criteria, the MARSS monitoring function alerts personnel through audio/visual alarms, e-mail, or alphanumeric paging. The monitoring and display features provide users with the ability to detect fast-moving, hazardous weather conditions and initiate protective action to avoid injury to



ENSCO's MARSS system was used during the 1998 wildfire emergency affecting much of Florida.

personnel and damage to critical assets. By generating models that indicate the atmospheric location of toxic and hazardous plumes, MARSS provides real-time information to decision-makers for evacuation and property protection.

MARSS can be used in agricultural, industrial, and scientific applications that require weather forecasts and predictions of toxic smoke movement. In 1998, the MARSS system aided firefighters battling Florida's drought-induced wildfires. ENSCO installed a MARSS unit at the Brevard County Agricultural Center in Cocoa, Florida, to provide real-time fire threat data to firefighters. The system's displays and monitoring capabilities alerted firefighters when lightning activity threatened to ignite additional fires, and indicated when wind conditions would affect the large number of fires burning over the area. MARSS is also designed to protect urban areas, seaports, rail facilities, and airports from direct/indirect airborne releases of hazardous chemical substances. The system can integrate with local facility protection units and

provide instant threat detection and assessment data that is reportable for local and national distribution. In the event of an incident, the continuous graphic display of plume movement allows for enhanced communication between safety personnel and related agencies. With the need for advances in homeland security, ENSCO is looking at expanding the MARSS capabilities to provide for civil and Department of Defense detection and warning of chemical and biological attack.

Several units of the MARSS system are currently deployed at Kennedy and Cape Canaveral Air Force Station, Florida. The system is now commercially available, with its first contract to Lockheed Martin as a weather toxic support system for the Eastern and Western Range, which refers to the 45th and 30th Space Wing, respectively. The U.S. Air Force awarded ENSCO a contract to produce and install the next generation of MARSS for the Cape Canaveral and Vandenberg Air Force Base space launch ranges. ❖



MARSS' toxic hazard prediction models help safety managers plan and react to the release of hazardous materials.

Airing Out Anthrax

While America continues to work around the clock to search for solutions that would thwart any future attempts of terrorist and biochemical attacks, a company located in Kennesaw, Georgia, has created groundbreaking technology that could not have come at a more appropriate time.

KES Science & Technology, Inc., a company renowned for its expertise in preserving perishables, is taking a giant leap forward to preserve freedom. The company is assuaging the fears and concerns of the American public with an

answer to the onslaught of anthrax-related incidences that followed the tragic events that affected our Nation on September 11, 2001.

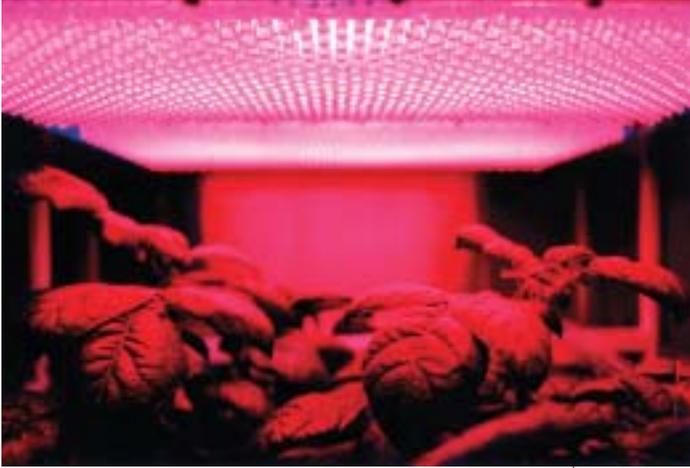
The AiroCide TiO₂ is an air purifier that kills 93.3 percent of airborne pathogens that pass through it, including *Bacillus anthracis*, more commonly known as anthrax. It is essentially a spinoff of the company's Bio-KES system, a highly effective device used by the produce industry for ethylene gas removal to aid in preserving the freshness of fruits, vegetables, and flowers. In 1994, scientists at the University of Wisconsin-Madison and the Wisconsin Center for Space Automation and Robotics (WCSAR) co-developed the original ethylene gas removal technology, also known as an ethylene scrubber. WCSAR, one of NASA's Commercial Space Centers, is sponsored by Marshall Space Flight Center's Space Product Development Office.

The TiO₂-based ethylene removal technology that is incorporated into the company's AiroCide TiO₂ and Bio-KES products was first integrated into a pair of plant-growth chambers known as ASTROCULTURE™ and ADVANCED ASTROCULTURE™. Both chambers were designed and built by WCSAR, and have housed commercial plant growth experiments in space on either the Space Shuttle or the International Space Station. This technology is still used in enclosed plant growth chambers in commercial space research.

After the September 11th attacks, a KES employee questioned whether the Bio-KES system could be altered to eliminate pathogens from the air at a higher rate, considering its non-depleting Titanium Dioxide-formula catalyst material (TiO₂) and ultraviolet bulb technology. More specifically, the employee wanted to know if the system could act as a combatant against airborne anthrax spores. Research proved a revelation, and the answer was yes.



A technician at KES Science & Technology, Inc., assembles the AiroCide TiO₂, an air purifier that kills 93.3 percent of airborne pathogens that pass through it, including anthrax spores.



A first-generation ethylene scrubber, which used the same coating technology as the anthrax-killing device, removed ethylene inside the ASTROCULTURE™ plant growth unit during Space Shuttle mission STS-73 in 1995.

To reach this conclusion, researchers prepared a prototype of the AiroCide TiO₂ that consisted of 52 high-powered germicidal ultraviolet lamps, a catalyst bed of small pellets coated with TiO₂, and a heating block set to 100 degrees Fahrenheit. The device was exposed to 1,386 *Bacillus thurengiensis* spores (*Bacillus thurengiensis* is a non-virulent member of the anthrax bacteria family that contains most of the same properties as the deadly germ). The spores made their way into a Plexiglas chamber situated over the intake port of the device, and were then introduced to an aerosolizing blast of bio-active hydroxyl radicals that was released from a compressed air cylinder.

After overnight incubation of the bacteria, researchers determined that of the 1,386 *Bacillus thurengiensis* spores consumed by the AiroCide TiO₂, only 101 survived the experiment. Although the surviving spores are released from the machine's chamber, they are likely to be sucked back inside the device, without a chance to make it out alive, according to KES officials.

The AiroCide TiO₂ also has a proven record of destroying 98 percent of other airborne pathogens, such as microscopic dust mites, molds, and fungi. Moreover, the device is a verified killer of Influenza A (flu), *E. coli*, *Staphylococcus aureus*, *Streptococcus pyogenes*, and

Mycoplasma pneumoniae, among many other harmful viruses.

With its AiroCide TiO₂ technology, KES is quickly positioning itself as a harbinger in the fight against bacteria, especially in light of the various strains that are developing resistance to antibacterial products. The available unit, which is a flat, metal box approximately the size of a tabletop, is designed to be mounted to a ceiling, but can be placed on a wall, if necessary. Once properly installed, the unit is capable of purifying 15,000 cubic feet of air in a 24-hour period. Possible commercial applications for the device include mail rooms; kitchens; offices; conference rooms; break rooms; hospitals; doctors' waiting rooms; veterinary facilities; day care centers; and other common areas that are susceptible to bacteria. In addition, KES is planning to develop a residential model of the AiroCide TiO₂, in response to an overwhelming demand from homeowners looking to stave off common household allergens. The proposed model would also likely benefit individuals who suffer from severe cases of asthma. ❖

ASTROCULTURE™ and ADVANCED ASTROCULTURE™ are trademarks of Wisconsin Center for Space Automation and Robotics.

Pure Water From a Pure Genius

UMPQUA Research Company (URC), a veteran **Small Business Innovation Research (SBIR)** partner with NASA, has once again stepped up to the plate with a solution to protect one of the world's most precious natural resources: water. After helping to develop a baseline water purification system for the International Space Station and a microwave regenerable air purifier for Moon base and Mars missions, URC of Myrtle Creek, Oregon, has come back down to Earth with a process for destroying perchlorate and nitrate in water.

Ammonium perchlorate is widely used throughout the aerospace, munitions, and pyrotechnics industries as a primary ingredient in solid rocket and missile propellants, fireworks, and explosive charges. Following the Cold War, the U.S. Department of Defense was left with roughly 140 million pounds of ammonium perchlorate to dispose of between 1993 and 2005. This highly soluble salt has tainted soils and water sources all over the world, and is believed to be an endocrine disrupter, adversely affecting the growth patterns of a fetus or a young child, according to recent medical studies.

Perchlorate contamination was first discovered in northern California in 1997. Upon further investigation prompted by these findings, environmental officials uncovered substantial levels of perchlorate in southern California water wells, Las Vegas wells, Lake Meade in Nevada, the Colorado River, and various other areas through-

out the United States where the chemical was used.

In response, the California State Department of Health Services (DHS) adopted an action level for perchlorate in drinking water of 18 micrograms per liter. In addition, the DHS informed water utility companies responsible for drinking water that they were required to develop a regulation plan for treating perchlorate as an unregulated chemical that must be monitored and reported to the department. Although no State or Federal drinking water standards regarding perchlorate exist at this time, the chemical has been placed on the current Drinking Water Contaminant Candidate List by the U.S. Environmental Protection Agency. This list, which falls under the policies of the Safe Water Drinking Act Amendments of 1996, identifies potentially hazardous elements that could affect drinking water. Presently, studies are underway to identify the occurrence of perchlorate in such water.

Once a small drinking water testing laboratory and a research and development contractor for NASA's manned spaceflight applications, URC has evolved as a leader in water purification and analysis. With a total of 11 patents issued for new technologies created by URC under NASA SBIR contracts and a 25-year commitment to water recycling, the company clearly possessed the necessary qualifications to tackle the presence of perchlorate in water. An SBIR contract with NASA's Marshall Space

Upon discovering perchlorate contamination in 1997, the California State Department of Health Services informed water utility companies responsible for drinking water that they were required to develop a regulation plan for treating perchlorate as an unregulated chemical that must be monitored and reported to the department.



Flight Center that concentrated on the stringent water quality requirements of long-term, manned spaceflight was the source for URC's process and catalyst to facilitate the destruction of perchlorate and nitrate in water. In addition to the funding from Marshall, URC received financial support from the U.S. Air Force for the elimination of environmental contaminants associated with aviation fuel, solvents, and soluble propellant and munitions by-products.

Well-versed in the areas of air and water purification, disinfection, sterilization, and regenerative life support, URC has developed catalysts and reactor systems that rapidly oxidize alcohols, ketones, amides, amines, aromatics, and halocarbons in water using dissolved oxygen as the oxidant at moderate temperatures and pressures. Carbon dioxide, water, and constituent inorganic species are the primary derivatives of these oxidation reactions. When perchlorate, nitrite, and nitrate ions are destroyed by this process, they become the oxygen source, and are catalytically reduced, forming innocuous chloride ions and nitrogen gas.

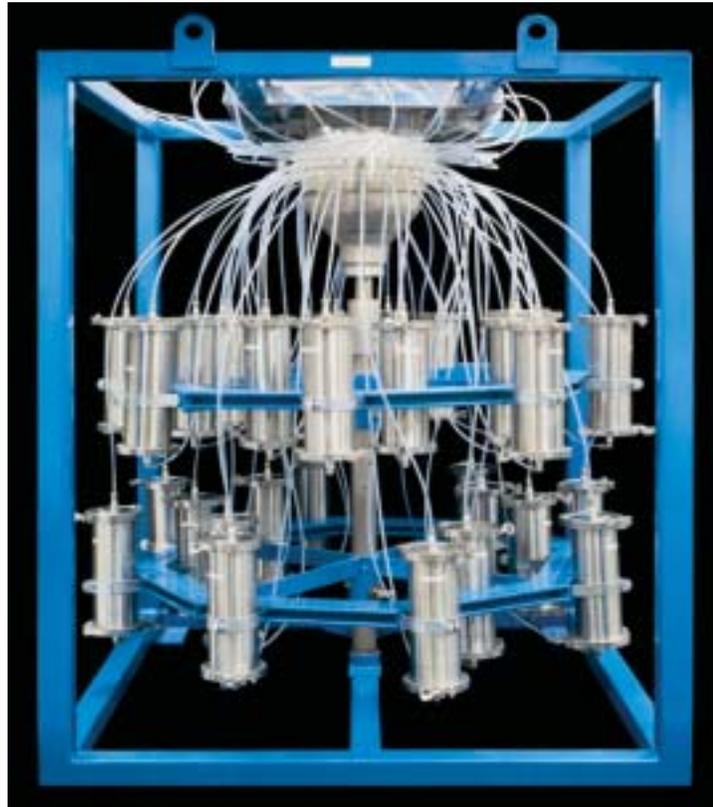
With support from Marshall, URC applied for U.S. and European patent protection for this unique reduction reaction process, as well as the necessary catalysts involved. URC also licensed the rights of this technology to the Pittsburgh, Pennsylvania-based Calgon Carbon Corporation for use with the company's perchlorate/nitrate remediation process, otherwise known as ISEP.[®] Calgon's ISEP process is a continuous ion exchange system that achieves high perchlorate and nitrate removal with minimal production of waste. This method was incorporated into Calgon's ISEP+[®] system, which is capable of eradicating perchlorate and nitrate in the waste brine, thereby allowing the waste brine to be recycled or safely discharged into the environment.

NASA sponsored a 7-month pilot study in which a prototype of the ISEP+ system successfully demonstrated the removal of perchlorate concentrations in water from as high as 1500 parts per billion (ppb) to less than 4 ppb, a non-detectable level. At the same time, perchlorate and nitrate ions in the ISEP regeneration

brine were also completely destroyed, verifying the applicability of this technology. As for its first commercial challenge, the ISEP+ system is demonstrating remarkable results in an ongoing effort to destroy perchlorate in the water at the site of a former perchlorate manufacturing facility.

The alliance between URC and Calgon fosters NASA's goals to continue solving the mysteries of the Earth and space while protecting the environment, its present population, and future generations to come. ❖

ISEP[®] and ISEP+[®] are registered trademarks of Calgon Carbon Corporation.



A prototype of Calgon Carbon Corporation's ISEP+[®] system successfully demonstrated the removal of perchlorate concentrations in water from as high as 1500 parts per billion (ppb) to less than 4 ppb, a non-detectable level.

Shedding Light on Solar Power

In the late 1970s, ENTECH, Inc., of Keller, Texas, developed a solar power concentrator for terrestrial applications that was spun into a concentrator for space in the early 1980s. Nearly 25 years later, the company has gone back to its terrestrial roots with a new concentrator that is a direct spinoff from its space technology.

In journeying back and forth between Earth and space, ENTECH formed strong business relationships with various U.S. Government agencies, including NASA, which expressed interest in the company's expertise and understanding of solar concentrators and solar energy conversion. Specifically, the company was building solar power concentrators using Fresnel lenses that efficiently convert the sun's energy into electricity by concentrating sunlight onto photovoltaic cells, or solar cells, which are non-mechanical devices made from silicon alloys. Sunlight is composed of particles of solar energy called photons, and when these particles strike a photovoltaic cell, they may be reflected, pass right through, or be absorbed. Only a portion of the absorbed photons provides energy to generate electricity.

ENTECH's Fresnel lens concentrators possess a shape error tolerance more than 200 times higher than other reflective concentrator approaches, making mass production, installation, and long-term operation in an outdoor environment far more practical than for other comparable systems. Additionally, by using air-cooled photovoltaic cells to convert concentrated sunlight to electricity, ENTECH is able to avoid all of the complexities associated with the fluids and conversion machinery used for solar thermal conversion.

For the past 2 decades, ENTECH has worked exclusively with Fresnel lens concentrators. As a result, the company developed two commercial solar array product lines: the SunLine Array for small power terrestrial applications, and the SolarRow Array for large power terrestrial applications. The SunLine product utilizes two concentrator modules, providing an output of roughly 800 watts under peak sunlight conditions, and is intended for remote and residential applications. On a much grander scale, the SolarRow product uses 72 concentrator modules in the world's largest two-axis sun-tracking structure, which is longer than a football field, according to ENTECH. SolarRows have an output of about 25 kilowatts each under peak sunlight conditions, and are designed to produce electricity at power plant capacity levels.

In the late 1980s, NASA's Glenn Research Center sponsored a **Small Business Innovation Research (SBIR)** contract with ENTECH, in which the company worked to mold its successful terrestrial concentrator technology into applications that would generate power for space missions. ENTECH's first application made use of small, dome-shaped Fresnel lenses to direct sunlight onto high-efficiency photovoltaic cells. After some key adjustments, the mini-dome lens array was flown as part of the U.S. Air Force/NASA Photovoltaic Array Space Power Plus Diagnostics (PASP Plus) flight experiment in 1994. This flight also included 11 other leading photovoltaic array technologies. According to ENTECH, its mini-dome lens array achieved the best performance and the least degradation of all 12 arrays in the year-long mission, which flew through the Van Allen Belts in a high-radiation elliptical orbit.

Due to their three-dimensional shape, the mini-dome lenses entailed construction by a batch molding process, which is naturally more costly than a continuous process. To overcome this



ENTECH, Inc.'s SolarRow Arrays are designed to produce electricity at power plant capacity levels.

disadvantage and meet the requirement for precise solar pointing in two axes, ENTECH started developing solar concentrator arrays for space using a line-focus lens that can be mass-produced by a continuous process.

This new technology, referred to as Solar Concentrator Array with Refractive Linear Element Technology (SCARLET), was created with support from Glenn and the Ballistic Missile Defense Organization, now officially known as the Missile Defense Agency (MDA). It was used to power the NASA/Jet Propulsion Laboratory Deep Space 1 spacecraft, which successfully completed two extraterrestrial rendezvous, first with asteroid Braille in July 1999, and later with comet Borrelly in September 2001. In addition to supplying power for the spacecraft, SCARLET was used to power the ion engine that enabled the probe to reach its two close encounter targets. The SCARLET array has won numerous honors, including the Schreiber-Spence Technology Achievement Award in 1999, and the prestigious NASA Turning Goals into Reality Award in 2001.

The ENTECH research team is currently testing a new ultra-light offspring of SCARLET, called the Stretched Lens Array (SLA), to be used for future space missions. Compared to the original unit, the SLA offers 50-percent higher power density and 300-percent better specific power, according to the company. In



2000, under a Space Solar Power contract with NASA's Marshall Space Flight Center, ENTECH created the first prototype panel of the new SLA technology, and submitted it for further testing at Glenn. The company is currently enhancing the SLA concept under an Advanced Cross-Enterprise Technology Development contract with Glenn, and is planning to deliver a four-panel demonstration unit within the next year.

With space-qualified hardware development efforts underway, research continues to improve the performance of the SLA concept. ENTECH set a world record by measuring over 27-percent net operational efficiency for a small SLA module in outdoor testing. To verify the accuracy of this world-record-level efficiency, the company sent the module to the Golden, Colorado-based National Renewable Energy Laboratory (NREL) for independent testing. NREL confirmed that the SLA technology set the record, despite the fact that the array was optimized for space, not Earth.

Upon further testing with advanced solar cell technology in 2001, ENTECH surpassed its previous record by measuring a 30-percent net operational efficiency for the SLA. The company, with support from the U.S. Department of Energy, believes that the SLA is the first solar device of any kind to break the 30-percent solar-to-electric conversion efficiency barrier in outdoor testing. The former world record for any type of solar device tested in an outside environment was a 29.4-percent efficiency rate, set in 1984 by a parabolic dish/Stirling engine unit. ENTECH is now actively developing its next-generation terrestrial concentrator products to incorporate the new lens and cell technology initially developed for space applications.

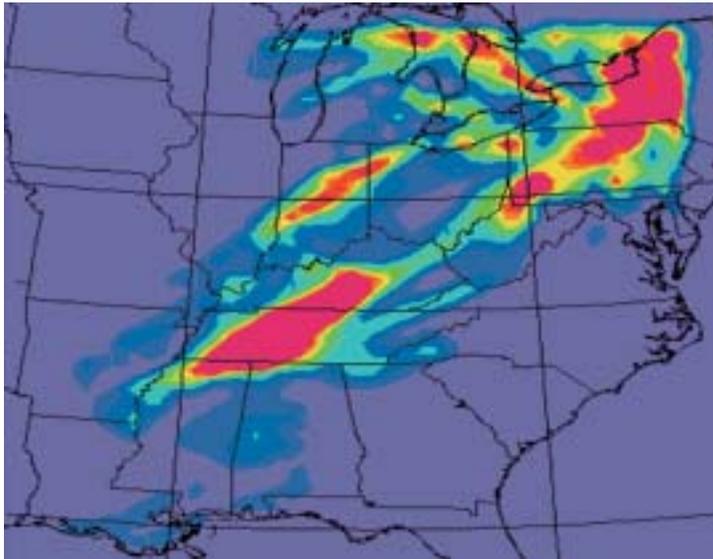
Building on this recent accomplishment, ENTECH hopes that its super-efficient concentrator technology will light the way for consumers and provide a significant contribution to the Nation's electricity supply for decades to come. ❖

The Stretched Lens Array set a world record for net operational efficiency in outdoor testing.

Smooth Sailing for Weather Forecasting

Individuals responsible for maritime, terrestrial, and aviation operations have a constant need for accurate weather forecasts. Advanced warnings of severe weather, such as tropical storms and hurricanes, can save time, money, and most importantly, lives. NASA's remote sensing technology and data contributed to a new product that dramatically increases the reliability of weather forecasting. Through a cooperative venture with NASA's Stennis Space Center and the U.S. Navy, WorldWinds, Inc., of Picayune, Mississippi, developed a unique weather and wave vector map using space-based radar satellite information and traditional weather observations. The product, called WorldWinds, provides accurate, near real-time, high-resolution weather forecasts.

WorldWinds initially derived part of its satellite information from the NASA Scatterometer (NSCAT) instrument. NASA's Jet



Using space-based radar satellite information and traditional weather observations, WorldWinds provides accurate, near real-time, high-resolution weather forecasts.

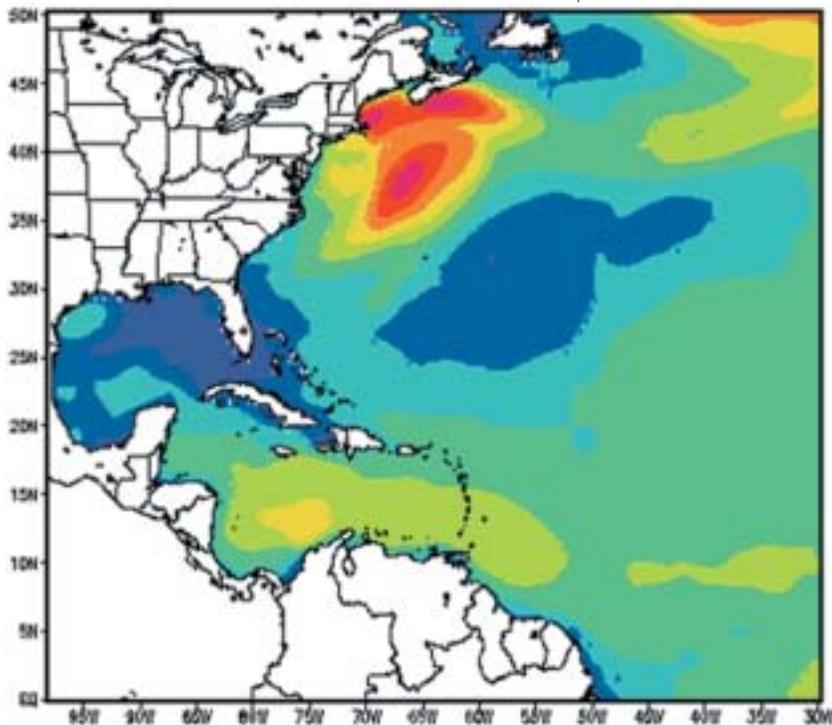
Propulsion Laboratory (JPL) designed and built the NSCAT in an effort to better understand global climate change and weather patterns, as well as to improve weather forecasts near coastlines. Scatterometers measure near-surface ocean wind vectors, which include both speed and direction, over the global oceans. These measurements are critical in determining regional weather patterns and global climate. Scatterometers gather this data by sending a constant stream of radar pulses toward Earth from an orbiting satellite. When the radar pulse reflects back off the ocean surface, some of its energy is scattered by small, wind-driven waves rippling across the sea. By measuring these changes in the reflected radar signals, engineers can deduce the speed and direction of the winds that caused the ocean waves. Scatterometers can acquire hundreds of times more observations of surface wind velocity each day than can ships and buoys. The NSCAT, flown on the Advanced Earth Observing Satellite (ADEOS) in 1996, yielded 268,000 measurements of ocean winds each day, covering more than 90 percent of Earth's ice-free seas. When the ADEOS satellite lost power 9 months after its launch, NASA replaced NSCAT with the Quick Scatterometer (QuikScat), which now provides data to WorldWinds.

After gaining access to the information generated from NSCAT, the WorldWinds team worked with JPL to learn how to derive wind vectors from the raw satellite data. WorldWinds pulls the QuikScat data from data taps at the National Oceanic and Atmospheric Administration's National Environmental Satellite, Data, and Information Service in Suitland, Maryland. It also pulls supplemental data from Stennis' Commander, Naval Oceanographic, and Meteorology Command Office. WorldWinds combines all of the wind, wave, and weather information acquired by the satellites with National Weather Service observations for input to numerical weather models. The models generate forecasts for wind, wave,

and weather variables for a period of 12 hours to 7 days. Measurements are available over most of the world's oceans, and two forecasts are provided daily. WorldWinds can forecast data down to the 1 km level, whereas the National Weather Service generally publishes forecast data from 110 km to 25 km. In one case, this level of specificity enabled WorldWinds to provide more accurate forecasts for a client towing an oil rig from Brazil to Houston, Texas.

Based at the Stennis Space Center, WorldWinds, Inc., is a member of the Mississippi Space Commerce Initiative, a consortium with the goal of developing the remote sensing industry in the state by commercializing technology developed at Stennis. The WorldWinds product was developed for commercial and scientific users. In addition to weather forecasting, the product's applications include maritime and terrestrial transportation, aviation operations,

precision farming, offshore oil and gas operations, and coastal hazard response support. Target commercial markets include the operational maritime and aviation communities, oil and gas providers, and recreational yachting interests. Science applications include global long-term prediction and climate change, land-cover and land-use change, and natural hazard issues. Commercial airlines have expressed interest in the product, as it can provide forecasts over remote areas, such as South America. WorldWinds, Inc., is currently providing its product to commercial weather outlets. ❖



WorldWinds combines wind, wave, and weather information with National Weather Service observations for input to numerical weather models. The models then generate forecasts for a period of 12 hours to 7 days.

Powering the Future

New engine technology from Kennewick, Washington-based Stirling Technology Company (STC) is paving the way for the use of more efficient power systems for NASA deep space missions, while also providing cleaner, more efficient power here on Earth. The technology stems from the innovative work of Robert and James Stirling, who invented the Stirling engine in 1816. The technology has come a long way from the original 1800s invention, with STC contributing extensively to its development. As part of U.S. Government space and terrestrial power research, NASA's Glenn Research Center supported many of the company's efforts through various **Small Business Innovation Research (SBIR)** and other contracts. Glenn's involvement with STC, spanning more than 20 years, includes work on free-piston Stirling engines, small Stirling radioisotope power systems, and related component technologies.

STC developed the RG-350, a Stirling convertor (Stirling engine with a linear alternator), using components from separate Goddard Space Center and U.S. Army Natick SBIR contracts. Glenn engineers demonstrated the use of the RG-350 convertor to power a Hall effect electric thruster. Together, these two technologies operated as an integrated system for the first

time, providing a path to lower mass and higher efficiency propulsion systems for future NASA deep space missions. Primary Glenn Stirling activity is focused on supporting the Department of Energy development of a high-efficiency, 100-watt class Stirling Radioisotope Generator (SRG) for NASA deep space and Mars rover applications. STC is developing the Stirling convertor for the SRG.

Based on the RG-350, STC commercialized a product line of Stirling cycle generator sets, known as RemoteGen,TM with power levels ranging from 10W_c to 3kW_c. Under SBIR agreements with Glenn, the company refined and extended the capabilities of the RemoteGen family of convertors.

The RemoteGen engines offer numerous commercial benefits. They can provide power in remote locations from Alaska to Zimbabwe by efficiently producing electricity from multiple-fuel sources, such as propane, alcohol, gasoline, diesel, coal, solar energy, agricultural waste, or wood pellets. Essentially, the engines utilize any fuel source that can create heat, enabling the end-user to choose the most appropriate fuel source available. Remote or distributed power generation also eliminates the need for costly transmission lines and allows utility co-ops to increase their revenues as a power provider.

RemoteGenTM engines use multiple-fuel sources to efficiently provide power to remote locations.



In addition to the multi-fuel capabilities, the engines operate without friction, wear, or maintenance as a result of STC's design approach. One RemoteGen engine demonstrated over 70,000 hours (8 years) of continuous, maintenance- and degradation-free operation. The continuous operation reduces the capital and related maintenance costs associated with batteries and over-sizing of conventional generators to charge a bank of batteries. These abilities pave the way for self-powered appliances, such as refrigerators and furnaces, that continue to operate during an electrical blackout.

STC developed its products with the environment in mind. The fuels used for RemoteGen have ultra-low exhaust emissions, and converting biomass and agricultural wastes into fuel provides a cost-effective and environmentally friendly energy solution. The engines are hermetically sealed and use no oil or other fluids that can damage the environment. Implementing these engines will not alter the landscape either, since building and maintaining power lines becomes unnecessary. Sound pollution is also avoided, because the engines operate virtually silent.

The reliability and environmental advantages led to the selection of the RemoteGen engines for residential combined heat and power applications by the consortium ENATEC microcogen BV. ENATEC licensed the rights to a 1kW_e RemoteGen engine and integrated it with a residential boiler. The exhaust heat from the engine and burner provides hot water for a hydronic heating system. The integrated system can provide enough electricity and hot water for a typical European home. By producing electricity in the home from natural gas, ENATEC estimates a 50-percent reduction in CO₂ and NO_x emissions, as well as a 15-percent reduction in primary energy use. Electricity not used in the home is returned to the utility grid. Mass production of these systems is slated for 2004.

There are numerous U.S. applications for RemoteGen as well. Uses currently being evaluated by STC clients include quiet, pollution-free generators for RVs and yachts, power for cell phone towers remote from the grid, and off-grid residential power variously using propane, ethanol, and solid biomass fuels. Two domestic utilities and the State of Alaska Division of Energy are involved with these applications. In addition, one utility and the National Renewable Energy Laboratory are evaluating a solar dish concentrator version with excellent potential for powering remote irrigation pumps.

With energy and environmental concerns rising, STC is powering the way for more energy savings and less pollution. ❖

RemoteGen™ is a trademark of Stirling Technology Company.



Stirling Technology Company's design approach enables RemoteGen™ engines to operate without friction, wear, or maintenance.

Vexcel Spells Excellence for Earth and Space

A remote sensing satellite ground station based on the turnkey system specially designed for direct reception and processing of data from NASA's Terra satellite and follow-on missions is now commercially available to users in search of a quick and affordable means to capture geographical information. To date, satellite ground stations have appealed to renowned scientific groups, academic institutions, and commercial users that are interested in remote sensing data acquisition, not to mention the potential economic incentives they could reap from direct reception. Despite this appeal, the high costs associated with obtaining and operating a remote sensing ground station make ownership an implausible option for some national remote sensing centers worldwide.

An economical solution to this problem emerged from a **Small Business Innovation Research (SBIR)** contract involving NASA's Stennis Space Center and Vexcel Corporation of Boulder, Colorado. With assistance from Stennis, Vexcel was able to strengthen the properties of its Apex Ground Station,TM an

affordable, end-to-end system that comes complete with a tracking antenna that permits coverage within an approximate 2,000-kilometer radius of its location, a high speed direct-to-disk data acquisition system that can download information from virtually any satellite, and data processing software for virtually all synthetic aperture radar (SAR) and optical satellite sensors. Vexcel also offers training, installation, and ongoing support with the ground station package. Furthermore, transportable systems, larger and smaller antennas, and processing capabilities for a variety of sensors are also available options. Apex Ground Station customers can select processing capabilities for a range of Earth Observation Satellites, including LANDSAT, MODIS, and Quickbird.

Vexcel is using an Apex system linked to the Terra satellite to help scientists and NASA personnel measure land and ocean surface temperatures, detect fires, monitor ocean color and currents, produce global vegetation maps and data, and assess cloud characteristics and aerosol concentrations. The systems have been sold to customers worldwide, including the Alaska SAR Facility, a NASA Distributed Active Archive Center that acquires, processes, archives, and distributes satellite SAR data for the U.S. Government and research communities.

In addition, Vexcel is providing NASA with close-range photogrammetry software for the International Space Station. The technology, commercially available as FotoG,TM was developed with SBIR funding and support from NASA's Jet Propulsion Laboratory (JPL). Commercially, FotoG is used for demanding projects taken on by engineering firms, nuclear power plants, oil refineries, and process facilities. It offers engineers and computer-aided design (CAD) professionals with an in-house capability to process photographic images to gain accurate field measurements and create three-dimensional, as-built CAD models.



Vexcel provides complete remote sensing ground stations to receive and process data from imaging satellites.

NASA is currently utilizing FotoG to extract complex measurements from digital images for a host of projects onboard the Space Station. Beyond aerospace, FotoG's application areas include process and manufacturing, petrochemical, power, pulp and paper, equipment design and installation, ship-building, construction, X-ray evaluation, forensics, cinematic special effects, architecture, and automotive.

For example, FotoG contributed to the reengineering of equipment used to process radioactive material. In this application where two pieces of the apparatus were not produced to design specifications, the processing equipment only had an operating life of 2 years, compared to the originally intended life expectancy of over 10 years. Thus, it became necessary to manufacture additional pieces identical to the prototype. Vexcel's photogrammetry application determined critical dimensions and other high-precision measurements, and then produce an accurate 3-D model of the equipment in just 2 hours. A version of Vexcel's

close-range photo measurement system was also used to create virtual 3-D backdrops for a high-tech science fiction film.

Vexcel was founded in 1985 by a photogrammetrist who previously worked at JPL. John Curlander, Vexcel's president and chief executive officer since 1992, also worked at JPL for many years, prior to joining the company. Vexcel was recently selected to build Florida's new Center for Southeastern Tropical Advanced Remote Sensing, a state-of-the-art satellite data reception and analysis facility to be situated at the University of Miami's Rosenstiel School of Marine and Atmospheric Science. Supported by NASA, the new facility is slated to be fully operational by October 2002. ❖

Apex Ground Station™ and FotoG™ are trademarks of Vexcel Corporation.



A 3-D CAD model of a refinery from photography using Vexcel's FotoG™ close-range photogrammetry software.

A Data-Driven Solution for Performance Improvement

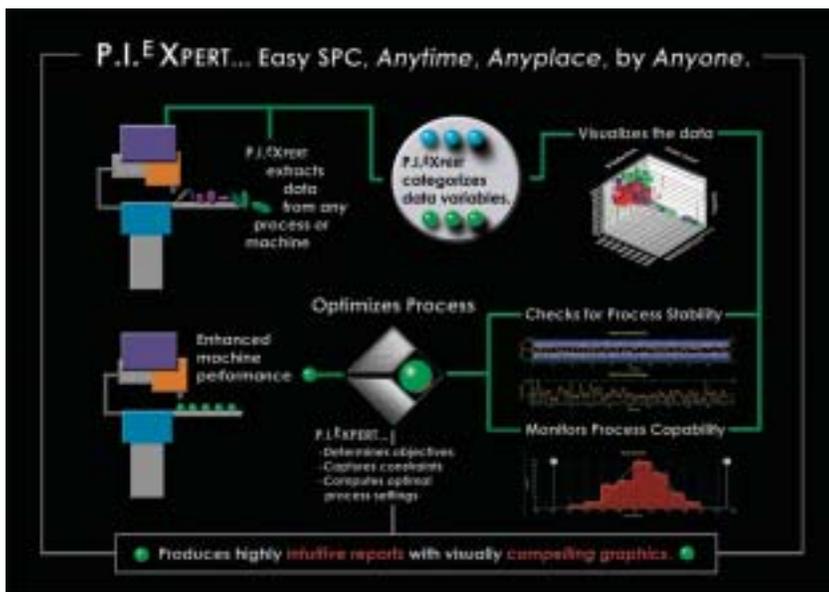
Intelligent software utilized by NASA to monitor and improve Space Shuttle maintenance operations is now available for the very first time to companies seeking to enhance overall performance. Marketed as the “Software of the Future,” Optimal Engineering Systems’ P.I.^EXPERT™ technology offers statistical process control (SPC) and optimization techniques that are critical to businesses looking to restructure or accelerate operations in order to gain a competitive edge.

Based in Daytona Beach, Florida, Optimal Engineering Systems was founded by three former Embry-Riddle Aeronautical University professors who recognized a growing need for a versatile software application that can provide unparalleled SPC analysis. The founding professors went to work on a conceptual platform for process monitoring and improvement, and the potential impact of their vision soon caught the attention of NASA.

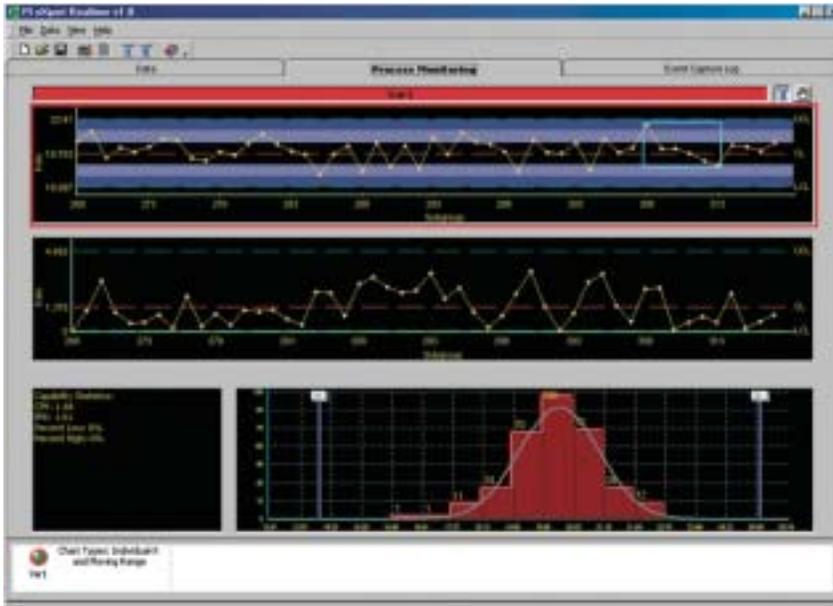
Through a Phase I **Small Business Innovation Research (SBIR)** contract with NASA’s Kennedy Space Center, Optimal Engineering Systems obtained the funding and aid necessary to develop a prototype of the process monitoring and improvement software. Completion of this prototype demonstrated that it was possible to integrate traditional statistical quality assurance tools with robust optimization techniques in a user-friendly format that is visually compelling.

Kennedy expressed satisfaction with Optimal Engineering Systems’ work on the prototype, and granted the company additional funding through a Phase II SBIR contract to create a version specifically for NASA’s use. As a result, Kennedy engineers have been employing P.I.^EXPERT since February 2001, to ensure that Shuttle maintenance operations are run more efficiently.

One Kennedy project that yielded considerable savings concentrated on the structural bonding process used on a Shuttle orbiter. Over a period of time, Kennedy workers realized that a significant number of bonds required rework because the shear strength of the components being attached to the orbiter was less than the minimum allowable shear strength for a bond. A preliminary analysis showed that one particular bonding agent was responsible for most of these failures. For this particular adhesive, over two-thirds of the bonds failed, necessitating removal and replacement of the component, which could potentially further damage the orbiter, making the problem even more costly. Based on the preliminary analysis, a set of designed experiments was implemented in a laboratory setting over a 4-day period to determine the most effective bonding method for the orbiter’s components. In order to measure the conditions that resulted in the maximum pull strength of the bond, Kennedy scientists and engineers depended on P.I.^EXPERT. The software application identified the problems and offered a solution, allowing the engineers to decrease the number of adhesive failures from more than 66 percent to less than 10 percent.



P.I.^EXPERT™ automatically imports data, selects the appropriate technique for analyzing the data, computes the solution, interprets the results, and prepares a fully formatted report.



The software can interpret data with scatter plots, box plots, histograms, pie charts, and bar charts that are visually attractive and easy to comprehend.

Optimal Engineering Systems' crowning achievement with NASA prepared the company for launch of the P.I.^{EXP}ERT technology within the commercial sector. This software, using an expert system knowledge base, allows the user to determine objectives, capture constraints and out-of-control processes, predict results, and compute optimal process settings. The tool takes just minutes to install, and is capable of automatically importing data from other software, such as Excel, Access, Oracle,[®] SQL, as well as text files, thereby reducing the burden of data entry. With point-and-click accessibility, P.I.^{EXP}ERT is able to generate professional Microsoft[®] Word or HTML reports, complete with formatted graphics, tables, and narrative content. Furthermore, the software can capture dynamic, 5D graphics that are fully rotatable, with zoom and edit features, and can interpret data with scatter plots, box plots, histograms, pie charts, and bar charts that are visually attractive and easy to comprehend.

P.I.^{EXP}ERT also possesses real-time functionality that can monitor up to 20 processes simultaneously. This option can be applied across an

entire organization or a manufacturing plant. For instance, a plant manager may select specific processes to be monitored, and the status of each of these processes is presented in a simple color-coded format. The manager may then view the current data stream exactly how it is presented on the shop floor, in addition to receiving audio alarms and e-mail alerts when corrective action is needed.

The software has the ability to provide improvement solutions for a variety of fields, including service organizations and health care facilities. Whether the goal is reducing costs, maximizing profits, saving lives, or producing quality products, Optimum Engineering Systems' P.I.^{EXP}ERT technology provides companies with the luxury of focusing solely on process improvement as an alternative to being preoccupied with laborious data analysis. ❖

P.I.^{EXP}ERT[™] is a trademark of Optimal Engineering Systems.

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Getting the Bigger Picture With Digital Surveillance

As the digital age continues to evolve at breakneck speed, analog technologies such as audio recorders, VCRs, and tape cassettes are quickly becoming things of the past. Such analog components can be severe liabilities in an industry where speed, accuracy, and clarity are essential to daily operations. This especially holds true for financial institutions, banking facilities, and other high-security/surveillance areas that rely heavily on real-time data to continuously monitor monetary transactions, as well as customer behavior.

To keep in step with the needs of these entities, Diebold, Inc., has crossed over the digital threshold with new observation technology that the company believes will transform the surveillance world in the same manner that the compact disc revolutionized the music industry. Diebold's answer to analog stemmed from a Space Act Agreement with NASA's Glenn Research Center, in which the North Canton, Ohio-based company acquired the exclusive rights to video observation technology that was designed for high-speed applications and does not require human intervention.

Glenn developed the Video Event Trigger and Tracking System technology to accelerate video image analysis for various ongoing and future space applications. For instance, microgravity experiments aboard the Space Shuttle or the International Space Station (ISS) require high-resolution, high frame-rate video

technology to replace photographic movie film, which is too heavy and bulky, and cannot be processed in space. While still being considered for use on a variety of future experiments scheduled for the ISS, NASA's trigger and tracking system has the capability to process images at up to 200 frames per second, a faster rate than most video systems currently on the market.

Diebold, a global leader in providing integrated self-service delivery systems and services, implemented the patented trigger and tracking technology into its AccuTrack™ digital, color video recorder, a state-of-the-art surveillance product that uses motion detection for around-the-clock monitoring. AccuTrack captures digitally signed images and transaction data in real-time, and stores this information on a multi-gigabyte hard drive. This process replaces the onerous tasks involved in operating a VCR-based surveillance system, and subsequently eliminates the need for central viewing and tape archiving locations altogether. Even more, AccuTrack can transmit stored images and data to virtually any Web-enabled laptop or desktop personal computer. This feature allows for immediate access to valuable evidence anywhere in the world, including instances of fraud and crime caught on AccuTrack's monitoring cameras. In the event of a robbery, photos of the suspect can be immediately sent electronically to the police and the media.

With up to 24 camera inputs and programmable camera sequencing, the AccuTrack can monitor an entire branch facility, including four automated teller machines (ATMs), multiple teller lines, and new account areas, all from one central location. The system also allows banks to handle Regulation E claims regarding unauthorized ATM withdrawals on the spot. Such claims are reviewed immediately by customer service representatives who use the digital recorder to access relevant transaction photos and data. The end result is less time spent on investigating fraud and a lower limit of acceptable losses.



The AccuTrack™ digital, color video recorder uses motion detection for around-the-clock monitoring.

In addition to receiving assistance from NASA, Diebold sought advice from security personnel across the country to develop AccuTrack. During an alpha testing phase in 1996, the digital recorder flourished for the Bank of Hawaii, allowing the institution to perform certain operations in just “seconds,” compared to the 2 to 3 days previously required.

The first commercial AccuTrack units were installed at the USAlliance Federal Credit Union in Rye, New York. Since AccuTrack is compatible with existing general surveillance equipment, USAlliance was able to use its existing cameras and wiring in conjunction with Diebold’s digital technology to monitor ATMs serving customers in remote locations.

In a rather unusual situation, AccuTrack was able to determine whether a natural disaster had affected a bank in Fort Worth, Texas. The First State Bank of Texas installed AccuTrack recorders throughout its branches in the Fort Worth/Dallas metropolitan area in an effort to phase out analog systems. In March of 2000, a series of tornadoes struck the city of Fort Worth, and media reports indicated that a glass building located just a few blocks away from the bank was shattered by one of the funnel clouds that swept through the region. Following the disaster, police and emergency response personnel shut down a 12-square-block area of the city. Unfortunately, officials from the First State Bank of Texas had no way of knowing if their vaults, personal computers, safe deposit boxes, and other bank property were scattered among the city streets.



After unsuccessful attempts to get to the bank that evening and the next day, the president traveled to the headquarters office in Denton, where he logged on to the Ft. Worth branch’s AccuTrack recorder. To the president’s relief, AccuTrack’s lobby camera showed that the building’s glass windows were still intact, the teller line cameras showed that papers and files were unscathed and in order, and the drive-through camera showed that there was no structural damage to the building.

Regardless of the scenario, whether it be a minor transaction error or a destructive tornado, it is safe to say that AccuTrack has it covered from all angles. ❖

AccuTrack™ is trademark of Diebold, Inc.

The state-of-the-art technology can transmit stored images and data to virtually any Web-enabled laptop or desktop computer in the world.

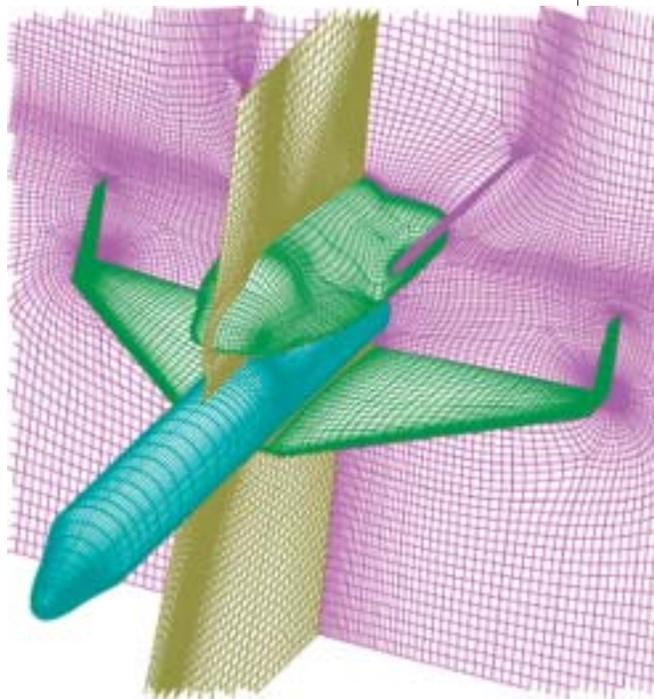
Getting a Grip on Grid Generation

Program Development Company of White Plains, New York, is spinning a web around engineering and manufacturing industries with a mesh-generation tool that provides smooth lines throughout the entire volume of a design, no matter how geometrically complex it may be. The company's GridPro technology is an automatic, object-oriented, multi-block grid generator that provides ease of use, high quality, rapid production, and parametric design. When paired with a 3-D graphic user interface called az-Manager, GridPro presents users with an extremely efficient, interactive capability to build topology, edit surfaces, set computational fluid dynamics (CFD) boundary conditions, and view multi-block grids.

The origins of the GridPro technology date back to a 1989 **Small Business Innovation Research (SBIR)** contract with NASA's Glenn Research Center, in which Glenn was seeking a multi-block grid generation program that would

run automatically upon identifying a pattern of grid blocks supplied by a user. Moreover, Glenn desired a system with recognition capabilities to make the necessary adjustments to patterns that were not created exactly to scale. With the Research Center's support, Program Development responded to these needs with a software tool that optimizes grids to be smooth and orthogonal throughout, and to be clustered near locations of high boundary curvature. At the heart of this technology is an intelligent code that frees users from error-prone judgment and allows them to construct high-quality grids with a few clicks of a mouse.

GridPro was purchased by Glenn Research Center and Ames Research Center, and was integrated to work with NASA's own CFD analysis codes, namely GlennHT and WIND CFD. The technology was also used by Glenn to successfully address a recent case involving several hundred cooling holes in a complex turbomachinery blade. GridPro resolved the



Program Development Company's GridPro technology was used to create the conceptual design of a two-stage-to-orbit launcher.

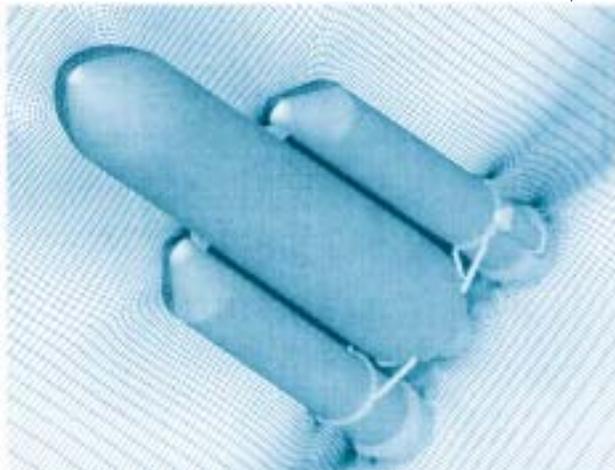
cooling hole problems by producing a high-quality grid in significantly less time than would be required for most grid generators.

According to Program Development, a two-stage-to-orbit vehicle can be created in just 1 day using GridPro. The company attributes this rapid processing to its powerful topology engine, and graphically oriented, user-friendly tutorials. Once a topology is created, it can be used as a template for future applications, therefore expediting the process for further design work.

GridPro also differs from most grid generators on the market, because it does not use surface projection schemes. Models that employ such methods must undergo the painstaking process of creating a new grid every time the surface on the geometry is altered. With GridPro, a user simply needs to replace the

geometry in the topology template, and restart the previous grid file to create an entirely new grid. This advanced feature translates into a dramatic reduction in design analysis time. To reduce time even further, GridPro also enables the user to group link topology files and weld independently created grids into one large grid.

GridPro is currently used in many engineering fields, including aerospace, turbo-machinery, automotive, and chemical industries. Customers include Dow Chemical, Solar Turbines, Concepts-Northern, Toshiba, and Mitsubishi. Academic institutions such as Penn State University, Rutgers University, University of Illinois, and Stanford University also rely on GridPro. ❖



The multi-block grid-generator provides smooth lines throughout the entire volume of a design, despite geometrical complexities.

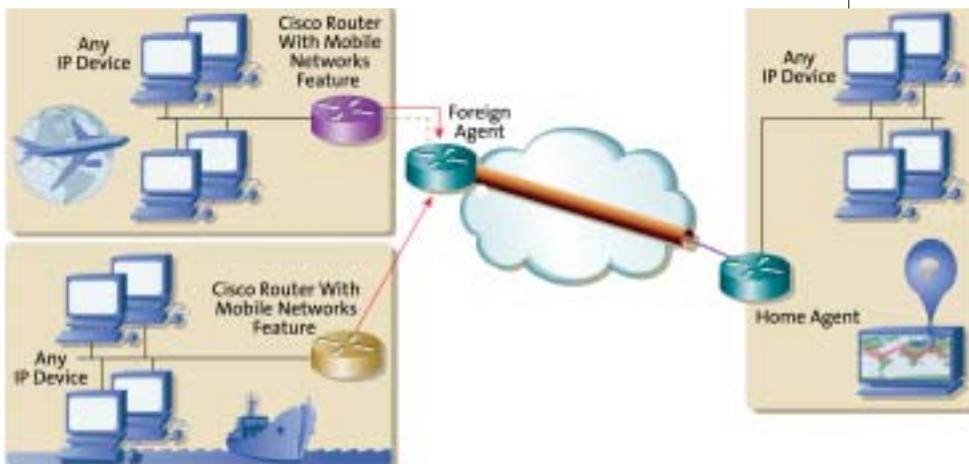
Continuously Connected With Mobile IP

With cellular phones, laptops, and personal digital assistants (PDAs) more popular than ever, wireless service providers are racing to keep up with customers' needs. Being able to access information on the Internet from a home or office computer alone is no longer sufficient, as more and more people are depending upon Internet Protocol (IP) devices in laptops and PDAs to stay connected. While cellular phones have built-in technology that picks up and carries the phone's signal as it moves from one coverage area to another, IP devices have not been as fortunate. In response to this, Cisco Systems of San Jose, California, worked with NASA's Glenn Research Center to make IP devices as mobile as their cellular counterparts.

When a computer or device communicates over the Internet, it has an assigned IP address which uniquely identifies it from other devices linked to the Internet. IP routing is based on stationary IP addresses, similar to the way that postal deliveries are made to a fixed address on an envelope. However, if a device roams away from its home network and is no longer reachable using normal IP routing, its active session is terminated. Cisco developed Cisco Mobile Networks in its internetwork operating system software (Cisco IOS® Software) to solve this problem. With this innovation, a Cisco router and its connected IP devices can roam across network boundaries and connection types. Because a mobile user is able to keep the same IP address while roaming, a live IP connection can be maintained without interruption.

According to William D. Ivancic, a senior research engineer at Glenn, "Cisco's Mobile Networks technology enables formation-flying craft to correlate information and talk with each other, even as they move across different systems." Glenn jointly tested the technology with Cisco, and is working to use it on low-earth-orbiting research craft. NASA may also utilize the technology for near-planetary observation and sensing spacecraft. Ivancic explains, "For our work, the continuous connectivity is key. Additionally, Cisco's solution does not require special software, equipment, or anything unique behind the router; any device that runs IP will work. This provides unprecedented flexibility."

With Cisco's Mobile Networks functionality now available in Cisco IOS Software release 12.2(4)T, the commercial advantages and benefits are numerous. The technology can be applied to markets such as public safety, military/homeland security, emergency management services, railroad and shipping systems, and the automotive industry. The technology will also allow ambulances, police, firemen, and the U.S. Coast Guard to stay connected to their networks while on the move. The real-time connectivity to hospitals may help to save countless lives. In the wireless battlefield, the technology will provide rapid infrastructure deployment for U.S. national defense. For those seeking convenience, airline passengers utilizing Cisco Mobile Networks can fly all around the world with a continuous Internet connection. The same holds true for train and cruise passengers. With continuous connectivity, everyone benefits. ❖



Cisco IOS® Software is a registered trademark of Cisco Systems.

Cisco Mobile Networks allows a Cisco router and its connected IP devices to roam across network boundaries and connection types while maintaining a live IP connection without interruption.

A System for Planning Ahead

A software system that uses artificial intelligence (AI) techniques to help with complex Space Shuttle scheduling at NASA's Kennedy Space Center is now commercially available to private industry. Stottler Henke Associates, Inc. (SHAI), of San Mateo, California, is marketing its automatic scheduling system, known at Kennedy as the Automated Manifest Planner (AMP), to industries that must plan and project changes many different times before the tasks are executed. The system creates optimal schedules while reducing manpower costs.

Planning and scheduling NASA Space Shuttle missions is no small task. The complex, knowledge-intensive process, begun anywhere from 5 to 10 years prior to a launch, requires the expertise of experienced mission planners. Some of the many factors that the long-term plans must reflect include the resources required, constraints, work shift requirements, intervals between launches, and maintenance issues.

In order to ease some of this workload, Kennedy granted a **Small Business Innovation Research (SBIR)** contract to SHAI in 1992 to develop a system to automate and maintain the long-term Shuttle processing schedule known as the "mission manifest." The resulting AMP product enables expert Shuttle schedulers to input their knowledge to create a working automatic scheduling system. In contrast, personnel unfamiliar with long-term scheduling can maintain the system without the years of training that were previously required to handle such a task. For the past 8 years, AMP has been maintaining the mission manifest, performing advanced scheduling studies, and producing manifest reports for all NASA field centers on a daily basis. Kennedy also uses AMP to schedule the short- and long-term external tank/solid rocket booster processing in a much faster and more accurate manner than the previous manual process.

The Automated Manifest Planner makes scheduling decisions based upon resource limitations and other constraints.

End-users find that AMP is readily adaptable. Using information entered into the system by expert planners, the system automatically makes scheduling decisions based upon resource limitations and other constraints. It provides a constraint authoring system for adding other constraints to the scheduling process as needed. An extremely flexible and user-friendly tool, AMP plans orders of magnitude faster than existing tools. One user reported performing over 100 planning studies in a year, a task that would have been impossible without AMP.

AMP is also adaptable to assist with a variety of complex scheduling problems in manufacturing, transportation, business, architecture, and construction. In cases where scheduling different pieces of equipment that work together impacts rates and costs, AMP can be particularly helpful. This type of scheduling is common in vehicle assembly plants, batch processing plants, semiconductor manufacturing, printing and textiles, surface and underground mining operations, and maintenance shops.

For most of SHAI's commercial sales, the company obtains a service contract to customize AMP to a specific domain and then issues the customer a user license. Current commercial sales of the product total \$400,000, exceeding NASA's SBIR investment. ❖



Quick Fix for Managing Risks

The critical components of a risk analysis software package intended for creating, analyzing, and communicating quantitative models have been integrated into a new system that is helping NASA's Kennedy Space Center manage and balance major tasks for Space Shuttle ground processing.

Under a Phase II **Small Business Innovation Research (SBIR)** contract, Kennedy and Lumina Decision Systems, Inc., of Los Gatos, California, jointly developed the Schedule and Cost Risk Analysis Modeling (SCRAM) system, based on a version of Lumina's flagship software product, Analytica.® Acclaimed as "the best single decision-analysis program yet produced" by *MacWorld* magazine, Analytica is a "visual" tool used in decision-making environments worldwide to build, revise, and present business models, minus the time-consuming difficulty commonly associated with spreadsheets. Lumina contends that Analytica helps users to visualize problems with a clarity and power "far beyond what is possible in a spreadsheet."

With Analytica as their platform, Kennedy and Lumina created the SCRAM system in response to NASA's need to identify the

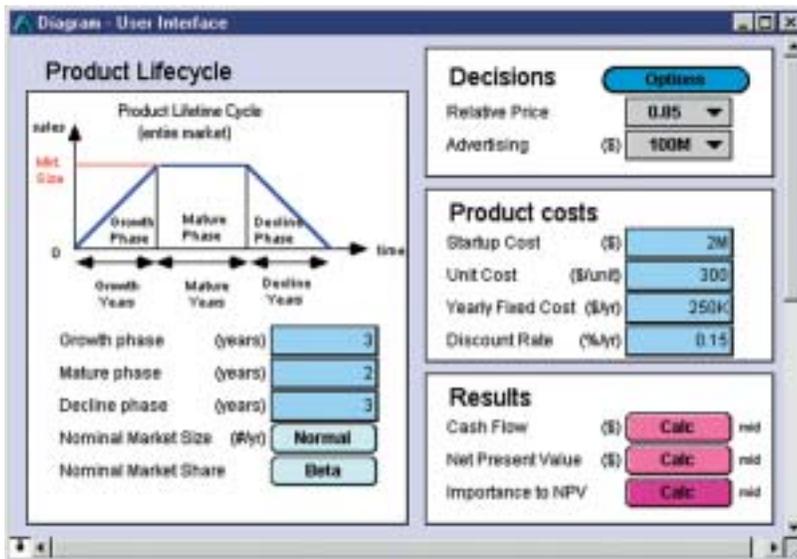
importance of major delays in Shuttle ground processing, a critical function in project management and process improvement. Landing-to-launch ground processing between Shuttle missions, also known as Shuttle turn-around, is a highly complex cycle that includes approximately 1,000 major processing tasks arranged around 24 subsystems. Roughly half of these tasks must be completed for every Shuttle turn-around, while the remaining tasks include periodic maintenance and inspection, and duties to handle special problems and mission-specific processing requirements.

With Kennedy being fully accountable for all aspects of Space Shuttle ground processing—including the testing and checkout of the three major Shuttle components: the orbiter, the external tank, and the solid rocket boosters—a new system was needed to replace its existing risk analysis tools, which provided constrained and limited modeling capabilities.

SCRAM methodologies were successfully implemented at Kennedy to improve the risk management processes, and NASA considered the new technology to be a significant improvement to the state-of-the-art in schedule and cost

Analytica® is a visual software tool for creating, analyzing, and communicating quantitative business models.





Analytica® contains built-in functions that allow for the creation of a user control panel in minutes. Key inputs and outputs can be organized in one place so that users can quickly explore model behavior without navigating the model structure.

risk analysis, due to its ability to create and analyze realistic models of schedule variables (task lengths).

As part of the SCRAM development project, Lumina designed a version of Analytica called the Analytica Design Engine (ADE) that can be easily incorporated into larger software systems. ADE was commercialized and utilized in many other developments, including web-based decision support. For example, the design engine technology was used to power Ask Jeeves, Inc.'s Jeeves Purchase Advisor, an online assistance tool that helps consumers make informed purchase decisions that best suit their individual needs on products such as digital cameras or running shoes.

Resources for the Future, a nonprofit, non-advocacy research organization based in Washington, D.C., used the design engine technology to

facilitate a U.S. Department of Energy assessment of the 1990 Clean Air Act Amendments. Decision Strategies, Inc., of Cumming, Georgia, also used ADE to develop interactive flow charts models in record time, saving a customer \$15 million. Further applications include economic analysis of the cost-effectiveness of pollution-control technologies for fossil-fuel power plants, selecting a portfolio of research and development projects to maximize return and balance risk for aerospace and pharmaceutical companies, and forecasting needs for hospital beds and healthcare resources. ❖

Analytica® is a registered trademark of Lumina Decision Systems, Inc.

Virtually Out of This World!

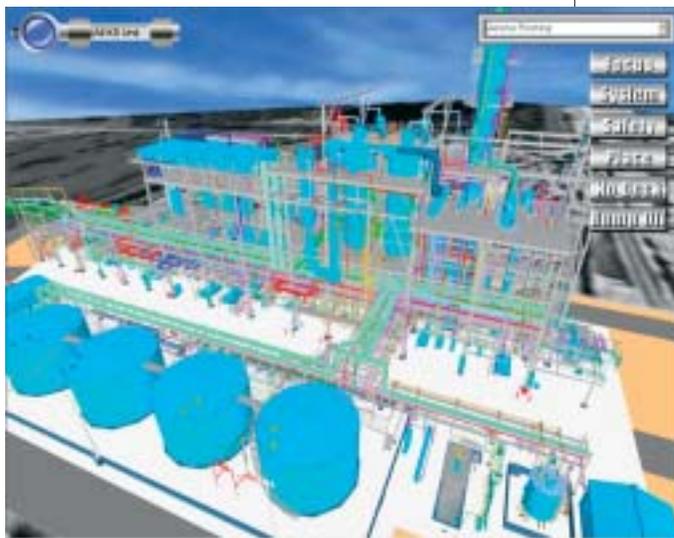
Virtual reality is much more than advanced entertainment for video game enthusiasts—the technology is proving its value both on Earth and in space. NASA-developed virtual reality software designed to explore Mars is now helping to build complex facilities before even breaking ground.

NASA's Ames Research Center developed the Mars Map software to guide scientists through the 1997 Mars Pathfinder mission by creating a three-dimensional landscape of the planet. With a map of Mars' surface, NASA mission controllers planned and executed their mission using the model as a point of access and control. The information from Mars Map allowed scientists and operations personnel to command and control remote robotic spacecraft within a virtual environment. The software proved to be critical to the mission's success, since virtual models of Mars' contours and geography were needed to effectively deploy the Mars Rover.

Just as the Pathfinder mission benefited from the Mars Map software, the same technology now aids owners and operators of large, complex industrial facilities who need an intelligent model of their facilities to integrate with their other systems for planning and executing their missions. Therefore, Ames granted Reality Capture Technologies (RCT), Inc., of San Jose,

California, a license to further develop the software platform, bringing the technology back to Earth. RCT provides enterprise software to streamline the efficiency and effectiveness of industrial facilities, speed startup time to production, reduce life-cycle costs, and help create a safer working environment. The company incorporated NASA's innovation into software that uses the Virtual Plant Model (VPM)[™] to structure, modify, and implement the construction sites of industrial facilities, as well as develop, validate, and train operators on procedures.

The VPM orchestrates the exchange of information between engineering, production, and business transaction systems. This enables users to simulate, control, and optimize work processes while increasing the reliability of critical business decisions. Engineers can complete the construction process and test various aspects of it in virtual reality before building the actual structure. With virtual access to and simulation of the construction site, project personnel can manage, access control, and respond to changes on complex constructions more effectively. Engineers can also create operating procedures, training, and documentation.



Using RCT's products, engineers can complete the construction process and test various aspects of it in virtual reality before building the actual structure.

Just as NASA used Mars Map to navigate the Red Planet, facility operators can use the VPM to learn how to better “pilot” the sophisticated and expensive industrial plant. According to RCT chief executive officer Ted Blackmon, “What makes this software even more unique is how simple it is. It is almost like a video game where you hold a joystick and walk around making sure everything is working right.” In fact, the company’s promise to operators and construction foremen is, “If you can play an arcade game, you can use our technology.”

Within the VPM, RCT’s ConstructSim™ product provides the simulation and optimization of construction sequences to drive the scheduling process and automate the production of work packages. Benefits include data access to those who need it when they need it; improved business decisions using a real-time model and construction schedule of the production plant; leveraged and maximized existing investments in information technology; and a significantly lowered cost of systems integration and maintenance. Moreover, ConstructSim automatically and dynamically produces optimized work packages that reduce construction time and cost.

Another RCT product, OpSim™ works with the VPM by making the real-time simulation of a plant’s start-up, shut-down, operating, and maintenance procedures readily available to plant operators. Similar to pilot training on flight simulators, the technology enables plant operators to acquire the necessary training in a virtual environment. Some benefits of OpSim are improved operator safety, a well-trained workforce, improved plant productivity, faster plant start-up, and reduced costs in procedure development.

RCT clients include Shell Chemicals USA, Rohm and Haas Texas, Inc., and the National Institute of Standards (NIST). Shell has signed an agreement to implement Version 2.0 of OpSim at a new process plant currently under construction in Louisiana. Shell will use the tool to create, maintain, and validate operating procedures. The company can also import existing written procedures contained in text documents through an automated process. Operators will be able to interact with plant components, equipment, structures, and systems using the simple joystick interface, commencing training in a virtual environment months before the plant is fully built. ❖

Virtual Plant Model™, ConstructSim™, and OpSim™ are trademarks of Reality Capture Technologies, Inc.



OpSim™ enables operators to interact with plant components, equipment, structures, and systems using a joystick interface. As a result, training can begin in a virtual environment months before a plant is fully built.

Mining Marketing Data

Marketing and sales professionals finally have a software tool that is tailored to meet their needs. MarketMiner® Products, a line of automated marketing analysis tools manufactured by MarketMiner, Inc., of Charlottesville, Virginia, can benefit organizations that perform significant amounts of direct marketing. MarketMiner, formerly known as AbTech, originally developed the software as a data modeling tool for space mission applications. The technology was then built into the company's current products to provide decision support for business and marketing applications. With the tool, users gain valuable information about customers and prospects from existing data in order to increase sales and profitability.

The process began when NASA's Johnson Space Center awarded MarketMiner a **Small Business Innovation Research (SBIR)** contract to develop the technology. In Phase I of the

contract, the company proposed that its software would reduce mission operations data analysis costs, enhance the ability of operators to handle the large volume of incoming data, and increase the ability to detect soft failures before they cause significant damage to valuable components. By the end of Phase II, the company had developed a data mining tool that could significantly reduce the cost, time, and expertise required to implement diagnostic and decision-aiding models for a large range of complex applications. In addition to being valuable to several Johnson initiatives, the tool has many commercial advantages.

Data mining is a process that uses various statistical and pattern recognition techniques to discover patterns and relationships in data. The MarketMiner software goes a step further by combining data mining techniques with data analysis and business intelligence. This enables the tool to produce useful marketing information geared specifically toward the needs of marketing



MarketMiner® software produces useful marketing information geared specifically toward the needs of marketing and sales professionals.



and sales professionals. Even better, MarketMiner does not require users to be experts in statistics or data mining. According to the company, the software can be learned in approximately 30 minutes by professionals familiar with direct marketing and ways to execute test campaigns to validate models.

The software features standard functions such as address standardization, geocoding, and data enhancement, making it very easy to use. Functioning as a personal “Virtual Marketing Analyst,” the software also generates comprehensive Microsoft Word documents with insightful reports, scores lists, applies six mining technologies, and outputs lists of a user’s best prospects. With these capabilities, MarketMiner has successfully uncovered a way for users to leverage time, personnel expertise, and computer processing resources. ❖

MarketMiner® is a registered trademark of MarketMiner, Inc.

By combining data mining techniques with data analysis and business intelligence, the MarketMiner software generates reports and score lists.

completed the development of *SinapsPlus*,[®] which also originated from the founders of C&R while at Martin Marietta. *SinapsPlus*, a sketchpad graphical user interface (GUI), provides a visual means of accessing the solution power of SINDA/FLUINT, making the system more approachable.

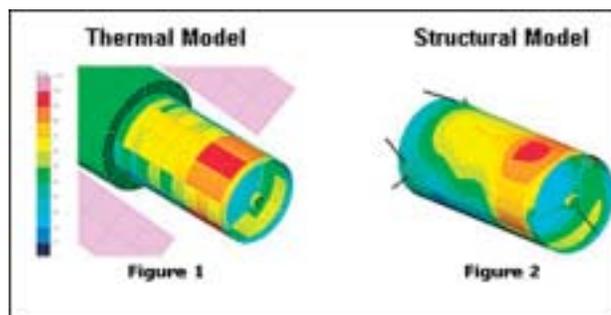
C&R also created a geometric GUI to work with SINDA/FLUINT, known as Thermal Desktop.[®] An optional computer-aided design (CAD) module of Thermal Desktop, RadCAD,[®] calculates radiation exchange factors for input to SINDA/FLUINT. Together, these two codes, which began as SBIR projects at NASA's Marshall Space Flight Center, solved a long-standing concurrent engineering problem. Thermal Desktop is the first tool that enables concurrent engineering for thermal analysts by providing full access to CAD-based geometry, as well as data exchange to and from structural codes without compromising traditional thermal modeling practices. Eliminating productivity bottlenecks, these two products benefit the aerospace and electronic packaging communities.

According to C&R, the funds generated from the success of the NASA-initiated products supported the development of the company's FloCAD[®] product, a geometric GUI for fluid network modeling (the FLUINT side of SINDA/FLUINT). This GUI provides fast, inexpensive, parametric modeling capabilities for air-, liquid-, or two-phase-cooled electronics. It also facilitates the analysis of heat pipes.

With over 4,000 users in 30 countries, applications for SINDA/FLUINT include the

pharmaceutical, petrochemical, biomedical, electronics, and energy industries. The system has simulated nuclear reactors, windshield wipers, and human windpipes. SINDA/FLUINT simulates the transient liquid/vapor flows within air conditioning systems, helping the automotive industry to meet standards for fuel efficient, low-emission cars. The system was the basis of General Motor's E-Thermal vehicle-level thermal management software, which is being deployed globally. ❖

SinapsPlus,[®] Thermal Desktop,[®] RadCAD,[®] and FloCAD[®] are registered trademarks of Cullimore & Ring Technologies, Inc.



A long-standing concurrent engineering problem was solved by the integration of SINDA/FLUINT within C&R's Thermal Desktop.[®] Thermal engineers can work side by side with structural engineers and CAD designers for the first time, greatly enhancing both productivity and analysis accuracy.

Geography From Another Dimension

It used to be that teachers would begin a lesson by asking students to open their textbooks. However, in this day and age, textbooks are starting to take a back seat to computer technology at numerous school systems throughout the United States.

With young students becoming more acclimated to personal computers, teachers now have the luxury of utilizing various software programs and applications to provide real-time learning. This alternative approach to education has made the classroom a more enjoyable atmosphere for students of all ages.

To further emphasize the important balance between computer literacy and education, Berkeley Geo-Research Group (BGRG) created a state-of-the-art program called GEODESY that helps students in middle and high schools develop proactive problem-solving skills to answer questions about where they are, why they are there, and how they can improve the quality of life in their community, and ultimately, in their world. Back in 1994, Orinda,

California-based BGRG began developing GEODESY with technical assistance and financial support from Stennis Space Center's Commercial Remote Sensing Program Office, now known as the Earth Science Applications Directorate. In addition, BGRG received an award from NASA's Earth Observations Commercial Applications Program, which co-funded the project in its early development stages.

GEODESY is intended to promote geographical awareness among students with its remote sensing capabilities to observe the Earth's surface from distant vantage points. Students and teachers using the program learn to interpret and analyze geographical data pertaining to the physical attributes of their community. For example, the program provides a digital environment of physical features, such as mountains and bodies of water, as well as man-made features, such as roads and parks, using aerial photography, satellite imagery, and geographic information systems (GIS) data in accordance with National Geography Standards.

The GEODESY technology is divided into four "core tracks," each building upon the other and introducing the student to a critical component of digital GIS use and analysis. The first core track acquaints students with the tools that are being used to study the environment. Students start off by studying a plan view of their local school area as seen in an aerial photograph. They are then introduced to the concepts of vector-based mapping using point, line, and polygon with respect to landscape features, including their school, roads, forested areas, and other local items that are identified in the aerial photograph.



GEODESY allows students and teachers to interpret human and physical elements in their local community to gain a better understanding of their surroundings. In this image, such elements are plotted across various regions of the Bay Area.



From a satellite image of San Francisco, GEODESY is able to map water depth, terrain, and transportation routes.

The next step for the students is to evaluate satellite images for recognizable features, using GEODESY's raster-based image viewing and processing technology. This functionality allows both students and teachers to interact with an image beyond its basic visual interpretation.

Students and teachers are now ready to use all of the tools they have learned thus far to study physical and human elements in their local community. The physical elements include atmosphere, biosphere, hydrosphere, and lithosphere, while the human elements are movement and settlement (the interaction between people and places), cultural mosaic (age, ethnicity, education), economic activities (housing values, employment statistics, per capita and median income levels), and political divisions (county and city boundaries, voting districts). Once students and teachers become more familiarized with the digital geography of their local surroundings, they can manipulate and overlay combinations of physical and human features to identify if a spatial relationship exists between them, and to evaluate whether such a relationship is direct or inverse. The main goal is to have the students, as well as the teachers, gain a better understanding of the unique forces that drive their coexistence.

BGRG has teamed up with Ridgeland, Mississippi-based Digital Quest, Inc., to implement GEODESY at 120 middle and high schools across Mississippi. Digital Quest is a member of the Mississippi Space Commerce Initiative, a consortium whose goal is to develop a remote sensing industry in the state by commercializing the technologies developed by NASA at the Stennis Space Center. BGRG and Digital Quest are expanding beyond the core of GEODESY by assembling a 3-year spatial science curriculum called SPACESTARS. This application, which is already in place at three high schools in Arkansas and Mississippi, will continue to help students answer challenging questions about the factors that contributed to the location of their school, including whether the local community will need more classrooms/schools in 10 years, and if the current bus routes are the most efficient and direct. Both GEODESY and SPACESTARS will be introduced to schools in Texas and Ohio in the 2002-2003 school year. ♦

A New Definition for Ground Control

Touted as the “best seat in the house” by NASA astronaut Ken Ham, an advanced flight visualization system that simulates conditions of a real flight from a remote location is making way for safer landings. Rapid Imaging Software, Inc.’s LandForm® VisualFlight® blends the power of a geographic information system (GIS) with the speed of a flight simulator to transform a user’s desktop computer into a “virtual cockpit.”

The software product, which is fully compatible with all Microsoft® Windows® operating systems, provides distributed, real-time three-dimensional (3-D) flight visualization over a host of networks. From a desktop, a user can immediately obtain a cockpit view, a chase-plane view, or an airborne tracker view. A customizable display also allows the user to overlay various flight parameters, including latitude, longitude, altitude, pitch, roll, and heading information. Additionally, LandForm VisualFlight’s telepresence technology lets users construct and deploy their own immersive multidimensional display applications on Windows-based platforms.

Rapid Imaging Software created the technology in response to its customers’ desires for a version of the already-existing LandForm product that they could integrate with software they wrote themselves. In particular, the customers were seeking a version of LandForm which would let them combine their aircraft and vehicle models, live flightpaths, and heads-up displays with LandForm geographic data servers in three dimensions.

The company sought assistance from NASA, and the VisualFlight technology came to fruition under a Phase II **Small Business Innovation Research (SBIR)** contract with Johnson Space Center in 1998. Three years later, on December 13, 2001, Ken Ham successfully flew NASA’s X-38 spacecraft from a remote, ground-based cockpit using LandForm VisualFlight as part of his primary situation awareness display in a flight test at Edwards Air Force Base, California. This simulated a realistic flying environment and landing for the windowless X-38, which is expected to eventually serve as NASA’s Crew Return Vehicle for the International Space Station.

From a remote personal computer, Ham was able to determine the X-38’s position and attitude information via transmissions received from an onboard Global Positioning System that provided the correct camera perspective. The remote cockpit utilized a hybrid synthetic vision system that combined live, forward-looking video with computer-generated 3-D topography of the X-38’s flight path to touchdown. A terrain database that features topography, satellite imagery maps, and aeronautical charts was also used to synthesize the 3-D view.

Astronauts in the remote cockpit of the X-38 fly the vehicle using LandForm® VisualFlight® situation awareness displays.

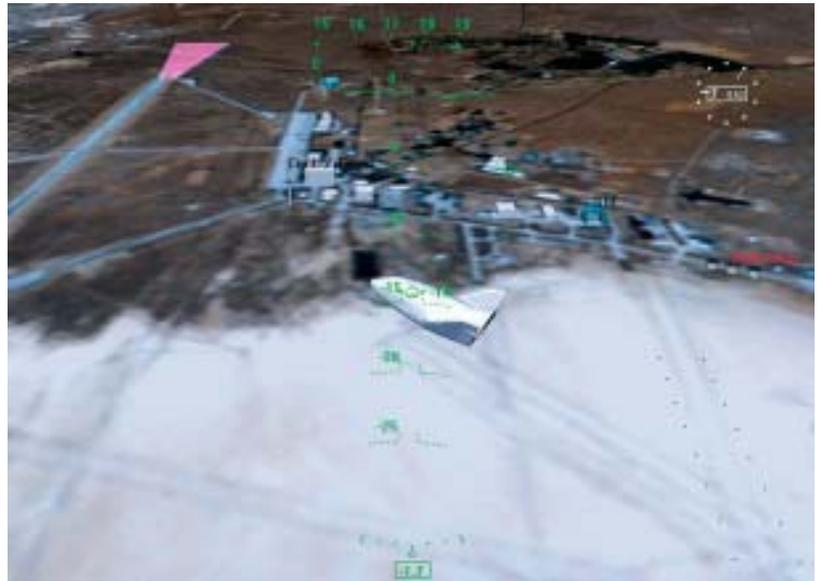


The commercial model of LandForm VisualFlight (available to qualified users) is comprised of a LandForm Server control that contains and manages all terrain, image, entity, track, and real-time data; a MapView control that provides a moving map view of all information in the databases; and a LandForm 3-D view control that provides a real-time, 3-D “out-of-the-window” (or chase-plane) view including all elements of the databases.

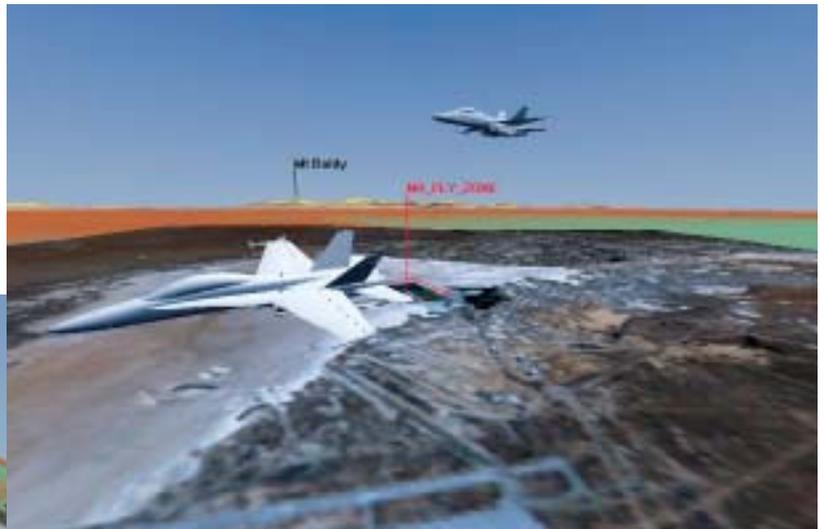
LandForm VisualFlight is now used for virtual reality training of crews, analysis of flight test data, teleoperation of remotely piloted vehicles, and as an onboard immersive situation awareness display. The flight visualization software assisted a major consulting firm in airport approach planning, and continues to play a significant role as an analysis tool for air safety investigations led by legal firms and air safety experts. ❖

Landform® and VisualFlight® are registered trademarks of Rapid Imaging Software, Inc.

Microsoft® and Windows® are registered trademarks of Microsoft Corporation.



Chase plane view of the X-38 Crew Return Vehicle.



VisualFlight® view also showing other traffic in the area.



VisualFlight® synthetic vision view out the window at Dryden Flight Research Center.

Security in Full-Force

In the wake of September 11, 2001 and the ensuing demand for stringent homeland security measures, organizations worldwide are going to greater lengths to safeguard their business practices. While NASA is among the ranks of those constantly evaluating their security infrastructures, the Agency is firmly shielded by a gold-standard protection system, thanks to an ongoing relationship with Vanguard Integrity Professionals of Las Vegas, Nevada.

NASA teamed up with Vanguard shortly after the Chaos Computer Club of Hamburg, West Germany, hacked into the NASA Space Physics Analysis Network (SPAN) in early 1987. The unlawful intrusion was not discovered by NASA until 3 months later in July. In addition, NASA learned that the Space Shuttle's Primary Avionics Software System (PASS) flight software code had been compromised in November of that same year.

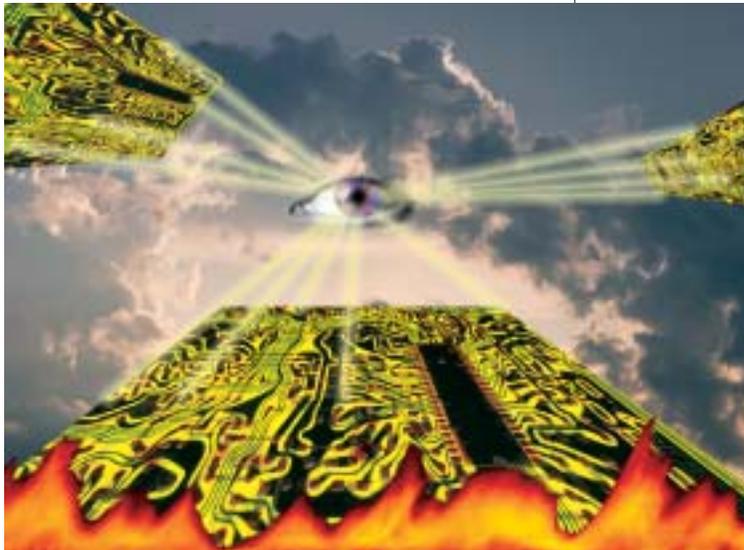
This led to the formation of the Joint Mission Operations Directorate/Mission Support Directorate Resource Access Control Facility Team in April of 1988. Tasked with performing a forensic investigation, the team unveiled that the security rules for the PASS data file were deleted on June 11, 1987, as a result of a human error made by an authorized security administrator. Essentially, the programs that NASA utilized to protect the lives of American astronauts and enable them to perform critical tasks of the Nation's space program had proven vulnerable to both malicious attack and human error.

In June of 1988, NASA recruited the IBM America Team to perform an assessment of the Software Development Facility (SDF). Within months of this date, the Mission Support Directorate (MSD) formed its own security committee to address specific issues within the SDF and other MSD-managed systems. The committee recommended that several actions be taken, including training and certification of security administrators. The thorough evaluation process concluded that the only way to provide fault tolerant security would be to implement a system that did not require human intervention. Subsequently, NASA's MSD/SDF approved the development of an automated security monitoring and enforcement system that would prevent human error and deliberate attacks. Work on a security software platform that would later become known as "Enforcer" began in March of 1989.

During that same year, a request for proposal was issued to create and implement the security administration certification program for NASA. Vanguard was awarded the contract, and subsequently, developed the NASA Security Administrator Certification Program. Vanguard also instructed, tested, and certified the Agency's security administrators.

Meanwhile, work continued on the development of Enforcer. Ronn Bailey, Vanguard's chief executive officer and chief technology officer, informally consulted with the makers on product design. When fully developed for NASA, the software system—which emulates the

Like the ever vigilant eye, Vanguard Enforcer™ monitors the constant stream of data in and out of the server system. As unauthorized attempts to access data are noticed by the system, it shuts down entry to the files before information can be copied, removed, or corrupted.



activities of highly technical security system programmers, auditors, and administrators—was among the first intrusion detection programs to restrict human errors from affecting security, and to ensure the integrity of a computer's operating systems, as well as the protection of mission critical resources. The first version of Enforcer, now known as the Vanguard Enforcer™, was delivered in 1991 to NASA's Johnson Space Center and has been protecting systems and critical data there ever since.

After a decade of successful implementation at Johnson and other NASA facilities, the Agency approached Vanguard to assume all product development, support, and commercialization of the Enforcer technology. In August of 1999, NASA granted Vanguard exclusive rights to commercialize the Enforcer system for the private sector. In return, Vanguard continues to supply NASA with ongoing research, development, and support of Enforcer.

The Vanguard Enforcer 4.2 is one of several surveillance technologies that make up the Vanguard Security Solutions™ line of products. Using a mainframe environment, Enforcer 4.2 achieves previously unattainable levels of automated security management. It offers protection 24 hours a day, 7 days a week, while maintaining standards, policies, and operating system settings (such settings are continuously benchmarked against policy baselines and best practice security standards).

Enforcer 4.2 automatically sends notification of discrepancies or violations to individuals responsible for system oversight. Enforcer supports all Simple Mail Transfer Protocol-compatible e-mail systems, and will permit multiple recipients per notice. Once a discrepancy or violation is detected, the system will provide the option to automatically generate and execute the necessary commands to return the system security to the level defined in the baselines generated by the user.

According to Ronn Bailey, studies over the past 20 years have demonstrated that as much as 70 percent of actual information system losses have been the result of authorized users, the majority of which caused by human error, and some by malicious intent.

Moving forward, Bailey notes that there is a major commercial focus on protecting the Internet and networks with layers of firewalls (systems that enforce access control between two networks) and network intrusion detection. However, he adds that since the bulk of intrusions are tied to authorized, inside users accessing the computers that host critical information and transactions, the erroneous or malicious acts of these individuals fall out of the reach of firewalls and network intrusion detection. This theory applies to vital corporate, state, national, government, and military information that is stored and maintained on

mainframes behind the Internet, networks, and firewalls.

With this in mind, Vanguard is committed to expand upon its success with NASA to deliver superior security technology to corporations and other various entities all across the Nation. According to Bailey, “Enforcer is the first security software developed to defend a system against its own authorized users.” “We take great pride in knowing that this technology is protecting all manned space program missions. Vanguard is honored to bring this advanced security technology to all businesses.”

One customer that has benefited from the Vanguard Enforcer is The Depository Trust & Clearing Corporation (DTCC), the largest



financial services post-trade infrastructure organization in the world. Headquartered in New York, New York, with operating facilities throughout the United States and overseas, DTCC has become “far more proactive” in security measures with the use of the Vanguard Enforcer, according Paul de Graaff, the company’s corporate information security officer and vice president. de Graaff also notes that the Vanguard technology transcends paper-based reporting methods, is easy to maintain and track, and helps keep overall surveillance “clean.” ❖

Vanguard Enforcer™ and Vanguard Security Solutions™ are trademarks of Vanguard Integrity Professionals.

Ronn Bailey, Vanguard Integrity Professionals’ chief executive officer and chief technology officer (left foreground), confers with a client during an attempted security breach. The Vanguard Enforcer™ software intercepts the attempted hack on the system, which is displayed on the monitors in the control room of the server farm.

Surface Enhancement Improves Crack Resistance

Lambda Research, Inc., of Cincinnati, Ohio, has developed a low plasticity burnishing (LPB) process that will significantly increase the durability and life span of metal components—opening the door for new advances in the aircraft industry. The company received **Small Business Innovation Research (SBIR)** funding and technical support from NASA's Glenn Research Center to develop the process. Glenn's partnership with Lambda supports NASA's Ultrasafe Aviation Safety program and its ongoing efforts to bring safer aircraft propulsion systems to reality. Upon successfully completing its work, Lambda created a spinoff company, Surface Enhancement Technologies (SET), also of Cincinnati, Ohio, to market the new technique, which can be applied to turbine engine metal components.

The surface finish is a critical factor in creating a durable metal component. Manufacturers strive to produce metal surfaces free of scratches, nicks, and gouges, since such defects make components vulnerable to damaging cracks. A smooth surface alone is insufficient, however, to protect the component against the wear and tear of regular usage. A component's durability is substantially improved when residual compressive stress is produced in the component's surface. In a state of perpetual

compression, a surface can better withstand the stresses of fatigue and impact, increasing its life span and reducing the need for costly and time-consuming replacements.

Lambda's technique produces a deep layer of surface compression in a quick, affordable, and convenient manner. The process, designed for easy inclusion in the manufacturing environment, can be performed with conventional Computer Numerical Control machine tools. This allows parts to be processed during manufacturing, rather than as a post process in a separate facility. Unique to the process is the use of a smooth, free-rolling spherical ball suspended in a fluid, which enables single-point contact. The ball comes into mechanical contact only with the surface to be burnished, and can be moved in any direction.

The LPB process has considerable advantages over other methods of surface enhancement, such as shot peening and laser shock peening. Shot peening, the standard method, blasts tiny pellets at an area. While the method is inexpensive and widely used, the deformation from the pellet impacts can be harmful. LPB not only avoids impact damage, but also produces compressive residual stresses to a depth 4 times that of shot peening, providing much greater damage tolerance. Although its results are



The low plasticity burnishing process improves a surface's resistance to fatigue and damage.

comparable to laser shock peening, LPB does so at a fraction of the cost. LPB's easy adaptation to manufacturing also makes it a more desirable method.

LPB is applicable to all types of carbon and alloy steel, stainless steel, cast iron, aluminum, titanium, and nickel-based super alloys. In addition to improving a surface's resistance to fatigue and damage, treatment stops the growth of shallow cracks. The LPB process is currently used on the leading edges of turbine blades to improve resistance to foreign object damage and crack growth. This means significant savings for

aircraft owners, since maintenance requirements to inspect for fatigue damage, replace parts, and remove corrosion damage increase the cost of operation. According to Paul Prevey, president of Lambda Research, "We fully expect it to be very useful in aircraft engine and airframe overhaul, where it can extend the life of aging aircraft and substantially reduce the overall cost of ownership." Both the military and the commercial aircraft industry stand to benefit from Lambda and SET's accomplishment. ❖



A smooth, free-rolling ball comes into contact only with the surface being burnished.

Measuring Pressure Has a New Standard

DH Instruments (DHI), Inc., of Phoenix, Arizona, is enjoying commercial success with its Force-Balanced Piston Gauge (FPG) after developing the innovation for NASA's Kennedy Space Center. Formally known as the FPG8601 Calibration System for Very Low Pressure, the FPG tests and calibrates instrumentation operating in the low pressure range.

Piston gauges derive pressure directly from the base units of mass, length, and time. Because of their fundamental operating principles and long term stability, they are an essential tool in pressure metrology, which assures the integrity of pressure measurement throughout science and industry. According to Martin Girard, DHI's chief executive officer, the concept for the FPG grew from the need for a primary pressure standard for both gauge and absolute pressures to cover the range below what is covered by conventional piston gauges or deadweight testers. Original product concepts were based on the combination of a high-precision piston-cylinder and a digital mass comparator.

DHI, a supplier to the Kennedy Metrology Laboratory since the mid-1980s, worked with the Japanese National Research Laboratory for Metrology (NRLM) in the 1990s to produce conceptual drawings of the FPG. In 1994, Kennedy expressed the need for an easy-to-use, low-pressure, primary standard to support the calibration of instrumentation for the International Space Station. DHI provided an unsolicited proposal based upon its work,

resulting in a NASA contract to provide Kennedy with the FPG.

The Kennedy system was inspected and accepted for installation in August 2000. The FPG saves the Center time and money, since NASA can avoid sending certain components to the National Institute of Standards and Technology for calibration. The system provides a traceable, primary calibration standard for measuring pressures in the range of near 0 to 15 kPa (2.2 psi) in both gauge and absolute measurement modes. The hardware combines a large area piston-cylinder with a load cell measuring the force resulting from pressures across the piston. The mass of the piston is tared out, allowing measurement to start from zero. A pressure higher than the measured pressure, which keeps the piston centered, lubricates an innovative conical gap located between the piston and the cylinder, eliminating the need for piston rotation. A pressure controller based on the control of low gas flow automates the pressure control.

After achieving success with Kennedy, DHI is now marketing the FPG as an automated primary standard for very low-gauge and absolute pressures. Several metrology laboratories have already installed the system, including the NRLM in Tsukuba, Japan, and the National Measurement Institute in Helsinki, Finland. DHI is currently selling the FPG to high-end metrology laboratories on a case-by-case basis and expects a full commercial release to the general public in the summer of 2002. Due to the critical nature of accurate measurements of very low-gauge and absolute pressures, Girard believes that the FPG has applications in many industries, including aerospace, semiconductor manufacturing, nuclear fuel processing, and pharmaceuticals. ❖



The Force-Balanced Piston Gauge tests and calibrates instruments that operate in the low pressure range.

Grace Under Pressure

Developed in response to a NASA requirement to remotely measure tension in critical bolts on the International Space Station, American Remote Vision Company's (ARVC) SureBolt™ Correlation Bolt Gage is the first ultrasonic system to capture an entire "echo" pulse for determining the change in time of flight of an ultrasonic signal traversing a fastener for tension measurement. An ultrasonic bolt gage can characteristically be thought of as a "super accurate ruler" that measures how much a bolt stretches under tension pressure. To determine the amount of stretch, the bolt gage sends a sound pulse into one end of a bolt, and then measures the time for the echo to return.

Prior to the invention of SureBolt, ultrasonic bolt gages proved limited in reliability and resolution because they only tracked one point, or one zero crossing, in the echo time-of-flight assessment. The main problem encountered when using these one-point gages is known as the "peak-jumping" phenomenon. Peak-jumping is a result of the echo waveform distortion that often occurs when tension is applied to a bolt. This waveform distortion causes the bolt gage's zero-crossing detector to jump to another part of the echo waveform without any indication that this peak jump has occurred. Because SureBolt takes measurements using all of the sampled points of an echo waveform, and not just one zero-crossing point, the correlation technology provides far more accurate and reliable readings than its one-point predecessors, thus reducing the errors, inefficiencies, and frustrations generally associated with the use of bolt gage systems.

Furthermore, if any waveform distortions occur while using SureBolt, the system, which is built into an industrial-grade laptop computer, overlays and displays entire waveforms so the user can visually determine and analyze any effect on the data. The standard SureBolt system hardware has the capability of recording over 1 million bolt tension readings—with their complete waveforms—in Microsoft Excel-compatible format. The user-friendly Tension-Not-Torque© software interface offers tension change graphing in real time, and a place to store field notes, special parameters, tension calibration constants, and temperature changes for each measurement. SureBolt is also Web-ready, so

users such as engineers and managers worldwide can access measurements in real time.

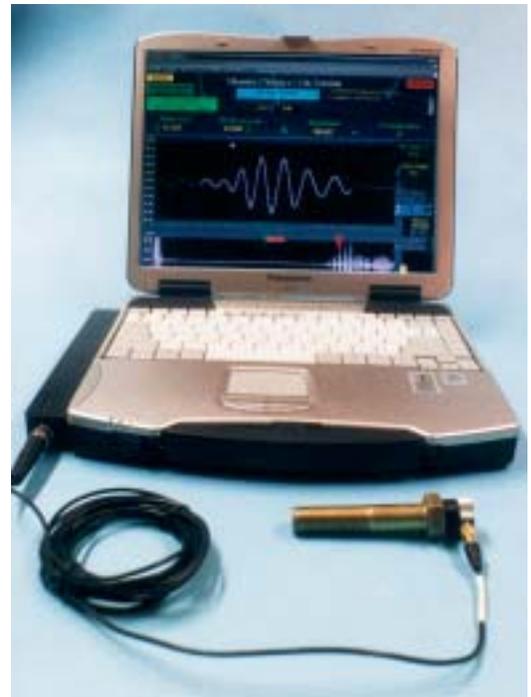
SureBolt correlation technology was developed over the span of 15 years by Stuart Gleman and Geoffrey Rowe while working for various contractors at NASA's Kennedy Space Center. A prototype of the SureBolt Correlation Bolt Gage was used at NASA's Marshall Space Flight Center on Space Station Common Berthing Mechanism Attach Ring flange bolts during preflight pressurization tests of the Structural Test Article Node, and at Boeing's facility in Huntington Beach, California, for tests on the Pressurized Mating Adapter and its Attach Ring. Data obtained from the Marshall tests demonstrated that, when tested side-by-side with single-point gages, the SureBolt correlation technology achieved superior accuracy and performance. A later prototype was used on the X-33 hold-down bolts.

Gleman's company, ARVC, which is based in Titusville, Florida, participated in a Phase I **Small Business Innovation Research (SBIR)** contract with Kennedy in 1998 for advanced development of correlation bolt gage technology. Later that same year, Kennedy patented the correlation bolt gage, and then licensed it to ARVC 3 years later in 2001.

The technology has been used on fasteners as small as fine-threaded, 1-inch bolts, and as large as 18-inch-diameter by 30-foot-long tie rods. SureBolt is finding increased application within NASA and the aerospace industry, as well as in the automotive and nuclear industries. ❖

SureBolt™ is a trademark of American Remote Vision Company.

Tension-Not-Torque© is a copyright of American Remote Vision Company.



Built into an industrial-grade laptop computer, the SureBolt™ Correlation Bolt Gage captures an entire "echo" pulse for determining the change in time of flight of an ultrasonic signal traversing a fastener for tension measurement.

An IDEA of What's in the Air

People with allergies know that particles in the air can have a major impact on their health. Particles can create problems for sensitive mechanical equipment as well, especially in cases where payload components must be kept in clean rooms. While clean rooms do protect this equipment, particle fallout contamination is still a major concern of NASA and aerospace-related industries. Depending upon the type and size of the particles, fallout can affect the performance of sensitive spaceborne instruments and support equipment. Because of this, contamination must be measured regularly to ensure equipment safety and reliability.

The Aerospace Engineering Group of IDEA, LLC, in Ellicott City, Maryland, has commercialized the Automatic Particle Fallout Monitor (APFM) in response to the need for a faster and completely automated instrument that can efficiently assess real-time particle contamination levels in a facility. IDEA's accomplishment grew from a partnership with NASA's Kennedy Space Center whose engineers developed the APFM, a detection instrument that directly images, sizes, and counts contamination particles. After Kennedy field tested the APFM, the Research Triangle Institute (RTI) assisted NASA with finding an industry partner interested in commercializing it. RTI, an organization devoted to the transfer of NASA technology, brought in IDEA and several other companies for briefings about the APFM. Through a competitive process, IDEA won a dual-use contract with Kennedy, giving it license rights to the NASA-patented prototype. IDEA was tasked with optimizing and commercializing the APFM system by easing the manufacturing process, validating the system's performance, and assessing market potential. This resulted in a commercial product for IDEA that also fulfills Kennedy's needs.

A collection disk is mounted below a video camera, which scans the disk's surface to detect particles. The disk rotates under the camera, which has two magnification levels.

Traditionally, particle fallout contamination levels in a facility are measured by placing a collection plate, known as a witness plate, in a specific area. After several weeks, the witness plate is transported to a laboratory where personnel manually count the particles under a microscope. IDEA's APFM provides an alternative to this method by directly counting the number of particles which collect on a witness disk, similar to a witness plate, inside the instrument. The monitor automatically measures the size and density of particles that collect on the surfaces of the room in which it is placed. The APFM, which has National Institute of Standards and Technology (NIST) traceable calibration, can measure particles as small as 1 micrometer in diameter and can differentiate between fiber-shaped and circular-shaped particles. The instrument provides a quantitative measurement of the cleanliness of a room according to Military Specification (Mil Spec) 1246 standards and provides real-time data



within 4.3 hours of deployment, making it the most advanced and fastest quantitative system on the market to date.

The APFM consists of a computer processor, a sensor head assembly, and custom application software. The processor analyzes images, archives them, and sizes and counts particle data. It also controls the positioning of the witness disk under the sensor heads. The two sensor heads image the accumulated particles on the witness disk. The two stepper motors rotate and shift the witness disk into position under the two cameras. One camera images small particles while the other images large particles. The images are then sent to the processor, which counts and sizes the particles in each image. The processor is a fully functional personal computer with customized application software and a graphical user interface, making it a specialized instrumentation controller. The software offers a user-friendly monitoring, control, and command display capability that allows for easy maintenance, calibration checks, and change-out of witness disks.

The APFM allows personnel to respond to particle contamination before it becomes a major problem. In NASA's case, the APFM improves the ability to mitigate, avoid, and explain mission-compromising incidents of contamination occurring during payload processing, launch vehicle ground processing, and potentially, during flight operations. Commercial applications can be found in semiconductor processing and electronics fabrication, as well as in aerospace, aeronautical, and medical industries. The product could also be used to measure the air quality of hotels, apartment complexes, and corporate buildings. IDEA sold and delivered its first four units to the United Space Alliance for the Space Shuttle Program at Kennedy. NASA used the APFM in the Kennedy Space Station Processing Facility to monitor contamination levels during the assembly of International Space Station components. ❖



The Automatic Particle Fallout Monitor is used in clean room environments where satellites are assembled.

Getting the Gold Treatment

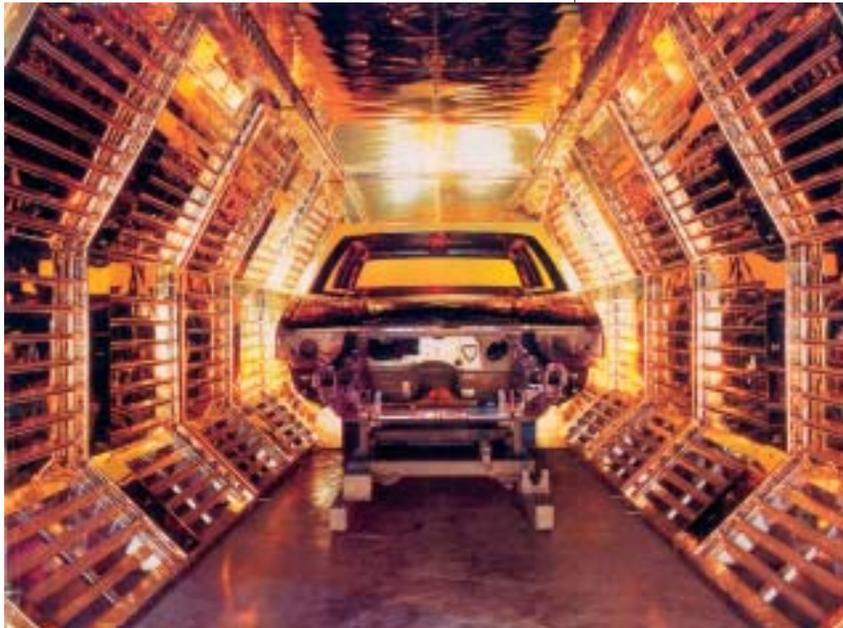
Epner Technology, Inc., of Brooklyn, New York, has a golden reputation at NASA's Goddard Space Flight Center. In 1996, the company first partnered with Goddard to gold-coat a telescope mirror for use on the Mars Global Surveyor. The mirror, known as the Mars Orbiter Laser Altimeter (MOLA), functioned as part of a laser device to chart Mar's topography. Epner Technology's LaserGold® process was used on the mirror to give it the sensitivity necessary for the operation. The success of this project led Goddard to call upon Epner's expertise again to work on the Vegetation Canopy Lidar (VCL) mirror. This partnership resulted in new commercial applications for the LaserGold process in the automotive industry.

The VCL mirror will orbit the Earth in 2003 as part of NASA's Earth System Science Pathfinder (ESSP) program. Intended to map the Earth's surface in the same way that the MOLA mapped Mars, the VCL mirror presented a unique challenge to Epner because of its size and worth. With a 0.9-meter diameter, the mirror was too large for Epner's plating

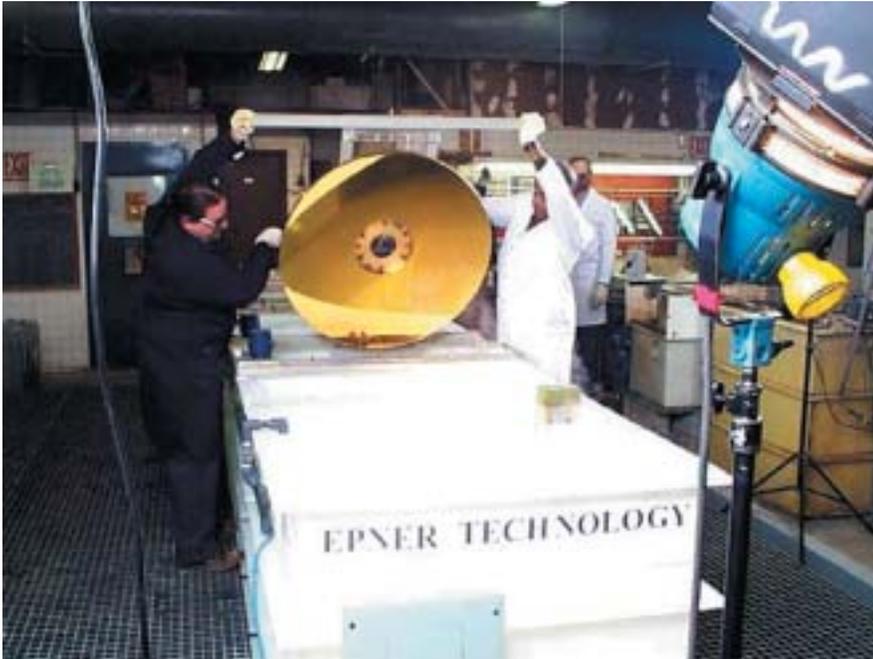
tanks. Made of beryllium, an expensive but ideal material for space optics, the mirror had a value of more than 1 million dollars. The company considered using the mirror itself as its own plating tank since it had a slight dish shape, but the danger to the mirror for such an experiment was deemed too great. Given the mirror's worth, the Epner team needed to find a solution that would be effective without risking the mirror's safety.

The safest method was to build a facility large enough to accommodate the VCL mirror, so that it could be plated the same way as the MOLA mirror. The greatest roadblock was the cost. NASA did not have the budget to cover the cost of the setup necessary to gold-coat a mirror of this size, in addition to the cleaners, acid dips, nickel plating, gold strike, LaserGold plate, and rinse steps involved. With the additional cost of the gold needed to charge the tanks and the necessary rehearsal time on a dummy mirror, it did not look like plating the VCL mirror would be possible.

Epner recognized a commercial opportunity that would make the project lucrative. A few



Epner Technology's new facility brought the company's LaserGold® process to the automotive industry.



NASA's Vegetation Canopy Lidar mirror was carefully gold-coated to provide it with the sensitivity necessary for operation.

years earlier, Epner explored the possibility of selling LaserGold-coated reflectors to the automotive industry. The company, thwarted by the size of the oven panels that are used in its production paint drying ovens, did not have equipment large enough to cost effectively handle the plating of the stainless steel panels. Seeing a chance to renew this effort, David Epner, owner and chief executive officer of the company, stated, "If we could come out of this project with a production capability to handle large parts, whole new markets would be open to us...not the least of which was the automotive industry." As a result of this new vision, Epner Technologies and Goddard entered into an agreement by which NASA would fund the facility needed to do the gold-plating, and the

company would cover all other costs as part of its internal research and development.

The VCL mirror project proceeded successfully, fulfilling Goddard's needs and leaving Epner with a new facility to provide LaserGold for the automotive industry. This new capability means increased energy savings and improvements in both quality and production time for BMW Manufacturing Corporation of Spartanburg, South Carolina, and Cadillac of Detroit, Michigan, as well as other manufacturers who have implemented Epner Technology's LaserGold process. ❖

LaserGold® is a registered trademark of Epner Technology, Inc.

Revealing Optical Components

Luna Technologies, Inc., of Blacksburg, Virginia, has commercialized an instrument that significantly reduces the time and cost of testing sophisticated optical components. The technology grew from the research Dr. Mark Froggatt, Luna Technologies' chief technical officer, conducted on optical fiber strain measurement while working at NASA's Langley Research Center. Dr. Froggatt originally developed the technology for non-destructive evaluation testing at Langley. The challenge was to put enough sensors in optical fibers on a launch vehicle to provide comprehensive strain measurements without adding weight to the structure. The result was a technique that could provide 10,000 independent strain measurements while adding less than 10 grams to the weight of the vehicle.

After licensing this new technique, Luna Technologies developed the Optical Vector Analyzer (OVA) 1550, the first instrument on the market capable of complete linear characterization of single-mode optical components used in high-bit-rate applications. According to Doug Juanarena, President and Chief Executive Officer of Luna Technologies, "Other test instruments provide very basic performance data, or what could be considered the equivalent of the device's blood type, but the OVA 1550 provides complete characterization. In essence,

it's like giving users the optical DNA of the component." The device can test most components over their full range in less than 30 seconds, compared to the more than 20 minutes required by other testing methods. The dramatically shortened measurement time results in increased efficiency in final acceptance tests of optical devices, and the comprehensive data produced by the instrument adds considerable value for component consumers. The device eliminates manufacturing bottlenecks, while reducing labor costs and wasted materials during production. The OVA 1550 is a single unit, removing the need for multiple instruments to provide the same degree of analysis. It can be easily integrated into a manufacturing production line. The device is also fully automated, requiring no special skills for operation. The control software's graphical user interface provides all key data and graphs in an easily accessible and understandable format.

The first OVA system was delivered to Lucent Technologies, Inc., in June 2001, for use in fiber measurements. Luna Technologies' goal is to become a premier supplier of test instrumentation for optical component developers and producers worldwide, eventually broadening its product line for additional applications and markets. ❖



The Optical Vector Analyzer 1550 gives a complete characterization of optical components.

High-Performance Valve Promises Safe Relief

In many industrial applications, pressure relief valves perform the critical function of safely releasing pressure before potentially damaging build-ups occur. Conventional relief valves can be unstable, however, leading to premature wear and devastating consequences. PRV95, a high-performance pressure relief valve manufactured by Marotta Scientific Controls, Inc., of Montville, New Jersey, provides an answer to premature wear and instability.

Using an improved valve design developed under a **Small Business Innovation Research (SBIR)** contract with Stennis Space Center, Marotta Scientific's PRV95 provides stability over the entire operational range, from fully closed to fully open. The valve employs a concept known as upstream control for valve positioning, making it more dependable with excellent repeatability and minimal lag time.

PRV95 "opens and closes softly, and does not oscillate or generate hard impacts; oscillation can result in a hard impact pressure release, which can lead to an explosion in the presence of oxygen," says Bill St. Cyr, the Test Technology Branch chief at Stennis.

Marotta Scientific's PRV95 design is unique in its ability to maintain a seal near the set point of the relief limit. Typically, relief valves seal tightly up to 90 percent set point and then reseal when pressure is reduced to 85 percent of set point. This new technology maintains seal integrity until 98 percent of set point and will reseal at 95 to 97 percent of set point. This allows the operator to protect a system without exceeding its limits.

Upstream control is the key to stable, soft-opening/soft-closing operation. A conventional "pop"-type pressure relief valve is characterized as operating under downstream control: once the valve has opened, the flow is controlled mainly by an effective cross-sectional area downstream of the valve seat. In the PRV95, the flow-limiting cross section remains upstream of the valve seat at all times, and so the valve is said to operate under upstream control.

Primarily designed to operate in systems containing gases and liquids in a variety of pneumatic, hydraulic, and cryogenic applications, the PRV95 offers several advantages over older

valves, including: a smooth transition from fully closed to fully open; noise and wear reduction through elimination of chatter; a decrease in the risk of product fire and explosion through elimination of hard impact; and corresponding reductions in the uncontrolled venting of hazardous fluids and products. The increased stability of the valve operation results in better performance, with wider operating ranges and control. All of these attributes translate into the additional advantage of lower life-cycle costs.

To date, sales of the PRV95 total over \$400 thousand, mostly to high-end customers, including the U.S. Navy, which installed the valves on its DDG-51 Class Destroyers. Notably, the recent repairs to the USS Cole—the ship damaged by a terrorist bombing in Yemen— included installation of the PRV95 relief valve. Marotta Scientific is currently pursuing a valve redesign effort to improve manufacturability and reduce the high price of the product.

The company is also working to obtain an American Society of Mechanical Engineers' Section VII certification, required for many industrial applications. To this end, Marotta Scientific and the Office of Technology Transfer at Stennis Space Center have entered into a Dual-Use Cooperative Agreement to gain the certification. ❖



Marotta Scientific Controls, Inc.'s PRV95 design is unique in its ability to maintain a seal near the set point of the relief limit.

Mirrors Steer NASA in the Right Direction

A 19th Century measurement system that paved the way for Albert Einstein's Theory of Relativity is still being used by NASA to answer questions about the size and age of stars and planets that make up the universe. First applied to astronomy in 1883 by Nobel Prize recipient Albert Michelson, interferometry is currently being utilized to measure precise angles and distances of various elements throughout space. Furthermore, this unique study of wave lengths will be the focus of the Space Interferometry Mission (SIM), a major initiative that is under development by NASA's Jet Propulsion Laboratory (JPL). Scheduled for launch in 2009, SIM intends to seek out new planets by providing measurements several hundred times more accurate than those from previous programs.

In designing the mission, JPL used combined fast-steering and alignment mirrors, from Longmont, Colorado-based Left Hand Design Corporation, in test beds to assure that the

devices would provide accurate measurements when applied to a space interferometer. These mirrors are capable of correcting distortions in the structure of an interferometer that result during launch and temperature changes. Left Hand Design's mirrors can also react at high frequencies to offset structural vibrations produced from such things as reaction wheels used to maintain the overall alignment of the space interferometer.

Left Hand Design completed the production of the mirror technology, better known as fine-steering mirrors, through 1995 Phase I and 1996 Phase II **Small Business Innovation Research (SBIR)** contracts with JPL's Interferometric Astronomy group. As a result, Left Hand Design was able to deliver a large-travel, high-bandwidth fine-steering mirror that satisfied JPL's needs and offered design solutions with its compact, lightweight, and low-powered characteristics. In Phase I, the company constructed a prototype that would serve as the



The cost-effective CE50 and CE25 fine-steering mirrors in the foreground and the larger FO100 and FO75 fine-steering mirrors in the background represent recent enhancements to the mirrors first produced during the 1995 SBIR contract with NASA.



Standard FO-series fine-steering mirrors are not reaction compensated, as seen here in FO15 and FO50 formats.

backbone for a family of fine-steering mirrors of varying sizes and substrate materials. This was a unique situation, considering that hardware is typically not developed in the first phase of an SBIR contract.

During Phase II, JPL and Left Hand Design produced a more advanced mirror based on enhanced versions of the actuator, flexure suspension, sensor, and mirror substrate technology developed in Phase I. Design analysis for this model—which is intended for more demanding, space-based applications—led to many lessons learned, allowing the company to produce an apparatus that is more capable of surviving the launch environment, and focus on maintaining mirror flatness over the space operating temperature range. Other design improvements led to increased sensor bandwidth and higher servo control bandwidths, which ultimately provide fast and accurate control needed for interferometrical measurements. For example, the mirrors stabilize the line-of-sight of a telescope to less than a micro-radian.

Prior to working with JPL, Left Hand Design accumulated years of experience designing technologies related to fine-steering mirrors, including flexures, actuators, sensors, and lightweight mirror substrates, based on a broad set of requirements for large applications. Presently, the work resulting from the collaboration with NASA represents the company's main

line of products for the commercial sector. Aerospace-related applications include: image motion compensation; interceptor seekers for the U.S. Army and Navy; Earth observation and resource monitoring from spacecraft and airborne platforms; space astronomy; helicopter-based surveillance; and interferometric metrology. Left Hand Design's fine-steering mirrors have also penetrated the commercial marketplace with non-aerospace applications, including laser communications, video cameras, infrared inspection, solar observatories, and bathymeters. These cost-effective, commercial mirrors perform a variety of functions, such as scanning, alignment, chopping, tracking, pointing, and beam stabilization. Potential future applications include laser surgery and photolithography.

Left Hand Design continues to improve the overall performance of its fine-steering mirrors with ongoing research and development efforts. The current family of mirrors includes full performance, cost-effective, and commercial off-the-shelf models, all of which may be customized to the user's specifications.

With the help of the company's mirrors for the interferometry mission in 2009, NASA someday may be able to develop telescopes powerful enough to capture images of Earth-like planets orbiting distant stars and to determine whether these planets sustain life. ❖

Technology Transfer and Outreach

NASA's Commercial Technology Network strives to ensure that the Agency's research and development activities reach the widest possible audience with the broadest impact. The network, dedicated to technology transfer, serves as a resource of scientific and technical information with real-world applications for U.S. businesses interested in accessing, utilizing, and commercializing NASA technology.

As the methods of transferring NASA technology continue to grow, the Commercial Technology Office at each NASA field center works closely with NASA incubators, Regional Technology Transfer Centers, and others in the Commercial Technology Network to provide private industry with NASA technologies. While not all technology transfers result in commercialization, countless U.S. citizens benefit from outreach and education successes each year.

The following section highlights this year's successful technology transfer activities. In addition, it provides a guide to the many organizations that comprise the NASA Commercial Technology Network.

Outreach Achievements

Our solar system's "Blue Marble" is getting special attention this year. NASA's Earth and space science experts are utilizing innovative technologies, including remote sensing applications, to solve global problems in agriculture, public health and safety, the environment, and economic development. Major endeavors are underway using the Agency's array of space-based satellites, including the Total Ozone Monitoring System and the Moderate Resolution Imaging Spectroradiometer (MODIS), onboard the Terra satellite, the flagship in NASA's Earth Observing System <<http://terra.nasa.gov/>>. The MODIS Blue Marble project has provided NASA with the most detailed images of the Earth to date <<http://eob.gsfc.nasa.gov/Newsroom/BlueMarble/>>.



This image of Earth was provided through the MODIS Blue Marble project.

The Agency's Earth Science Enterprise and the Goddard Space Flight Center operate the Healthy Planet program <<http://healthyplanet.gsfc.nasa.gov/index.html>>. Medical researchers apply remote sensing data and technologies to better understand the links between human

health and the environment, weather and climate, and to develop health-related surveillance and early warning system tools. One project concerns the high rate of childhood asthma in Baltimore, Maryland, a city in the top quintile of the disease. Other studies include malaria epidemics in Southeast Asia and the effect of African dust on asthma rates in the southern United States and the Caribbean islands.

The Women's Outreach Initiative <<http://www.nasa.gov/women/welcome.html>>, a NASA Headquarters-sponsored program, is taking a very close look at health issues. This research is especially welcome because many of the troublesome symptoms experienced by astronauts in space are similar to conditions that affect women, such as osteoporosis. Women's health is only one aspect of this outreach, called "There's Space In My Life," which also studies issues affecting men, families, the home, recreation, travel, and leisure.

Remote sensing is also central to Ag20/20, a unique industry/government partnership driven by the needs of crop producers. This partnership includes the Earth Science Enterprise, NASA's Stennis Space Center in Mississippi, the U.S. Department of Agriculture, and commercial crop growers. Ag20/20 develops innovative information tools that increase production efficiency, reduce economic risks, and diminish environmental impacts associated with farming. Air- and space-based sensors are used to assist the farmer in key decisions, such as the timing and location of fertilizer, herbicide, and pesticide applications. Additional information is available at <<http://www.esad.ssc.nasa.gov/ag2020/>>.

Another public safety program is developing new sensor systems to study and predict hurricanes. The Convection and Moisture Experiment (CAMEX) involves NASA's Goddard Space Flight Center, the National Oceanic and Atmospheric Administration, and several universities. A new sensor, the dropsonde, measures atmospheric temperature, pressure, wind and humidity. The probe is dropped into a storm by parachute and transmits measurement data at any point around and within a hurricane. Scientists are now looking more closely at microscopic ice particles inside hurricanes to determine if they contribute to the storm's

strengthening or weakening. Visit the CAMEX website at <<http://camex.msfc.nasa.gov/camex4/related.html>>.

Public safety in aviation has generated three new NASA technologies, including Kennedy Space Center's Personal Cabin Pressure Altitude Monitor and Warning System, now under commercial development. The pager-sized monitor warns of potentially dangerous or deteriorating aircraft cabin conditions through audio, vibratory, and visual alarms. It operates independently of other aircraft systems and monitors the pressure/time conditions when supplemental oxygen is needed. Originally designed to offer astronauts independent notification of depressurization, two major incidents spurred its development: the Mir/Progress collision in June 1997 and the aircraft accident involving professional golfer Payne Stewart in October 1999.

A second technology comes from an alliance of teams from NASA's Dryden Flight Research Center, the U.S. Navy, New Mexico State University in Las Cruces, and industry, supporting NASA's Environmental Research Aircraft and Sensor Technology (ERAST) program. The goal is to provide safe operation of remotely-piloted aircraft in the National Airspace System; however, NASA sees an added benefit—commercial airliner safety. Aircraft manufacturers are now devising unpiloted aircraft capable of performing long-duration missions. Uninhabited aerial vehicles can be used to monitor wildfires, study environmental phenomena, relay cellular phone service, and keep an eye on petroleum pipelines and remote borders. For more information on this program, visit the ERAST website at <<http://www.dfrc.nasa.gov/rt/erast.html>>.

A third technology, the Pilot Weather Advisor, is ready to enter the market as an accurate real-time, in-flight weather information service. ViGYAN, Inc., of Hampton, Virginia, developed the system under a NASA **Small Business Innovation Research (SBIR)** contract. The system provides a continuous satellite-based broadcast of weather information. Both radar and airport condition information is graphically displayed on portable and panel-mounted displays. NASA's Langley and Glenn Research Centers supported the development of this technology. For more information, visit

Langley's Aviation Weather Information program website at <<http://awin.larc.nasa.gov/>>.

Believing that commercial development of the space frontier is a great opportunity for our Nation, NASA is encouraging businesses to seize this opportunity through the Space Product Development Office, to ensure economic growth by delivering new advances, technological understanding, products, and jobs to the public. Product development is carried out primarily through Commercial Space Centers, including industry, government, and academia that conduct space-related research with commercial potential. More information is available at <<http://spd.nasa.gov/>>.

With its technologically advanced array of remote sensors, both air- and space-based, along with Space Shuttle and International Space Station resources and a strong technology transfer program, NASA continues to make our Blue Marble a better place to live by furthering our knowledge and solving the problems that affect all humankind. ❖



The unique Proteus aircraft served as a test bed for NASA-sponsored flight tests designed to validate collision-avoidance technologies proposed for uninhabited aircraft. The tests, flown over southern New Mexico in March 2002, used the Proteus as a surrogate uninhabited aerial vehicle.

Educational Frontier

Each year, NASA's emphasis on education continues to expand as one of five contributions to the Nation's science and technology goals and priorities. The Space Agency's Strategic Plan demands educational excellence—"we involve the educational community in our endeavors to inspire America's students, create learning opportunities, and enlighten inquisitive minds."

NASA's dedication to education benefits all participants and advances the Agency's mission. A full range of projects and activities contribute to the educational goal's aim by providing information, experiences, and research opportunities in support of the enhancement of knowledge and skills in science, mathematics, technology, and geography. One measure of success is through community participation. Data show that 22 million people, including teachers, faculty, and students, are involved in NASA education activities, as part of 151 separate NASA programs. Over 2,500 kindergarten through 12th grade schools participate, with a fair mix of urban, suburban, and rural institutions.

In a major announcement aimed at taking students on a new journey of learning, NASA Administrator Sean O'Keefe unveiled plans in April 2002 for a new type of space explorer—an Educator Mission Specialist. Shortly after completion of the core elements of the International Space Station in 2004, NASA will send Barbara Morgan, the Agency's first Educator Mission Specialist, into space.

Morgan was selected as the backup candidate in 1985 for the *Teacher in Space* program. She trained side-by-side with Christa McAuliffe and the Challenger crew at NASA's Johnson Space Center in Houston, Texas. The *Teacher in Space* program ended when Challenger exploded in early 1986.

"The time has come for NASA to complete the mission—to send an educator to space to inspire and teach our young people," O'Keefe said. "Working in partnership with Education Secretary Rod Paige, we will make Barbara's flight the first in a series of missions in the new *Educator in Space* program."

In a real out-of-this-world educational experience, an area of small, unnamed craters on



Barbara Morgan and Christa McAuliffe, *Teacher in Space* program backup and primary crew.

Mars was the first site explored by a group of middle school students operating the camera system onboard NASA's Mars Odyssey spacecraft. The group of 11 sixth and seventh graders visiting Arizona State University in Tempe, from Olympia, Illinois, kicked off the Mars Student Imaging Project, a science education program funded by NASA and its Jet Propulsion Laboratory, of Pasadena, California, and operated by the Mars Education Program at Arizona State. The students watched as commands were sent to Odyssey from the university's planetary imaging facility. While scientists hit the keys, the students, who chose the study site, directed commands to photograph a set of Martian coordinates. To see and download the image, go to <http://clasdean.la.asu.edu/news/images/msipix/>.

The Classroom of the Future™ serves as NASA's premier research and development program for educational technologies. This tool develops curricular materials that improve mathematics, science, geography, and technology education in ways consistent with the national educational reform movement. The program helps bridge the gap between America's classrooms and scientists who have expanded the frontiers of knowledge in virtually every field of science over the last 40 years. The website at <http://www.cotf.edu> provides detailed information and instructions regarding how educators can utilize and participate in this NASA education program.

One Classroom of the Future offering is BioBLAST® (Better Learning through Adventure, Simulation and Telecommunications), a multimedia curriculum supplement for high school biology classes. Based on NASA's advanced life support research, the program offers students both traditional and computer-based research tools to study the interdependent components of a bioregenerative life-support system for long-term space habitation. Another stellar offering is *Astronomy Village: Investigating the Universe*, a CD-ROM-based multimedia program that provides teachers and students with 10 complete astronomy investigations intended to complement and extend the science curriculum in 9th and 10th grade classes. Students, in teams of three, use the *Astronomy Village* software to conduct the investigations and learn about the nature of scientific inquiry. The *Astronomy Village's* interface is based on the village-like appearance of major



Two students from Olympia, Illinois, analyze visual data from the Mars Student Imaging Project while visiting Arizona State University.

observatories on mountain tops. Tools available to students include an image processing program, an image browser, and various simulation programs. The simulation programs include a star life cycle simulator, an orbital simulator, and a 3-D star simulator.

NASA has taken full advantage of electronic media to present students and teachers with distance learning programs. Langley Research Center's Education Office produces NASA Connect and the NASA *Why? Files* to reach both elementary and middle school students. Both tools offer free instructional distance learning programs delivered through satellite television and the Internet, designed to increase scientific literacy and to improve math and science competencies of both students and educators.

Engineers and technicians from Langley also lent a hand to a group of Virginia high school students, named the Future Engineers of Hampton High, who decided to tackle a real-life engineering challenge following the September 11, 2001 terrorist attacks. NASA researchers helped the students refine their designs for a reinforced airliner cockpit door and an onboard camera passenger surveillance system. ❖

Classroom of the Future™ is a trademark of National Aeronautics and Space Administration.

BioBLAST® is a registered trademark of National Aeronautics and Space Administration.

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, online 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



The National Technology Transfer Center is located on the campus of Wheeling Jesuit University in Wheeling, West Virginia.

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, FWRITC staff work closely with businesses and entrepreneurs to identify opportunities, expertise, and other necessary resources. The FWRITC enhances the relationships between NASA and the private sector by offering many unique 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.glitec.org/>>, 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, Massachu-

setts. 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://technology.arc.nasa.gov/small-business.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.

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Commercial Technology Network and Affiliations

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The **Emerging Technology Centers (ETC)** <<http://www.etcbaltimore.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 Incubation 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.

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, which was formed to commercialize remote sensing, geographic information systems, and related imaging technologies.

The **NASA Commercialization Center (NCC)** <<http://www.nasaincubator.csupomona.edu/>>,

run by California State Polytechnic University, Pomona, is a business incubator dedicated to helping small businesses access and commercialize Jet Propulsion Laboratory and Dryden Flight Research Center technologies.

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 Texas 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 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 complement 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, as well as 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 in effect 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.

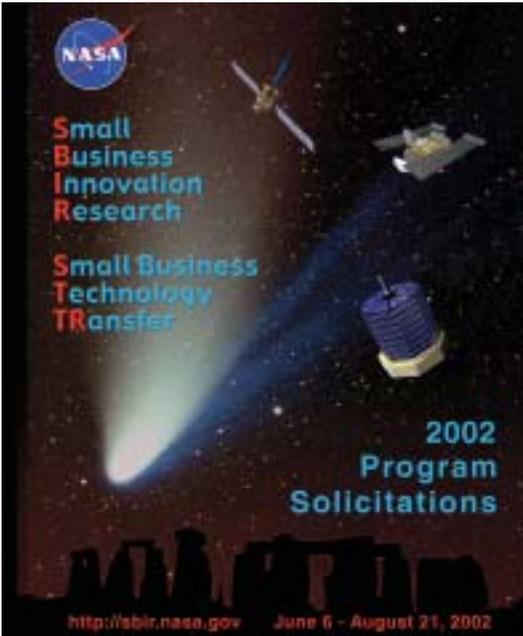
The NASA **Small Business Technology Transfer (STTR) Program** <<http://www.sbir.nasa.gov/>> awards contracts to small businesses for cooperative research and development with a research institution through a uniform, three-phase process. The goal of Congress in establishing the STTR Program was to transfer 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.

The **Federal Laboratory Consortium (FLC) for Technology Transfer** <<http://www.federallabs.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 main stream 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.

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Commercial Technology Network and Affiliations

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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, online 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.

For more than 3 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, 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 online publication featuring current research and development efforts, the NASA Commercial Technology Program, and successful commercial and industrial applications of NASA technology. ❖



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 or 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.
- ✕ 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.

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