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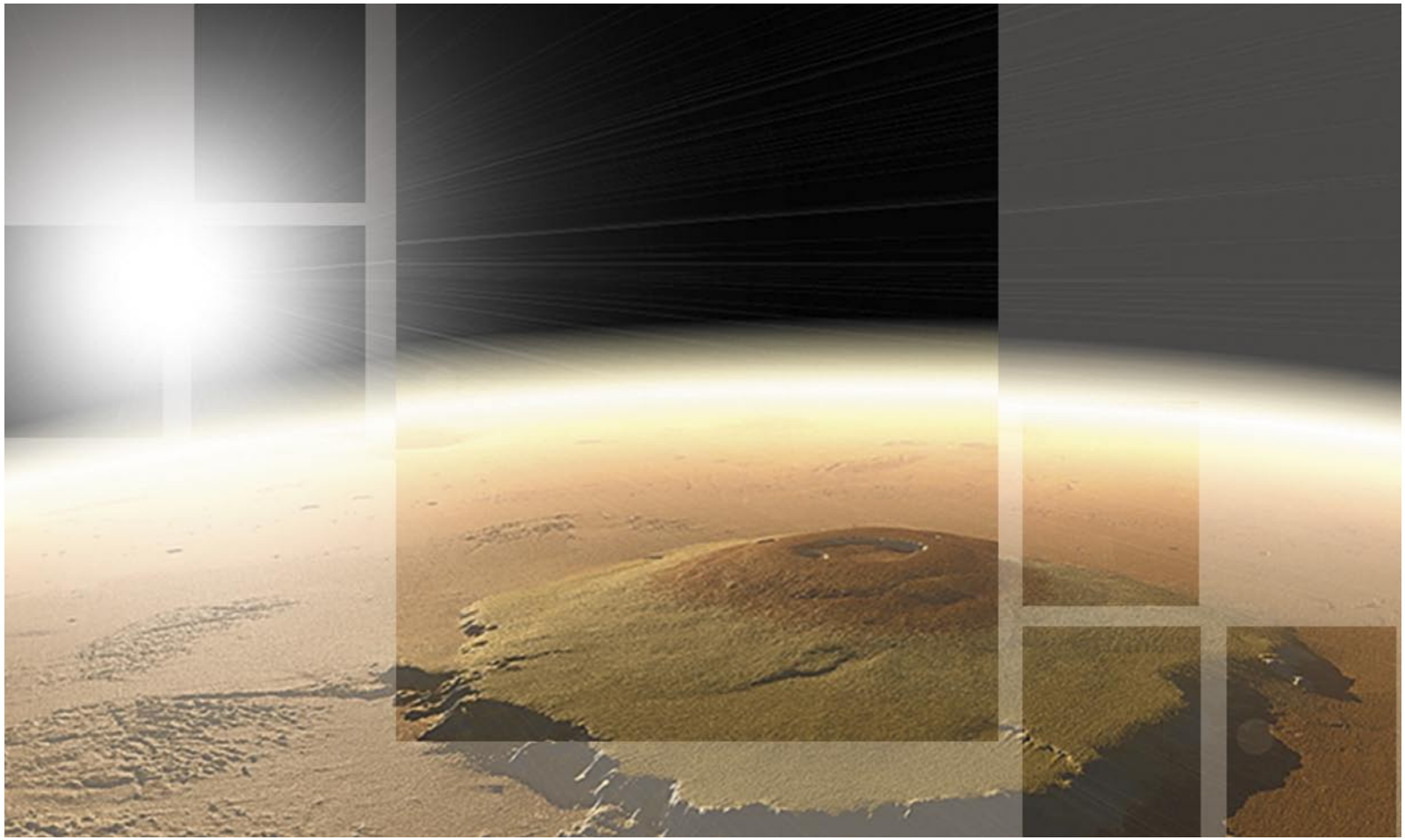
SPINOFF 2004



Exploration Systems Mission Directorate
Innovative Partnerships Program

Developed by
Publications and Graphics Department
NASA Center for AeroSpace Information (CASI)

National Aeronautics and
Space Administration

FOREWORD

On January 14, 2004, President Bush announced a new vision for extending our human presence across the solar system. The fundamental goal of the vision is to advance American scientific, security, and economic interests through a robust space exploration program. In support of this goal, NASA will:

- Conduct a sustained and affordable human and robotic program of exploration throughout our solar system
- Complete the construction of the International Space Station by 2010
- Return human explorers to the Moon as soon as 11 years from now in preparation for the exploration of Mars and beyond
- Promote international and commercial cooperation.

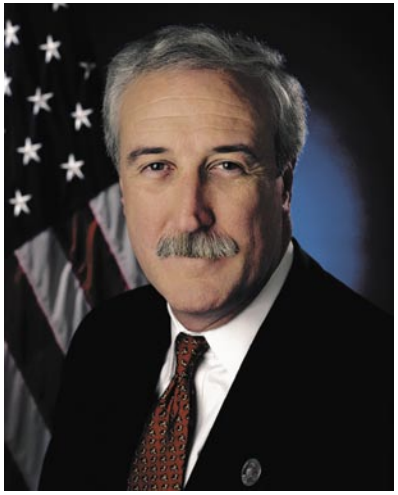
In pursuing this vision, NASA will explore answers to fundamental questions of importance to science and society. Questions such as: How did we get here? Are we alone in the universe? Where are we going? In doing so, we will help develop revolutionary technologies and capabilities for the future, while maintaining good stewardship of taxpayer dollars.

Most Americans do not realize that for every dollar paid in taxes, less than 1 penny funds NASA's activities. This level of investment will remain the same under the new exploration plan. In years past, the investment led to significant advances in weather forecasting, communications, computing, medicine, search and rescue technology, robotics, and electronics.

Looking forward, we believe the technology developments necessary to enable the expanded exploration of the solar system will accelerate advances in robotics, autonomous and fault tolerant systems, human-machine interface, materials, life support systems, and novel applications of nanotechnology and microdevices.

Even as our effort to pursue this bold exploration vision gets underway, NASA continues to produce important technological spinoffs for the American people. Among the beneficial, NASA-derived technologies highlighted in *Spinoff 2004* are: devices capable of filtering bacteria or viruses from water; a mineral identification tool that enables law enforcement and military personnel to identify suspicious liquid and solid substances; and a light bulb that provides 40 percent more surface illumination on work and reading surfaces, while reducing eye strain.

We are now 100 years into the age of flight, yet the journey of humanity to the heavens has barely begun. The men and women of NASA are proud to help lead humankind's next great leap into the cosmos, and of our role in producing beneficial technologies for people around the globe. It is in this spirit that we are pleased to present the positive information about our Nation's investment in space exploration contained in *Spinoff 2004*.



Sean O'Keefe
Administrator
National Aeronautics and Space Administration

INTRODUCTION

NASA's commitment to advancing and sharing technology dates back to the very origin of the Agency. After the dawn of aviation emerged with the Wright brothers' historic flight in 1903, Congress established the National Advisory Committee for Aeronautics in 1915 "to supervise and direct the scientific study of the problems of flight, with a view to their solution." When the committee was transformed into NASA by the National Aeronautics and Space Act of 1958, it was tasked with sharing its vast body of scientific and technical knowledge to benefit mankind.

Today, NASA continues to fulfill the 1915 Congressional directive and 1958 Space Act by reaching milestones in space exploration through a variety of programs. The technical expertise gained from these programs has transferred into the U.S. economy and society via academia, industry, and other Federal agencies, ensuring America stays capable and competitive.

The Innovative Partnerships Program of NASA's Exploration Systems Mission Directorate was established to guarantee the transfer of the Space Program's technical advances. Brimming with examples of technologies that have led to significant improvements in quality of life, NASA's technology transfer program has been the conduit for these achievements. The program excels by maintaining established relationships with commercial industries that include and extend beyond the aerospace sector.

Spinoff 2004 highlights the diverse benefits that have grown from NASA's partnerships with U.S. companies. These products span the many disciplines of our society. Included among this year's achievements are a natural, low-calorie sugar that is safe for diabetics and contact lenses that offer the benefits of a laser-corrective eye procedure without the need for surgery.

This issue also showcases some of the many research and development activities being conducted by NASA's field centers. These activities continue to fuel the Agency's missions, which collectively contribute to making the Vision for Space Exploration a reality. NASA is focusing on identifying common research interests with industry, enabling both parties to leverage their research and produce a technology that will help both the Agency and the private commercial venture. These dual-use joint ventures support the development of new exploration strategies, vehicles, and technologies, while continuing to bring space technologies back down to Earth.

With new goals in sight and partnerships in hand, NASA will continue to meet the challenges of the future.

Benjamin Neumann
Program Director, Innovative Partnerships Program
National Aeronautics and
Space Administration

TABLE OF CONTENTS

Foreword

Introduction

Partnership Benefits

- Health and Medicine
- Transportation
- Public Safety
- Consumer/Home/Recreation
- Environment and Resources Management
- Computer Technology
- Industrial Productivity/Manufacturing Technology

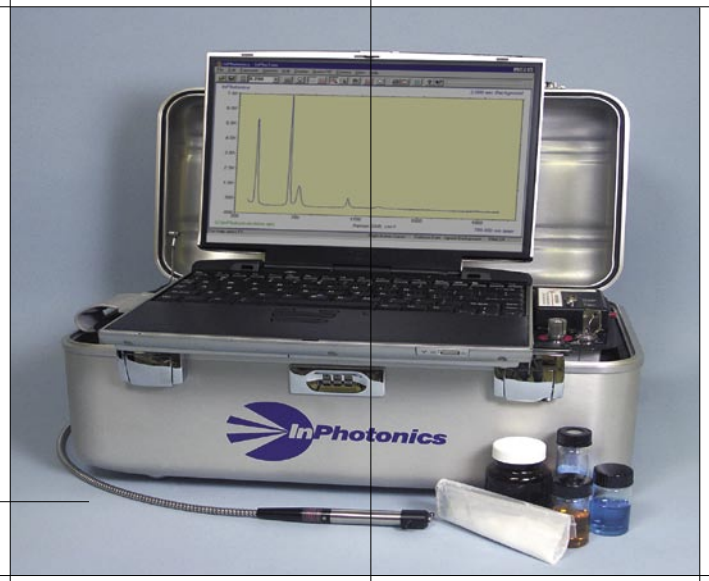
Research and Development at NASA

Education News at NASA

Partnership Successes

Technology Transfer Network and Affiliations

PARTNERSHIP BENEFITS



ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

Honored as an inductee of the U.S. Space Foundation's Space Technology Hall of Fame and recognized by the American Astronautical Society as "one of the true fathers of the space suit," Bill Elkins spent years conducting extensive research on clothing technology for hostile environments while he served as a NASA contractor at Ames Research Center. During the Apollo era, Elkins assisted Ames investigators in the development of a liquid-cooled garment to protect astronauts from extreme temperatures on the Moon. The garment successfully maintained the astronauts' body temperatures at a comfortable level by utilizing a battery-powered mini-pump to circulate chilled water through a network of tubes lining the garment.

PARTNERSHIP

As a holder of 19 patents covering inventions in restraint, space suit components, heat transfer, solar energy conversion, food preservation, and medical equipment, Elkins founded CoolSystems, Inc., based on his revolutionary findings that space suit technology could treat athletic injuries and offer therapeutic benefits to those who suffer from Multiple Sclerosis (MS). The products manufactured by CoolSystems are directly spun from the liquid-cooled garments worn by NASA astronauts.

PRODUCT OUTCOME

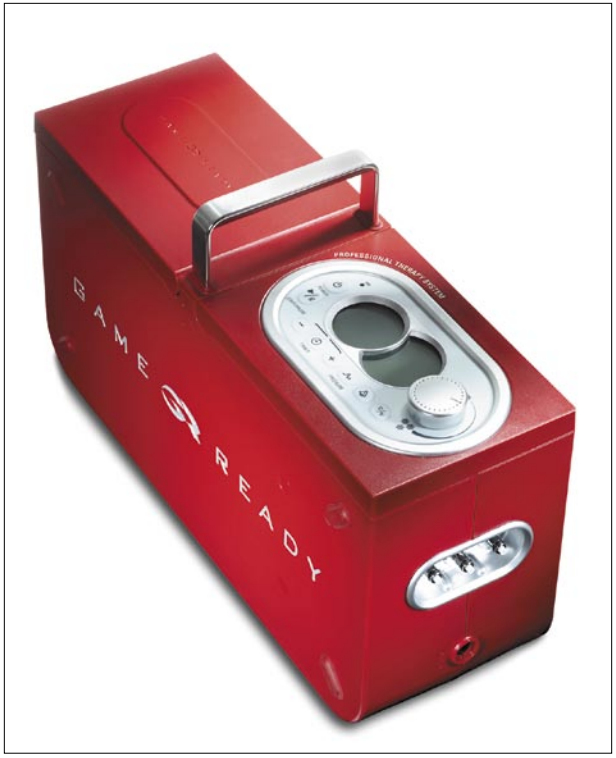
After years of collaboration with NASA, Elkins began working with sports trainers and doctors in 1998 to expand his discoveries into the realm of sports medicine. Early prototypes of his research were tested and met with glowing reviews from professional trainers and world-class athletes, such as National Football League Pro Bowl wide receiver and future Hall of Famer Jerry Rice. CoolSystems came together in 2000 as Elkins and his primary investors, The Roda Group, assembled a management team of executives, athletes, and engineers with extensive expertise in building flourishing sports brands. Tom Oliver, CoolSystems president and chief executive officer, was hired in May 2000 to bring the technology to market.

In June 2002, the CoolSystems team introduced its first product, the Game Ready™ Accelerated Recovery System, which combines space suit technology, medical research, and sports savvy to speed up the healing of athletic and post-operative injuries. Using patented ergonomic wraps and an adjustable control unit, the Game Ready Accelerated Recovery System is the first sports therapy product on the market to simultaneously provide deep tissue cooling therapy and intermittent compression, according to the company.

The seven ergonomic wraps, made from flexible fabric and designed to custom fit the ankle, knee, back, torso, shoulder, elbow, and wrist, effectively reduce pain, swelling, and tissue damage. They can be applied firmly and securely to injured areas, using hook and loop fasteners. The control unit connected to a wrap is filled with ice and water, so that cooled water can be circulated through the wrap over the course of treatment. The control unit additionally features microprocessors that control treatment time, temperature, and the level of intermittent compression that is being applied to the injured area.

When treating athletic and post-operative injuries, trainers and doctors follow the "RICE" (rest, ice, compression, elevation) formula. Although the RICE method is universally accepted, it can cause more harm than good when not applied properly. For instance, icing down an injury for too long or at too cold of a temperature can potentially cause further tissue damage ("freezer burn" is a term commonly associated with the overuse of ice packs). With the Game Ready system, athletes or injured individuals are subjected to controlled cold therapy within the optimum temperature range to maximize effectiveness and help prevent additional tissue damage.

The correct amount of compression is also difficult to calculate when properly implementing the RICE regimen. The Game Ready system provides "cyclical" compression, which has been shown to be superior to the "static" compression offered by other products and traditional therapies such as elastic bandages and cold wraps. Cyclical compression is preferable to static compression as it more closely mirrors the muscle contractions that the body itself uses to force tissue debris out of the affected area. In addition, with cyclical compression there is no known danger of restricting the body's natural efforts to evacuate excess fluid.



Where cold packs and ice packs offer limited flexibility, Game Ready's advanced injury treatment system allows you to control temperature and levels of compression.

The Game Ready technology also offers convenience for its users. The complete kit is portable and can operate off

of a battery pack, so it can be used on the field, in the car, on the bus, or on an airplane. Because the system is easier to apply, more comfortable, and less messy than ice packs, athletes and patients are more likely to comply with their rehabilitation programs.

Professional trainers using the Game Ready system report that they consistently see their athletes' recovery times cut in half from what they would expect for the injuries they commonly treat. Stan Conte, trainer for Major League Baseball's San Francisco Giants, is one of the trainers who have had newfound success in getting players back on the field. "I've seen a two-fold increase in recovery rates," Conte claims. "Guys that normally would have been out for a week are back in half the time." Today, more than 60 professional sports teams (including the Green Bay Packers, New England Patriots, Philadelphia Flyers, Boston Bruins, Atlanta Hawks, and the Sacramento Kings), 70 universities, and nearly 200 individual professional athletes (including Warren Sapp of the Oakland Raiders and Corey Maggette of the Los Angeles Clippers) have purchased Game Ready systems. In addition, the U.S. Olympic Training Centers, Navy SEALs, and the San Francisco Ballet have latched on to the new cooling technology.

The Recharge™ Active Cooling System is designed to enable users to lower core body temperature to effectively manage the symptoms of Multiple Sclerosis or other heat-related neurological disorders.

While the Game Ready Accelerated Recovery System is getting plenty of use in the world of sports, the CoolSystems team has introduced a sister product that is getting an abundance of attention off the field. The Recharge™ Active Cooling System reduces core body temperature, which can alleviate the symptoms associated with MS and other neurological disorders. Employing the same space suit ingenuity that offers precise temperature and pressure control within a flexible garment for astronauts and the same cooling principles of the Game Ready product, the Recharge system is comprised of a hooded vest that attaches to a control unit when cooling is required. The garment features a hidden cooling function so that it looks like ordinary outerwear when disconnected from the control unit.

The effectiveness of the Recharge system extends to athletes at risk for heat exhaustion or heat stroke as a result of physical exertion or exercise in high-temperature environments, as well as those who suffer from other heat-related neurological disorders. The hooded cooling vest will quickly and safely lower core body temperature in such extreme conditions.

Individuals suffering from MS and other neurological disorders are reaping benefits from the Recharge system in the form of long-lasting relief. The heat-induced symptoms of MS manifest themselves in a variety of ways, from increased fatigue and decreased balance, vision, strength, and endurance, to total body "shutdown." In an individual with heat-sensitive MS, the elevation of core body temperature above that person's normal baseline temperature—as may be caused by exercise or hot weather—can result in the onset or worsening of the symptoms. A NASA study published in the June 2003 edition of the journal Neurology shows that if these individuals can keep their core body temperatures at or below their baseline temperatures, many of the symptoms of the disease can be reduced.

Keeping core body temperature near baseline is a challenge, however. Methods such as cool baths, ice vests, or the provision of highly air-conditioned environments have been used to keep the body temperatures of those with MS down, but most of these methods are difficult to integrate into a normal routine. Recharge has been developed as a portable, convenient, and easy-to-use tool to enable people with MS to keep themselves cool wherever they are, even hours after a cooling session.

In February 2004, CoolSystems announced that it had entered into a collaboration agreement to test a "next-generation" cooling helmet with the Stanford University Medical Center's Stanford Stroke Center, which was recently acknowledged in a University Health Consortium survey as the leading academic institution in the country for stroke management, based on 20 different measures of patient outcome. The collaboration will further investigate the effectiveness of discrete hypothermia in stroke and head trauma patients.

Game Ready™ and Recharge™ are trademarks of CoolSystems, Inc.

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

Throughout its existence, NASA has made many amazing discoveries in the field of optics that have led to improved eye care and eye wear applications on Earth. Innovations such as laser eye-tracking for LASIK vision-correction procedures, eye trackers that enable people with severe disabilities to communicate and control their environment using only their eye movements, and scratch-resistant and radiation-blocking lenses are just a taste of the Space Agency's optical accomplishments.

In 2003, the world feasted its eyes on yet another optical offspring of NASA research: Westinghouse Lighting Corporation's Eye Saver™ Easy Reading Light Bulb. Over 2 years in the making, the Eye Saver bulb got its start when Barton Pasternak, executive vice president of Philadelphia-based Westinghouse Lighting Corporation, recognized a need to concentrate more light onto a work surface. Pasternak began working on a reflective insert for lamp shades, but quickly realized that optimum work space lighting could be attained with a light bulb. He and friend, Dr. Forrest Marshall, O.D., the chief executive officer of medical product developer Marshall Research, LLC, worked on ideas for innovative light bulbs that would make seeing easier under working conditions. To develop these ideas further, Dr. Scott Smith of NASA was brought in to apply his knowledge of deep space telescope optics to what would eventually become the Eye Saver bulb.

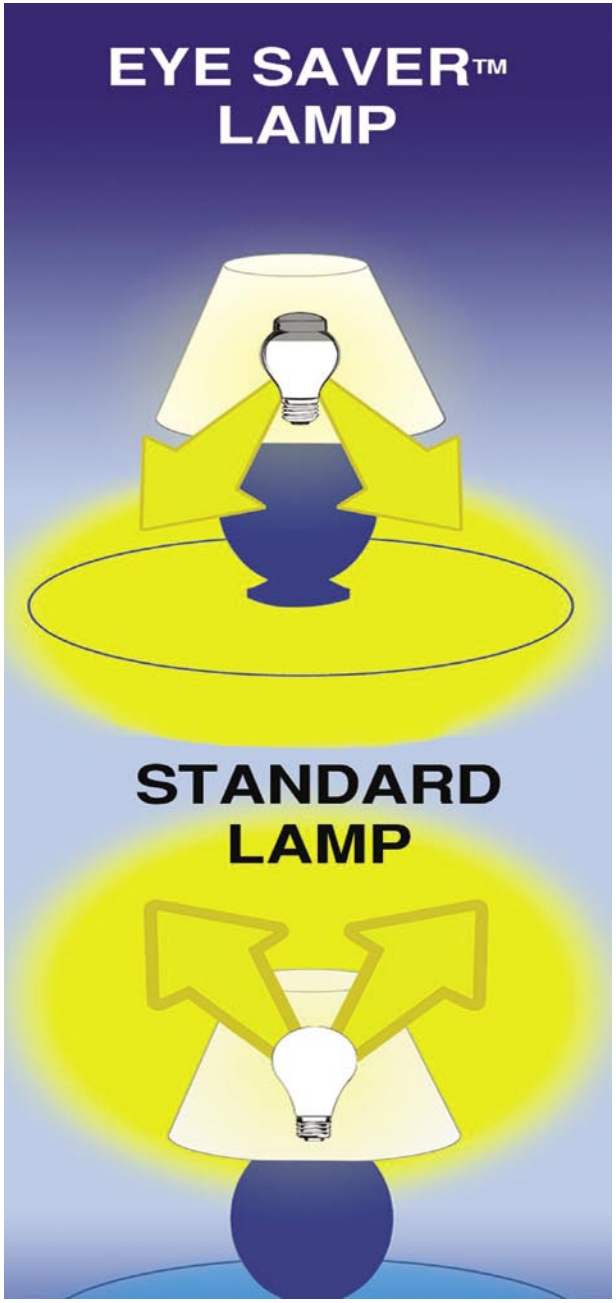
Westinghouse Lighting Corporation's Eye Saver™ Easy Reading Light Bulb is available in 125-Watt and 3-way (50/125/175-Watt) models.

PARTNERSHIP

As director of NASA's Space Optics Manufacturing Technology Center at Marshall Space Flight Center, Smith provides the leadership and direction required for research, design, development, fabrication, metrology, and testing of in-flight optical systems. Smith and his space optics center colleagues were introduced to Westinghouse Lighting Corporation by Ben Franklin Technology Partners, a Pennsylvania network that helps local companies develop new products to stimulate the state's economic growth. Together, Smith's team and members of Westinghouse Lighting Corporation, including Pasternak and Marshall, created a design for a light bulb consisting of a chrome top that would direct light to areas where it is needed most. By determining various angle degrees for the chrome top (critical to enhancing light) and studying different light sources and bulb shapes, Smith and his NASA colleagues were instrumental in producing the ideal design for the product.

PRODUCT OUTCOME

Available in 125-Watt and 3-way (50/125/175-Watt) models, the Eye Saver light bulb provides 40 percent more surface illumination on work and reading surfaces, compared to a standard incandescent light bulb, and possesses a lightly frosted finish that reduces eyestrain by diminishing



The Eye Saver™ directs light to areas where it is needed most, whereas a standard light bulb reflects a majority of the light off of walls and the ceiling.

glare. Additionally, the Eye Saver lasts 2,000 hours, twice as long as a standard incandescent bulb. The product is suitable for people of all ages and is particularly ideal for applications requiring high light levels, like reading, sewing, crafts, and numerous other recreational hobbies.

Notably, the light bulb helps those with macular degeneration and low vision to see easier in performing tasks that might otherwise prove daunting due to their conditions, especially seniors, who are most susceptible to these eye diseases. Age-related macular degeneration is the number one cause of vision loss and legal blindness in American adults over the age of 60, according to a non-profit organization known as the Macular Degeneration Partnership. Juveniles affected by macular degeneration and low vision also benefit from the Eye Saver bulb's ability to improve visual performance.

The practicality of Westinghouse Lighting Corporation's Eye Saver technology falls in line with recommendations made by Rensselaer Polytechnic Institute's Lighting Research Center, the world's largest university-based center for lighting education and research. According to the Lighting Research Center, placing light fixtures close to a task area and selecting bulbs with a high number of lumens or a strong light output is one of the best ways to combat the effects of low vision.

Furthermore, the Discovery Fund for Eye Research recognizes the Eye Saver as a useful light source for those who need enhanced lighting due to eye disease. Westinghouse Lighting Corporation donates a portion of its proceeds from the sale of each Eye Saver bulb to the Discovery Fund for Eye Research. The bulb retails from $8.99 to $11.99 and can be purchased through eye care professionals all around the country, or through select distributors and retailers such as Stormin' Norman's Discount Optics, Meijer Vision Centers, Boscov's, Carson Pirie Scott, JCPenney, and Sears.

Meanwhile, Westinghouse Lighting Corporation is continuing to develop professional optical products with the help it has received from NASA and further guidance from Marshall Research, LLC. In the works is a portable lamp attachment which uses a special bulb and motorized focus to develop intense, no-glare light for the severely visually impaired.

Marshall Space Flight Center's Space Optics Manufacturing Technology Center supports NASA's Science, Aeronautics Research, and Exploration Systems Mission Directorates. The optics center has been responsible for testing and calibrating the Chandra X-ray Observatory, the world's most powerful X-ray telescope, and is currently testing a new, advanced mirror system for the James Webb Space Telescope, the successor to the Hubble Space Telescope.

Eye Saver™ is a trademark of Westinghouse Lighting Corporation.

FREEING WATER FROM VIRUSES AND BACTERIA

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

Four years ago, Argonide Corporation, a company focused on the research, production, and marketing of specialty nano materials, was seeking to develop applications for its NanoCeram® fibers. Only 2 nanometers in diameter, these nano aluminum oxide fibers possessed unusual bio-adhesive properties. When formulated into a filter material, the electropositive fibers attracted and retained electronegative particles such as bacteria and viruses in water-based solutions. This technology caught the interest of NASA as a possible solution for improved water filtration in space cabins.

PARTNERSHIP

NASA's Johnson Space Center awarded Sanford, Florida-based Argonide a Phase I **Small Business Innovation Research (SBIR)** contract to determine the feasibility of using the company's filter for purifying recycled space cabin water. Since viruses and bacteria can be carried aboard space cabins by space crews, the ability to detect and remove these harmful substances is a concern for NASA. The Space Agency also desired an improved filter to polish the effluent from condensed and waste water, producing potable drinking water.

During its Phase I partnership with NASA, Argonide developed a laboratory-size filter capable of removing greater than 99.9999 percent of bacteria and viruses from water at flow rates more than 200 times faster than virus-rated membranes that remove particles by sieving. Since the new filter's pore size is rather large compared to other membranes, it is also less susceptible to clogging by small particles. In September 2002, Argonide began a Phase II SBIR project with Johnson to develop a full-size cartridge capable of serving a full space crew. This effort, which is still ongoing, enabled the company to demonstrate that its filter media is an efficient absorbent for DNA and RNA.

PRODUCT OUTCOME

Argonide supplies NanoCeram as laboratory-size filter discs and in the form of a syringe filter. The filter's unique character can be demonstrated by its ability to remove particulate dyes such as Metanyl yellow. Although Metanyl yellow's particle size is only 2 nanometers—approximately the size of a DNA molecule—the NanoCeram syringe filter is capable of retaining it as the fluid is passed through the syringe without much back pressure. Another distinctive advantage is the filter's ability to remove greater than 99.96 percent of endotoxins. As a contaminant formed from the residue of destroyed bacteria, endotoxins can cause toxic shock and present a major concern in pharmaceutical products.

Named one of the top 100 most technologically significant new products of 2002 by R&D Magazine, Argonide's NanoCeram syringe filters and laboratory filter discs provide the biotechnology and life science industries with fast, accurate, and cost-effective tools for separating proteins and other macromolecules. NanoCeram's key applications include sterilizing pharmaceuticals and medical serums; filtering DNA, RNA, and endotoxins; and immobilizing bacteria and mammalian cells in biosynthesis. The filters are capable of sterilizing water from all microbiological pathogens, including biological warfare weapons. Since the filter's absorption is based on the ionic charge of the macromolecules, the potential exists for separating proteins and other particulates on the basis of their charge differences. The separation of specific proteins signifies a major new thrust in biotechnology.

The NanoCeram® syringe filters and laboratory filter discs are fast, accurate, and cost-effective tools for separating proteins, viruses, and other macromolecules.

The NanoCeram® technology enables filter sterilization of medical serums and biological fluids.

Argonide's innovation may also be applied to tissue engineering, as the NanoCeram fibers have also been found to simulate new bone growth. When the material is grafted into damaged bone, the fibers attract and retain bone cells, permitting new growth at higher rates than hydroxyapatite, a natural bone mineral. Since the fibers mimic the natural fibrous hydroxyapatite's shape and adhesion, the result is a healthy new bone with physical properties almost identical to the patient's original bone. This application may help patients suffering from forms of osteosarcoma, osteoporosis, and sclerosteosis, a disorder in which progressive bone overgrowth leads to facial deformities.

Since the principal application of the NanoCeram filters is based on their ability to remove viruses from water, the filter cartridge Argonide is developing through its Phase II SBIR contract has many potential applications in water purification. For example, although municipal water is monitored for bacterial contamination on a routine basis, viruses are not monitored and there are no regulations for their removal. This is primarily due to the difficulty in monitoring for specific virus contamination. A low-cost filter cartridge such as Argonide's could be used for sampling viruses, allowing for a more routine analysis of municipal water treatment plant sources and effluents.

This potential application presents significant benefits, since viral hepatitis A and Norwalk virus epidemics have been waterborne on numerous occasions. Recent studies have shown that viruses can percolate far further underground than bacteria and can contaminate ground water supplies as a result.

The threat of terrorists contaminating water supplies is also increasing the need for a water filtration system with NanoCeram's capabilities. Argonide has received a contract to develop a concentrator that would collect biological agent viruses from water for the purpose of detection by real-time sensors. In another program, Argonide has demonstrated efficient collection of viruses containing aerosols, for the purpose of identifying aerosolized pathogens.

For consumers, Argonide is also developing a polishing filter that would be used in portable water purification devices for campers, backpackers, and military personnel. Present devices, while capable of filtering bacteria from water, are unable to filter viruses. Adding a NanoCeram polishing filter to the effluent of an existing filtration device could remove more than 99.99 percent of viruses. Another application is a point-of-use filter for residences with either municipal or pumped well water. On a global level, Argonide is working on low-cost gravity filters that might be used to purify surface or well water in Third World countries.

NanoCeram® is a registered trademark of Argonide Corporation.

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

Technology and medicine forged a bond in 1986 when a group of dedicated NASA scientists, University of Southern California (USC) medical professors, and a Dutch cardiologist joined forces to prevent heart attacks, using ultrasound images of astronauts' blood-flow patterns and the supercomputer depended upon to orchestrate the "Star Wars" Strategic Defense Initiative.

PARTNERSHIP

In the mid-1980s, a well-respected USC medical professor named Dr. David Blankenhorn was captivated by a New England Journal of Medicine article penned by noted preventive cardiologist Dr. Jacques Barth. Prior to reading this article, Blankenhorn had a global vision that the future of cardiology was prevention, especially with regard to diabetes, obesity, heredity, and other conditions that lead to serious cardiac events. Both Blankenhorn and Barth wanted to learn whether reversal or regression of cardiac diseases was possible.

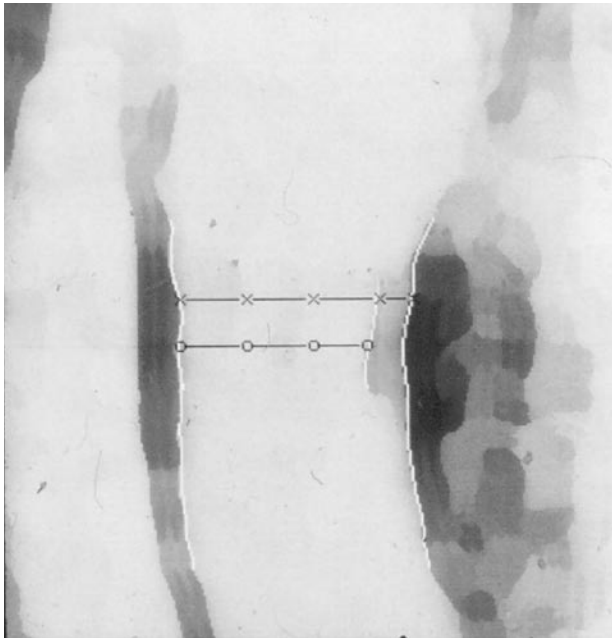
In the Netherlands, Barth directed a clinical trial called the Leiden Intervention Trial for patients who were deemed too advanced in their disease to be considered for cardiac bypass surgery. The patients being studied underwent lifestyle management modifications, including diet, exercise, and smoking cessation, to determine if the progression of cardiac atherosclerosis (clogging and hardening of the arteries) could be stopped or reversed. The outcome of the trial was considered revolutionary for the world of cardiology, as the majority of patients who complied with the healthy lifestyle changes actually stopped or reversed the progression of the disease.

Up until this time, the system for measuring cardiac profiles was angiography, known to be somewhat of a risky procedure. It was evident to Blankenhorn that a noninvasive system needed to be developed whereby patients could be monitored on a regular basis without risk. Because Barth had been conducting ultrasound of the common carotid artery for quite some time, the idea emerged to use this noninvasive technique as a quantitative system for assessing cardiac health. In the mid-1980s, quantified medicine, or the concept of calculating exact numbers from digital imaging without settling for "eyeball" estimations, was seen as the wave of the future.

Blankenhorn suspected that it would take a really big computer to develop a new, noninvasive system, as well as some scientific and medical "camaraderie." Knowing that NASA's Jet Propulsion Laboratory (JPL) was one of the only entities in the world to house a computer of the required magnitude and possess the expertise to convert analog images to digital moving images, Blankenhorn recommended that Barth submit a grant application to the National Research Council, in Washington, DC, for development of a cardiac system to monitor astronauts.

Blankenhorn was concerned with astronauts' lack of ability to endure zero gravity (a common ailment among astronauts and pilots is difficulty maintaining proper blood flow from the heart to the brain). In zero gravity, the heart does not always know where the brain is, so reversal of flow can become a problem. Barth reasoned that the system needed to monitor the blood flow from the brain to the heart. Interestingly, astronauts considered more "muscular" were not faring as well as other astronauts under zero gravity conditions. These astronauts required an increased amount of constant blood pumping to have sufficient blood flow, demonstrating that "less muscular"astronauts had an advantage.

The National Research Council awarded the grant to Barth, who then moved to Pasadena, California, to work with JPL experts and the large computer, as well as members from the USC medical staff. He and the JPL/USC team were able to conduct ultrasound on the astronauts in order to determine the level of elasticity of their blood vessels. The JPL supercomputer, already being utilized by the U.S. Department of Defense to control "Star Wars" technologies, was the only system in the world that could digitally capture the ultrasound images for this effort. By monitoring whether there was sufficient blood flow to the brain while astronauts acted in simulated space, the computer could indicate whether the oscillations of the targeted blood vessels resulted in a change of flow. One of the first signs of atherosclerosis is diminished elasticity, which adversely affects blood flow. From this condition, diagnosis and tracking can show whether an astronaut had an existing cardiac disease. According to Barth and company, the "Star Wars" computer technology was now the first line of defense for preventing heart attacks.



Although the quality of ultrasound imaging has improved dramatically since this grainy 1986 image of a 36-year-old astronaut—taken by Dr. Jacques Barth using a Jet Propulsion Laboratory computer considered superior at the time—it was clear that early signs of atherosclerosis were already present.

PRODUCT OUTCOME

Though blood flow was an important scientific study for astronauts, the practical applications for atherosclerosis became monumental. With assistance from the JPL scientists, the system for capturing images of blood flow from ultrasound images became more streamlined, allowing for the development of what the technique is today. For example, blood flow images can now be captured in 1/10 of a second, compared to a whole day when the project first started in the 1980s.

Barth and his USC partners incorporated what they learned from their astronaut research into additional studies where ultrasound was used as the predictive indicator for cardiac arterial progression. After 2 years, the studies concluded that the ultrasound method was reliable and had a predictive value higher than angiography for determining the likelihood of a serious cardiac event. Furthermore, as computers became smaller and software became more advanced, the development of ultrasound imaging was greatly enhanced. As a result, ultrasound equipment is now available in most physicians' offices, and the software for analyzing the images is accurate and readily available as a prevention tool for patients. The proven reliability, portability, and accessibility of ultrasound had set the stage for the major medical breakthrough known as CardioZone.™

As a culmination of years of medical and scientific expertise, the CardioZone system is at the top of the ultrasound technology currently available for the management of cardiac lifestyles. The U.S. Food and Drug Administration-approved method is a nonradiation, nonchemical, safe, and painless scan of the carotid arteries that is processed and computer-analyzed through proprietary software technology. Scans take from 10 to 15 minutes to perform and are analyzed by Barth's laboratory.

According to the provider of CardioZone, IMTHeartScan, Inc., the cardiac-testing technology is the only noninvasive procedure available for identifying fatty deposits called soft plaques. These deposits are held in place by a thin, fibrous cover susceptible to ruptures. The deposits may narrow the artery, but more importantly may trigger massive clots upon rupture, possibly filling up the entire artery and causing life-threatening heart attacks.

CardioZone is also more cost-effective than other diagnostic tests intended to detect atherosclerosis. At approximately $300 to $500, the procedure is far less expensive than either magnetic resonance imaging or electron beam computed tomography (whole body) scans, which can cost upwards of $2,000 and in many instances are not covered by insurance (CardioZone tests are reimbursable based on medical necessity).

One of the rewarding aspects of CardioZone is the opportunity to test asymptomatic individuals who do not know they have cardiovascular risk factors. Upon learning their "score," there is a "phenomenon of empowerment" for these individuals that tends to turn their lifestyles around in a positive manner. By looking at the disease as a whole, not just the risk factors, individuals can see through to a way of preventing progression of the conditions.

Barth and the CardioZone technology have saved the lives of countless individuals who did not experience symptoms of cardiac disease but were likely to suffer a serious event if not treated. If not for the collaboration and determination of NASA JPL scientists and a band of visionary preventive medicine physicians, the lives of many would not have been saved.

Ultrasound procedure of the common carotid artery, performed in a physician's office. This noninvasive, painless procedure takes approximately 10 to 15 minutes and the patient does not need to disrobe.

CardioZone™ is a trademark of IMTHeartScan, Inc.

‘CONTACT’ IN SPACE LEADS TO NEW LENSES

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

While gravity has its advantages in keeping us balanced and grounded here on Earth, scientists often find that they are at a disadvantage when trying to conduct research under its powerful, pulling influence. In these instances, the scientists prefer performing their studies in the weightless atmosphere of microgravity, where gravity is greatly reduced and solids, liquids, and gases behave differently.

In 1993, Paragon Vision Sciences, Inc., of Mesa, Arizona, participated in a research project with NASA’s Langley Research Center to perfect a process for developing contact lenses. The project called for three experiments that would fly onboard the Space Shuttle over the course of three separate missions, from 1993 to 1996. By unleashing contact lens materials to the microgravity settings of space, scientists from NASA and Paragon hoped to better understand how polymers—large molecules that make up plastics—are formed.

PARTNERSHIP

At Paragon, a manufacturer of premium performance plastics used in gas permeable contact lenses, scientists must perform a complicated process called polymerization to ensure that the materials they are using to make contact lenses are nontoxic, highly biocompatible, extremely permeable to oxygen, durable under abrasive cleaning conditions, wettable, transparent, and machineable. Given all of these divergent properties, it is necessary for the Paragon scientists to synthesize polymer chains wherein the various links in the chains are of substantially different chemical character.

During polymerization, some of the links are preferably incorporated into the growing chains simply due to their compatibility to the environment of the chains. The result, however, is an uneven distribution of these “precursor” links in the final polymer, leading to an uneven distribution of properties throughout the final product. This can be detrimental in developing materials for contact lenses.

To avoid this consequence, it is essential to minimize the redistribution of the precursor links during polymerization. While many of the driving forces for redistribution can be restrained in laboratories on Earth, one cannot: convection, the response to density differences arising from uneven heating in the reaction mixture. Since convection is driven by gravity, it was apparent to Paragon scientists that the microgravitational atmosphere of space was the only environment where they could correctly study the properties of new polymer formulations plagued by this problem.

Paragon and Langley designed three experiments to go into space on Shuttle Missions STS-57 (Endeavor), STS-63 (Discovery), and STS-77 (Endeavor) and explore such formulations. The “Gas Permeable Polymer Materials” experiments were performed in SPACEHAB, a pressurized research laboratory within the Space Shuttle’s cargo bay that was created for scientific and commercial experimentation.

The Space Shuttle research showed which plastic formulation components made the strongest contributions to the nonuniformity and lesser permeability characteristics seen

Paragon Vision Sciences, Inc. and Langley Research Center designed experiments to go into space aboard the Space Shuttle, in order to perfect a process for developing contact lenses.

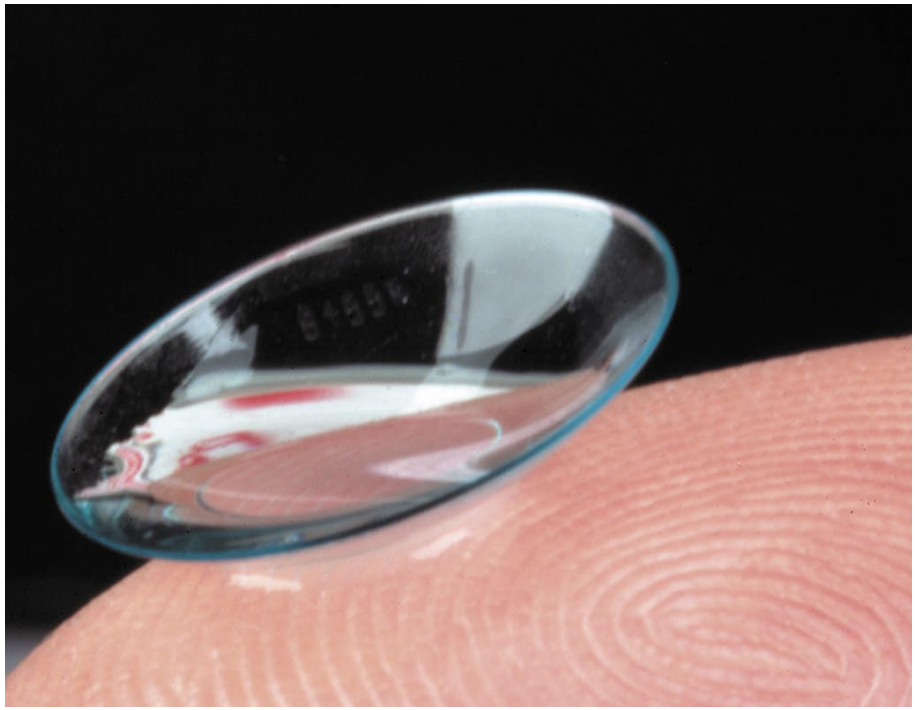
in similar formulations made on Earth (permeable plastics are ideal for extended-wear contact lenses because they allow more oxygen to reach the cornea, which is vital to preventing swelling of the eye). For Paragon, the findings led to an improved ground-based synthesis process and yielded new and better polymers for advanced uses in treating vision problems.

PRODUCT OUTCOME

Paragon's HDS® (hyperpurified delivery system) contact lenses are based on the unique technological advancements derived from the company's experiments with NASA. HDS lenses are considered gas permeable, and therefore do not contain water, are resistant from deposits, and are less likely than soft contact lenses to harbor bacteria. The rigidity of gas permeable contact lenses also makes them easier to handle than soft lenses, plus they retain their shape over time to provide crisper vision.

The HDS line effectively eliminated "bad" silicones, making the lenses extremely oxygen efficient. HDS has been approved by the U.S. Food and Drug Administration (FDA) for up to 7 days of continuous wear. Along with this approval, HDS was the subject of the most complete and comprehensive study on gas permeable extended-wear lenses ever conducted, according to Paragon. The National Institutes of Health-sponsored study confirming the safety and efficacy of the lenses was performed over a 5-year period and published in the August 2001 edition of the peer-reviewed journal, Ophthalmology.

Paragon additionally leveraged what it learned from the Space Shuttle experiments to invent a contact lens made from HDS materials that nonsurgically reshapes the cornea during sleep. Paragon CRT® (Corneal Refractive Therapy) is the company's latest product and the first therapeutic lens design approved by the FDA for overnight Corneal Refractive Therapy for the temporary reduction of myopia, or nearsightedness, with or without moderate astigmatism. When users awake, they simply remove the CRT lenses and experience clear, natural vision without daytime contact lenses or glasses. The FDA approval was based on results of an extensive and successful study in which almost 70 percent of the patients wearing the CRT contact lenses achieved 20/20 vision or better and more than 93 percent achieved 20/32 vision or better, which exceeds the 20/40 vision acuity that most states require to drive a car with an unrestricted license.



Paragon Vision Sciences, Inc.'s CRT® (Corneal Refractive Therapy) contact lens is a noninvasive alternative to laser-corrective surgery, as it reshapes the cornea during sleep to reduce nearsightedness. When users awake, they simply remove the CRT lenses and experience clear, natural vision without daytime contact lenses or glasses.

"Consumers no longer have to tolerate daytime contact lens irritation due to dry eyes, interference of glasses or contacts during sports and recreation, and countless other hassles," asserts Joe Sicari, Paragon's president and chief executive officer. "Further, consumers now have a nonsurgical option to gain the benefits of device-free vision."

Not only is Paragon CRT a noninvasive alternative to laser-corrective surgery, there are no age restrictions. The process is also reversible, so if a user wishes to discontinue wearing the lens, the cornea will return to its original shape. Moreover, Paragon CRT allows for adjustments for normal changes in vision that occur as people age.

Paragon has trained and certified over 2,000 eye care practitioners nationwide to prescribe Paragon CRT for overnight Corneal Refractive Therapy and tens of thousands of consumers are already enjoying the benefits of this safe, remarkable technology. The process is years ahead of the conventional methods of orthokeratology, which also depend on contact lenses to nonsurgically reshape the cornea, but take months to accomplish the desired result.

HDS® and CRT® are registered trademarks of Paragon Vision Sciences, Inc.

SEGMENTING IMAGES FOR A BETTER DIAGNOSIS

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

Originally conceived for use in terrestrial remote sensing applications, NASA's Hierarchical Segmentation (HSEG) software has found its way into a new medical imaging system, allowing for enhanced detection and management of medical conditions and diseases.

HSEG analyzes single band, multispectral, and hyperspectral imagery data with a resolution up to 8,000 by 8,000 pixels. The software evaluates each pixel and then groups pixels with similar imagery data characteristics into regions (pixels that are not adjacent may still belong to the same region if they share a similar spectral value). Similar regions are then combined to form composite regions. For example, an Earth satellite image may contain several lakes separated by land. HSEG will identify each lake as an individual region and then group all of the lake regions together into one composite region. This enables users to manipulate image resolution and therefore focus on data of interest—in this case, the lakes.

The segmentations fully utilize both spectral and spatial information from the imagery data. The result is a more accurate graphical representation of the imagery data with a fine resolution of detail and minimal distortion.

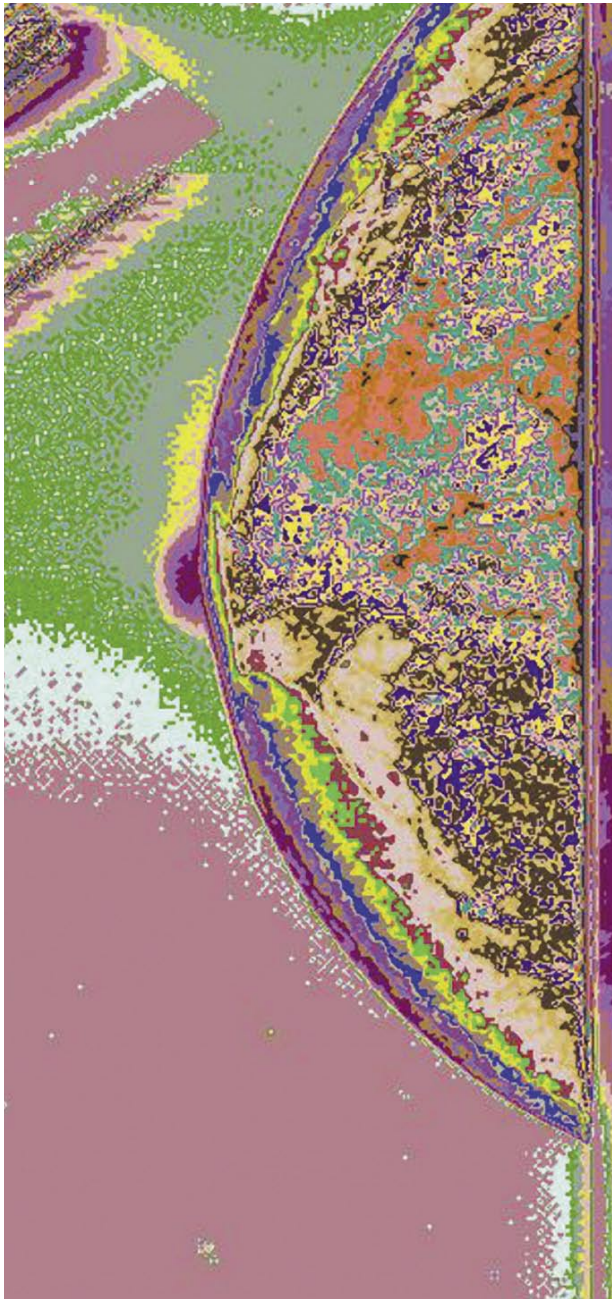
As an open workstation, Med-Seg™ is composed of a front-end terminal for segmentation feature extraction, pattern recognition, and classification of medical images, including computed tomography scans, positron emission tomography scans, magnetic resonance imaging, and ultrasound.

PARTNERSHIP

Bartron Medical Imaging, LLC, a small, minority-owned business based in New Haven, Connecticut, is dedicated to the development of imaging systems for medical diagnostic and environmental protection applications. Founded in 2000, the company set out to create a product that could differentiate difficult-to-see details in medical images from a complex matrix background, in order to improve diagnoses. Obtaining appropriate data from intricate images presented a hard challenge to hurdle for Bartron, especially given that none of the systems available at the time were capable of consistently generating such information.

In July 2001, Bartron was invited to NASA's Medical Imaging Workshop where it attended a presentation on the HSEG technology, given by NASA's Goddard Space Flight Center. Following the presentation, the company realized that HSEG was the missing piece needed to complete development of the intended new product, since the NASA software could process 16-bit medical image data to reveal information not normally seen by the human eye, let alone other image-interpreting procedures or algorithms.

Bartron contacted Goddard's Office of Technology Transfer (OTT) with the interest of exploring commercial application of the HSEG software. In response, the OTT facilitated meetings between Bartron and the developer of HSEG, Dr. James Tilton. With guidance from Tilton, the company conducted research to understand the HSEG concept and how to apply it to medical imaging. When it was determined that the software could be integrated into a medical imaging system, Goddard issued Bartron a non-exclusive license for the technology. Goddard also provided Tilton with $150,000 in funding over 2 years to continue assistance in improving the technology's commercialization potential.



Using Med-Seg,™ physicians and health care practitioners can take any unmanipulated medical image, such as a digitized mammogram, and segment it to "see" features in the image that were not previously visible to the naked eye.

In addition to the Goddard license, Bartron received licenses for other NASA-developed software programs it would need to manage the data for its new imaging system. The California Institute of Technology/Jet Propulsion Laboratory issued two licenses to the company to incorporate pattern-matching software, while Kennedy Space Center issued three licenses for data-mining and edge-detection programs (a technical report issued by Kennedy contends that edges carry the most important information in images, and accurate edge detection is vital to perform advanced image processing and analysis).

PRODUCT OUTCOME

Bartron's Med-Seg™ unit incorporating NASA's HSEG technology provides improved diagnoses for a wide range of medical images, including computed tomography scans, positron emission tomography scans, magnetic resonance imaging, ultrasound, digitized X-ray, digitized mammography, dental X-ray, soft tissue analysis, and moving object analysis; the technology is also equipped to evaluate soft-tissue slides such as Pap smears. Using Med-Seg, physicians and health care practitioners can take any unmanipulated medical image and segment it to "see" features in the image that were not previously visible to the naked eye. The clinicians can additionally isolate one particular area of interest in an image to compare it with many other reference images databased at other health care facilities, for instance.

As an open workstation, the Med-Seg system is composed of a front-end terminal for segmentation feature extraction, pattern recognition, and classification of the medical images. These images can be transmitted to Med-Seg via satellite, cable, digital subscriber line, or dial-up (for smaller images).

With faster, more precise identification of medical abnormalities, Med-Seg aims to reduce pain and suffering, as well as the costs associated with exploratory surgery and late decisions due to delayed diagnostic results and/or poor image quality. Bartron anticipates that its technology's rapid detection of pathogenic organisms could eventually play a critical role in handling bioterrorism or battlefield use of biological agents.

Bartron's initial strategy for the Med-Seg system is to work with research institutions and universities to develop proprietary databases which Bartron will solely own. The University of Connecticut School of Dental Medicine made the first purchase of a Med-Seg device in July 2003. It is applying the imaging system to evaluate jaw X-rays for tooth decay and bone loss. Results so far show that diagnostic data are much more readily visible with Med-Seg. In April of this year, the school reported that its Med-Seg-based approach "appears to provide dramatic improvement over other approaches for diagnosing osteoporosis."

U.S. Food and Drug Administration approval is being pursued by Bartron for further developments, including research related to drug development. Meanwhile, NASA is advancing its HSEG software to learn more about the region of space controlled by Earth's magnetic field. HSEG is helping to identify and extract magnetospheric radio-echo and natural plasma-wave signals recorded by the Radio Plasma Imager on the NASA Imager for Magnetopause-to-Aurora Global Exploration mission.

Back on Earth, HSEG continues to provide valuable segmentation of remotely sensed imagery, such as pictures taken from the orbiting Landsat satellite. The altered imagery leads to improvements in monitoring agricultural crops, identifying population densities and areas with rapid expansion, traffic congestion, roadways, resource planning, and global change.

Med-Seg™ is a trademark of Bartron Medical Imaging, LLC.

A LOOK FROM THE INSIDE

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

NASA's Hubble Space Telescope has given the world amazing images of the distant stars, planets, and galaxies. The cutting-edge imaging technology that enhances the Hubble images also extends its benefits to life here on Earth, from deciphering previously unreadable portions of the Dead Sea Scrolls to improving digital mammographies for advanced cancer detection. This imaging technology is now helping physicians to perform micro-invasive arthroscopic surgery, which is the visual examination of an interior joint such as the knee.

PARTNERSHIP

In 1997, NASA's Glenn Research Center signed a Space Act Agreement with Micro Medical Devices, Inc. (MMD), a medical device engineering company that licenses miniature surgical devices. Through the agreement, MMD gained access to NASA's expertise and technology in order to bring its micro-technology-based systems to the medical community faster and less expensively than if the company completed the necessary research on its own.

At that time, MMD was in the process of developing a new micro-endoscope. This tool enables surgeons to view what is happening inside the body on a screen, eliminating the need for a more invasive diagnostic procedure. The images from the micro-endoscope needed to be extremely clear, a challenge with the tool's small size. The images also needed to be viewed in real time to allow surgeons to see what was happening in the body at that very moment.

NASA supplied its expertise in image enhancement technology to perfect the images transmitted by the endoscope during surgery. Glenn's Photovoltaic Branch and Graphics and Visualization team worked with MMD to enhance and speed up the tool's graphic imaging. They applied algorithms to the endoscope system in order to remove the fiber patterns, lessen noise, sharpen the picture, and improve the color and illumination. As a result

The InnerVue™ Diagnostic Scope System enables surgeons to view what is happening inside the body on a screen, eliminating the need for a more invasive diagnostic procedure.

of their work, the NASA/MMD team won the NorTech Innovation Award, formerly known as the EDI Innovation Award, in 1999. The NorTech Innovation Award is part of Northeast Ohio's leading award program to recognize the most creative products and concepts by successful individuals and organizations.

PRODUCT OUTCOME

MMD established Clear Image Technology, LLC, of Elyria, Ohio, to commercialize the miniature endoscope. Clear Image Technology then partnered with Arthrotek, Inc., a sports medicine subsidiary of Biomet, Inc., to introduce the tool to the commercial market as the InnerVue™ Diagnostic Scope System.

The InnerVue system is designed for use in a diagnostic environment, such as an office or outpatient service, to evaluate conditions within a joint. While the InnerVue scope is primarily being applied to the knee and shoulder, other small joints such as the wrist, elbow, and ankle are being investigated. A physician can use the system alone or in conjunction with magnetic resonance imaging (MRI) to determine the next treatment step for each patient. The procedure can be more accurate than MRI, particularly with diagnosing cartilage and articular surface damage and assessing arthritis severity.

Components of the system include an endoscope, system hardware and software, and instrumentation. The scope's outside diameter is 1.2 millimeters (approximately the size of an 18-gauge needle). Since this micro-invasive scope only requires local anesthetic and allows the patient to be alert during the procedure, he or she cannot only see the pathology but can also aid the surgeon with dynamic events such as contracting a muscle.

One of the major benefits of the InnerVue system is its ability to provide an immediate diagnosis. Since the patient does not need to go offsite for testing, the InnerVue system puts a dynamic and active diagnostic test in the hands of the physician. The patient receives only one needle poke and may walk out of the office immediately after the procedure. Arthroscopy is well known as the diagnostic gold standard. The InnerVue system allows the surgeon to utilize this gold standard in a more efficient, less invasive, and timesaving approach.

The InnerVue™ Diagnostic Scope System evaluates conditions within the knee or shoulder in a diagnostic environment such as a doctor's office.

The InnerVue™ system provided this view of an Anterior Cruciate Ligament inside of a knee.

InnerVue™ is a trademark of Arthrotek, Inc.

THE PERFECT MATE FOR SAFE FUELING

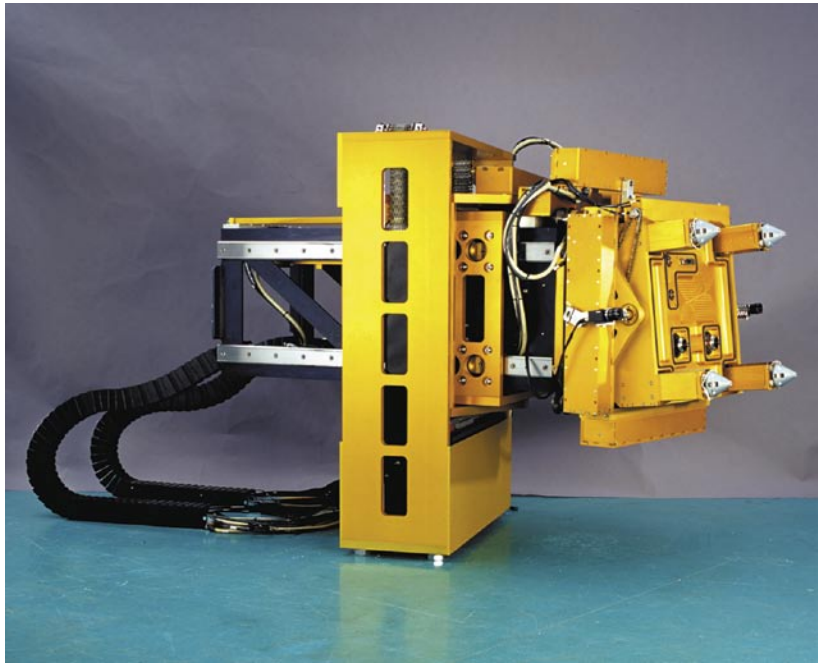
ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

Referred to as the "lifeline for any space launch vehicle" by NASA Space Launch Initiative Program Manager Warren Wiley, an umbilical is a large device that transports power, communications, instrument readings, and fluids such as propellants, pressurization gasses, and coolants from one source to another. Numerous launch vehicles, planetary systems, and rovers require umbilical "mating." This process is a driving factor for dependable and affordable space access.

With future-generation space vehicles in mind, NASA recently designed a smart, automated method for quickly and reliably mating and demating electrical and fluid umbilical connectors. The new umbilical concept is expected to replace NASA's traditional umbilical systems that release at vehicle lift-off (T-0). The idea is to increase safety by automatically performing hazardous tasks, thus reducing potential failure modes and the time and labor hours necessary to prepare for launch. The new system will also be used as a test bed for quick disconnect development and for advance control and leak detection. It incorporates concepts such as a secondary mate plate, robotic machine vision, and compliant motor motion control, and is destined to advance usage of automated umbilicals in a variety of aerospace and commercial applications.

PARTNERSHIP

Under a **Small Business Innovation Research (SBIR)** contract with Kennedy Space Center, Rohwedder, Inc., of Orlando, Florida, has successfully commercialized the Smart Remote Umbilical Mating System (SRUMS), based on NASA's next-generation umbilical technology. In June 2002, Rohwedder delivered a working prototype to NASA. The Space Agency then added its personal touches to fulfill its requirements for spacecraft applications, including remote operation capability and an improved vision system.



The Smart Remote Umbilical Mating System is one of the most advanced fueling systems available in today's market, as it decreases the need for human intervention during potentially dangerous fueling operations.

PRODUCT OUTCOME

SRUMS is one of the most advanced fueling systems available in today's market, as it decreases the need for human intervention during potentially dangerous fueling operations. Applications include the individual and gang mating of launch vehicles, as well as commercial aircraft at airport terminals, trucks at truck stops, military vehicles in the field or depot, and fleet automobiles at service stations and depots. The technology could potentially come in handy at fueling facilities for commercial vehicles utilizing alternative fuels. Major automotive companies are currently working on prototype hydrogen-fueled vehicles where the SRUMS technology could provide a useful margin of safety in fueling operations.

NASA tested the SRUMS technology at its Launch Equipment Test Facility, where it was installed on the Agency's "ASEA" robot—a mechanism that simulates the motions of a launch vehicle triggered by wind pressure. Looking ahead to future exploration missions, NASA is considering SRUMS for methane-fueled Mars exploration rovers. Additionally, with the capability to connect, disconnect, and reconnect during any point in the countdown process, SRUMS could lead to cheaper, safer, and more reliable launches for all future space vehicles.

The Space Launch Initiative is a NASA-wide research and development program managed by the Marshall Space Flight Center. Its mission is to open space for commercial, scientific, and personal pursuits, and to enable exploration of the universe by rendering space transportation much safer, less expensive, and more reliable than current commercial launch vehicles.

REDUCING THE TIME AND COST OF TESTING ENGINES

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

Producing a new aircraft engine currently costs approximately $1 billion, with 3 years of development time for a commercial engine and 10 years for a military engine. The high development time and cost make it extremely difficult to transition advanced technologies for cleaner, quieter, and more efficient new engines. To reduce this time and cost, NASA created a vision for the future where designers would use high-fidelity computer simulations early in the design process in order to resolve critical design issues before building the expensive engine hardware.

To accomplish this vision, NASA's Glenn Research Center initiated a collaborative effort with the aerospace industry and academia to develop its Numerical Propulsion System Simulation (NPSS), an advanced engineering environment for the analysis and design of aerospace propulsion systems and components. Partners estimate that using NPSS has the potential to dramatically reduce the time, effort, and expense necessary to design and test jet engines by generating sophisticated computer simulations of an aerospace object or system. These simulations will permit an engineer to "test" various design options without having to conduct costly and time-consuming real-life tests. By accelerating and streamlining the engine system design analysis and test phases, NPSS facilitates bringing the final product to market faster.

NASA's NPSS Version (V)1.X effort was a task within the Agency's Computational Aerospace Sciences project of the High Performance Computing and Communication program, which had a mission to accelerate the availability of high-performance computing hardware and software to the U.S. aerospace community for its use in design processes. The technology brings value back to NASA by improving methods of analyzing and testing space transportation components.

PARTNERSHIP

Wolverine Ventures, Inc., of Jupiter, Florida, signed a Space Act Agreement with NASA, sponsored by the Aerospace Propulsion and Power project under the Vehicle Systems program, enabling the company to commercialize NPSS V1.X. As part of the agreement, NASA Glenn and Wolverine jointly provide access and services for NPSS V1.X.

PRODUCT OUTCOME

NPSS V1.X is emerging as the U.S. standard for aerospace simulations. Serving as an object-oriented design code for aerospace engineers to analyze military, rocket, and commercial jet aircraft engines, the tool provides engineers with unprecedented capability, levels of interoperability, and ease of use. Wolverine Ventures and Glenn have put together two packages for NPSS V1.X that are available to universities and the general business community. In addition to delivering the software and documentation, Wolverine Ventures provides maintenance and support to users, and assists in the conversion and development of NPSS V1.X components, models, and utilities. The company develops software for interfacing NPSS V1.X with customer applications, and it offers various levels of training for its customers.

NPSS V1.X offers key technological advances in designing aircraft engines and enhancing the U.S. aerospace industry's competitiveness in the global marketplace. Using this technology, companies estimate a 55-percent reduction in the time to perform engine system simulation throughout the product life cycle. This translates into a projected annual savings to the aircraft industry of over $50 million a year from increased productivity. Companies could see a 50-percent improvement in the way they do business with industry partners and customers.

NPSS V1.X is not limited to aerospace engine applications. Any system, component, or process that can be modeled mathematically can take advantage of its capabilities, opening up the possibility for applications in the transportation, automotive, fuel cell, ground-based power, water treatment, and biomedicine industries.

Numerical Propulsion System Simulation (NPSS) Version 1.X serves as an object-oriented design code for aerospace engineers to analyze military, rocket, and commercial jet aircraft engines.

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

What do NASA and ballistics have in common? More than the average person may know. Everyday, millions of Americans drive in vehicles, cross over bridges, and fly in airplanes without knowing just how important NASA's role in studying ballistics is in making these actions viable and safe for them.

At Glenn Research Center's Ballistic Impact Facility, NASA scientists and engineers study the dynamics of high-speed projectiles and their impact on targets to create materials and structures that are smarter, lighter, and stronger. By applying the science of ballistics to new developments, these researchers are taking major steps in preventing catastrophic events. The Ballistic Impact Facility's main features are a 40-foot-long gas gun that can launch projectiles at speeds over 1,000 miles per hour and high-speed cameras that can capture up to 250 million images per second.

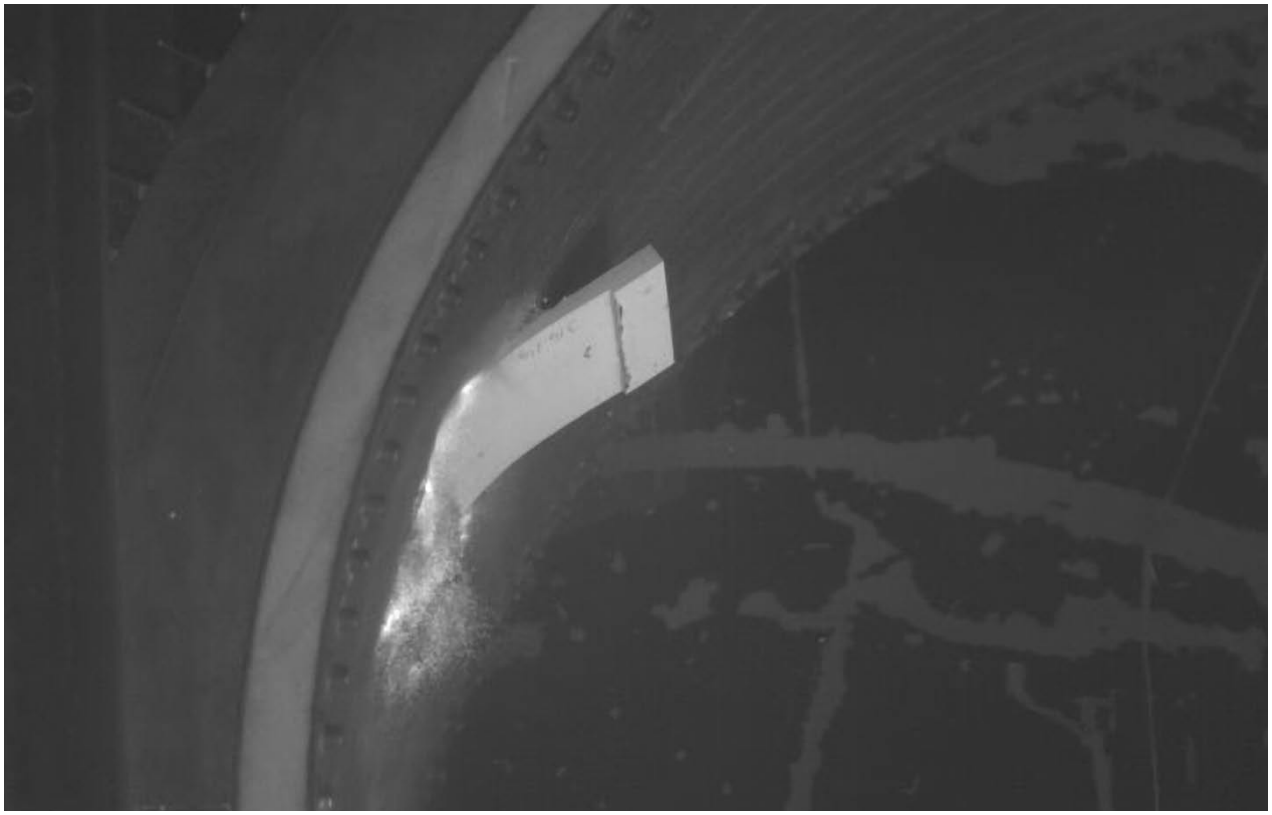
"The whole idea is to watch the impact and see how the structures impacted by the projectiles behave," says Dale Hopkins, a structures engineer and team leader for the facility. "It's not just whether they survive, but how they deform and fail."

One of the facility's main responsibilities is testing new concepts for aircraft engine housings to ensure they are capable of withstanding severe forces caused by fragments of rotating components that unexpectedly fail, for example, due to ingestion of foreign object debris such as hail or birds. Adequate engine housings are critical to reducing the risks of airplane damage and passenger injury.

On the ground, Glenn's ballistic testing is benefiting transportation and industry, thanks to a company named WebCore Technologies, Inc.

PARTNERSHIP

Based in Dayton, Ohio, WebCore Technologies utilized the Ballistic Impact Facility as well as other NASA resources to develop and commercialize its fiber-reinforced foam technology. Through prior experience with NASA personnel who participated in the "Consortium for the Design and Analysis of Composite Materials," the Great Lakes Industrial Technology Center (GLITeC)—Glenn's Regional Technology Transfer Center committed to providing commercialization assistance to Northeast Ohio companies—identified the expertise WebCore Technologies would need to invent a commercial product. In 2001, GLITeC facilitated a meeting between the company and Glenn, followed by a tour of the Ballistic Impact Facility. The two parties agreed to work together, using the ballistic facility to test samples of the product-to-be. GLITeC defined the scope of work in a simplified technology transfer agreement that required the commitment of less than $25,000 in Glenn resources, without special liability or intellectual property considerations. This agreement immediately helped to open the doors for WebCore Technologies to obtain $1.2 million in additional funding through **Small Business Innovation Research (SBIR)** contracts with Glenn and the U.S. Air Force.



High-speed photography from the Ballistic Impact Facility at NASA's Glenn Research Center reveals that a simulated fan case constructed with the TYCOR® material exhibits high stiffness and excellent damage localization during an impact event.

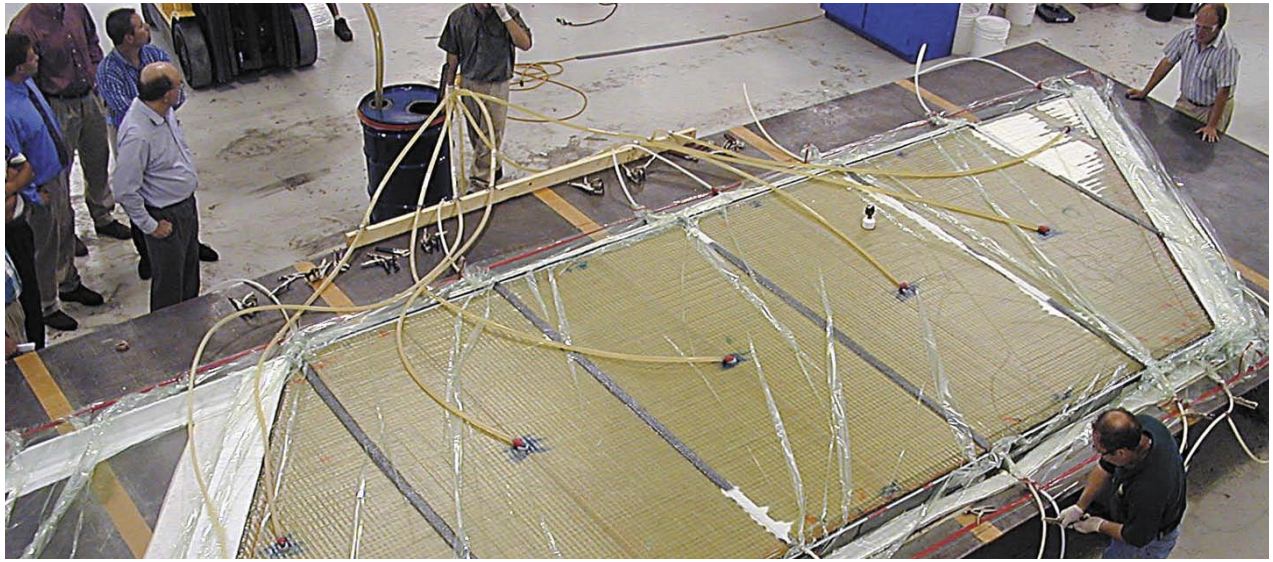
Additionally, WebCore Technologies received a NASA Glenn Garrett Morgan Assistance Award to establish a comprehensive sales and marketing force for the fiber-reinforced product. The award, intended for small, minority- or women-owned companies in the "Great Lakes" states as well as in New York, North Carolina, and Georgia, also entitled WebCore Technologies to seek help from the Garrett Morgan staff in solving a particular technical problem that arose during product development.

PRODUCT OUTCOME

The TYCOR® fiber-reinforced foam composite is WebCore Technologies' answer for a lightweight, low-cost sandwich panel that offers superior structural performance to aerospace, defense, construction, transportation, marine, and industrial markets. TYCOR consists of a foam core that is covered with fabric skins and then stitched with reinforcing fibers. When the skins and fibers are impregnated with resin, the result is a very strong, damage-resistant composite system.

The core manufacturing process integrates porous fiberglass or carbon fiber reinforcements in a three-dimensional architecture, in the form of structural "webs." The porous reinforcements act as resin flow channels that are easily controllable during resin infusion. The core process delivers a high degree of design flexibility using different types of foam and fiber, which are tailored to meet the functional requirements and cost targets for specific applications.

The key features of TYCOR include high-shear strength and stiffness, and high-tensile pullout strength coupled with excellent damage tolerance. To demonstrate TYCOR's shear strength and stiffness characteristics, WebCore Technologies subjected the fiber-reinforced foam to head-to-head testing against a balsa-cored panel of identical density, in a demanding U.S. Navy ship structural application. The panels were 5 inches thick, constructed with 4.5-inch cores, quarter-inch-thick glass fabric facings, and vinyl ester resin. The test results showed that the TYCOR panel was almost twice as strong as the balsa panel. The balsa panel also experienced abrupt failure under shear stress, whereas the TYCOR panel experienced only gradual failure. Follow-on work with the Navy led to a watertight composite door for Navy ships that offers a 50-percent weight reduction over existing watertight doors.



Shown above is an example of the WebCore Infusion Process (5 minutes after the start of infusion) that was used to fabricate a 20-foot-long, 8-foot-wide, 3-inch-thick bridge deck panel. The panel, comprised of TYCOR® core preforms, fiberglass skins, and epoxy vinyl ester resin, was fully infused in less than 10 minutes and had a final panel weight of 1,200 pounds.

TYCOR panels were used in the first composite bridge deck installed on a Federal property: the Hebble Creek bridge site located at Wright-Patterson Air Force Base. WebCore Technologies designed, fabricated, tested, and installed four 8-feet by 32-feet composite panels to form the bridge deck. The deck was tested for over 250,000 load cycles to simulate over 50 years of traffic, successfully showing TYCOR's long-term durability.

The technology is now a part of a lightweight airfield matting system being developed to replace the aluminum matting currently used in temporary runways, taxiways, aircraft parking areas, and other surfacing applications. WebCore Technologies is even exploring the possibility of replacing traditional manhole covers with fiber-reinforced covers that could better handle load-bearing vehicles.

Further, TYCOR cores and sandwich panels can be used for various interior and exterior components of commercial aircraft. Potential interior applications include floors, doors, bulkheads, seats, and luggage bins. Potential exterior applications include control surfaces, landing gear doors, access doors, fairings, radomes, and fuselage panels. NASA, too, can benefit from TYCOR, with potential applications for rocket fairings, payload adapters, cryogenic tanks, and structural members. WebCore Technologies is in the midst of completing Phase II of its SBIR contract with Glenn to bring these applications—and others—closer to reality.

TYCOR® is a registered trademark of WebCore Technologies, Inc.

NEW OUTBOARD MOTOR FIRING ON ALL PISTONS

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

Seven years ago, NASA was in the planning stages of producing an aluminum alloy with higher strength and resistance at elevated temperatures for aerospace applications. At that time, a major automobile manufacturer happened to approach NASA for solutions to lowering engine emissions and the costs associated with developing aluminum engine pistons. The Space Agency realized the answers to the manufacturer's problems could lie within the proposed alloy.

Jonathan Lee, a structural materials engineer at Marshall Space Flight Center's Materials, Processes, and Manufacturing Department, and PoShou Chen, a scientist with Huntsville, Alabama-based Morgan Research Corporation, partook in the development project as the inventors. The resulting NASA High-Strength Aluminum Alloy, or "MSFC-398," was capable of casting metal components at both high volume and low cost, making it extremely attractive for commercial application, not just in automotives, but in a variety of other industries, as well. NASA patented the technology and introduced it for public licensing in 2001.

PARTNERSHIP

A worldwide leader in the design, development, and distribution of outboard motors and a wide variety of land and water vehicles, Bombardier Recreational Products Inc. (BRP), in 2002 came across a description of the NASA alloy on the Internet and was immediately intrigued. The Sturtevant, Wisconsin-based company decided to meet with NASA in April of that year, wanting to learn if and how the technology could strengthen its products. BRP and NASA identified an application for high-performance outboard engine pistons. Prototype production started in July, and the licensing agreement was signed exactly 1 year later.

Marshall Space Flight Center's Jonathan Lee prepares to test the strength of the new aluminum alloy he co-invented.

According to Lee, the company worked hard with a casting vendor and NASA to perfect the casting of the pistons. "The usual cycle for developing this type of technology—from the research stage to the development phase, and finally into a commercial product phase—may take several years and more than a $1 million investment," said Lee. "In this case, it had occurred in less than 4 years at a fraction of the cost."

BRP also applauded NASA for its prompt assistance. "The demands of the outboard engine are more significant than any other engine NASA had ever encountered," claimed Bob Young, the company's vice president of engineering, outboard engines. "The team from NASA was on the fast track, learned all the intricacies, and delivered an outstanding product." BRP incorporated the alloy pistons into a brand new mid-power outboard motor coined Evinrude® E-TEC™ (E-TEC) that the company affirms is "years beyond two-stroke, four-stroke, or even direct injection" engines.

PRODUCT OUTCOME

By adopting the high-strength, wear-resistant aluminum alloy from NASA for its latest product line, BRP has created a boater's dream: the first outboard motor engine that will not require oil changes, winterization, spring tune-ups, or scheduled maintenance for 3 years of normal recreational use.

Not only is the E-TEC engine maintenance-free from such tedious upkeep responsibilities, its piston design

Evinrude® E-TEC™ is the first outboard motor engine that will not require oil changes, winterization, spring tune-ups, or scheduled maintenance for 3 years of normal recreational use.

successfully reduces the so-called "slapping" sound that occurs when pistons slide up and down in the engine's cylinder (this "whisper quiet" feature is particularly appealing for trollers looking to avoid scaring off fish, especially in shallow waters). The NASA alloy greatly improves piston durability because it is 2.5 times stronger than conventional cast aluminum pistons at high temperatures and can be produced with a material cost of less than $1 per pound. Engineers finalizing the product also saw environmental advantages from the alloy, as it would help the new engine comply with the California Air Resources Board's emissions standards—some of the most stringent in the United States.

The E-TEC features a low-friction design completely free from belts, powerhead gears, cams, and mechanical oil pumps; a "sure-start" ignition system that prevents spark plug fouling and does not require priming or choking; and speed-adjusting failsafe electronics that keep it running even if a boat's battery dies. A central computer controls the outboard engine's single injector, which is completely sealed to prevent air from entering the fuel system. This minimizes evaporative emissions. Furthermore, the E-TEC auto-lubing oil system eliminates the process of having to mix oil with fuel, while complete combustion precludes virtually any oil from escaping into the environment. When programmed to operate on specially designed Evinrude oil, the E-TEC uses approximately 50 percent less oil than a traditional direct injection system and 75 percent less than a traditional two-stroke engine. Additionally, when compared to a four-stroke engine, the E-TEC creates 80 percent less carbon monoxide while idle.

Ranging from 40-horsepower (hp) models to 90-hp models, the E-TEC engines won the prestigious 2003 Innovation Award from the National Marine Manufacturers Association at the annual Miami International Boat Show. In the same year, E-TEC also received a vote of confidence from an individual who put the engine to an incredible test in the most unusual of conditions. While BRP often hears from boaters who depend on its engines in tropical, warm, or—at worst—temperate climates, the company had heard about an individual from the small Alaskan village of Koyokuk who runs the Yukon River in his boat just about everyday, from break-up of the iced-over body of water to freeze-up. The nearest "sizable" town is 400 miles upstream from Koyokuk, so the individual uses the rugged river as his "highway" to deliver and transport goods such as tools, supplies, and groceries.

Upon learning about the E-TEC engine from a Fairbanks, Alaska-based dealer, the individual felt the need to challenge the motor's performance against the unbearable, uncompromising conditions that he had grown accustomed to. As a result, the 90-hp E-TEC engine got his boat up and running on step quicker and carried his loads easier than his previous motor. Right up until the river froze over for the year in October, the individual was the only boater on the water. He was able to start his E-TEC instantly at temperatures as low as 8 ºF (-13 ºC).

Taking torque to the next level, BRP will offer three new options to the E-TEC family in the 2005 model year: 200 hp, 225 hp, and 250 hp. Like their smaller 40- to 90-hp relatives, the proposed higher-powered engines are anticipated to present outstanding durability and reliability in extreme environments, while offering low emissions, quiet operation, and virtually no maintenance.

The introduction of the E-TEC engine has brought a whole new meaning to two-stroke engines, which have long been the focus of intense environmental scrutiny for their high rate of pollution emissions. Together, BRP and NASA have not only revived this struggling breed of outboard motors, but have reinvented it for generations to come.

Evinrude® is a registered trademark of Bombardier Recreational Products Inc.

E-TEC™ is a trademark of Bombardier Recreational Products Inc.

FORECASTING WEATHER WITH A WAVE OF THE HAND

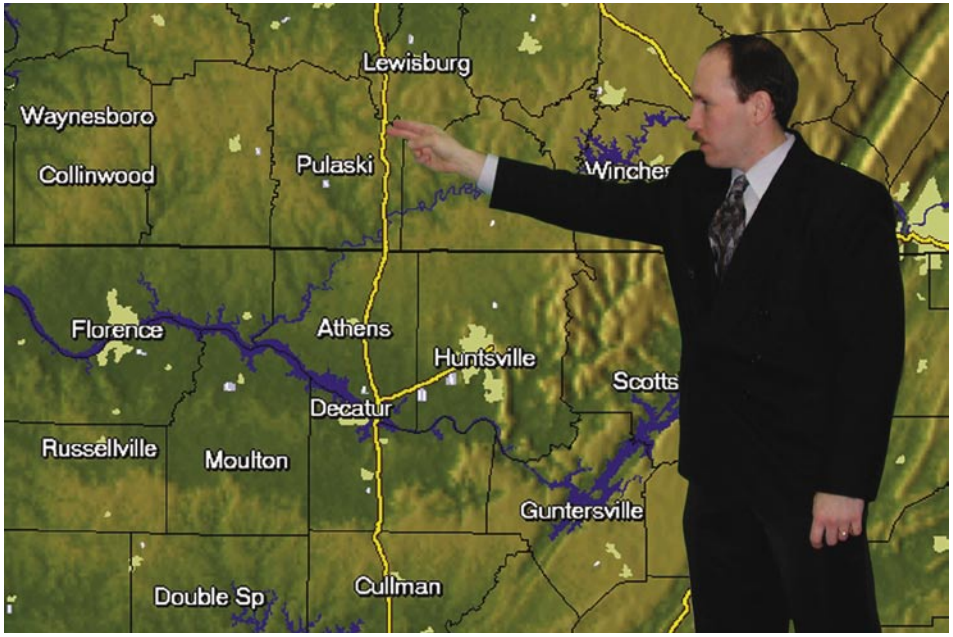
ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

Cybernet Systems Corporation, of Ann Arbor, Michigan, originally developed its gesture recognition technology for the U.S. Department of Defense. A 1997 Phase II **Small Business Innovation Research (SBIR)** contract with NASA's Johnson Space Center also contributed to the development of the company's gesture recognition and tracking system, which observes human hand motions and interprets gestures in order to control devices.

PARTNERSHIP

Cybernet responded to NASA's request for an educational outreach device that would capture children's attention without the need for a keyboard or mouse. By integrating its gesture recognition technology with NASA's Virtual Astronaut software, the company created a gesture-controlled space station kiosk for Johnson's Bioastronautics Exhibit. Giving the public a chance to explore the International Space Station without leaving Earth, the kiosk enabled visitors to lead their own virtual space station tours, as they moved throughout the station's interior using hand gestures. Visitors could point a finger, move a hand, or open and close a fist to manipulate doors and viewports or request more information.

Johnson's Space and Life Sciences Directorate designed the exhibit to help the public understand the purpose of NASA's mission and how it relates to life on Earth. The gesture recognition technology added a futuristic feel to the kiosk, while adding practical benefits. Since visitors did not have to touch anything to interact with the virtual space station, dirty computer screens and broken parts were not a concern. The kiosk demonstrated that gesture recognition technology can provide a viable alternative to physical contact or remote controls for sending commands to devices.



GestureStorm™ enables a meteorologist to interact with a weather map in real time for televised broadcasts.

PRODUCT OUTCOME

Building upon its successful collaboration with NASA, Cybernet introduced GestureStorm,™ a weather map management system that utilizes both body tracking and gesture recognition technology for televised weather reports. The GestureStorm software interface enables meteorologists to control the computerized visual effects on weather maps using hand gestures and body movements. Prior to this, meteorologists prepared scripted on-air reports to coincide with the timing of graphics on the computerized maps. They knew when and where weather and Doppler radar maps would appear on the monitor, but could not react in real time.

Cybernet's new product frees forecasters from a script, enabling them to directly interact with the weather picture in real time, significantly reducing the preparation time for the broadcast. With this technology, meteorologists control the pace of the visuals and can incorporate spontaneous close-ups with simple hand movements. In cases of severe weather, meteorologists strive to report new information as quickly as possible. GestureStorm gives forecasters an edge as they track late-breaking storms. The reduced preparation and real-time interaction shave critical minutes from the time required to broadcast severe weather warnings.

The first deployment of GestureStorm was at WKMG TV, a CBS-affiliate station in Orlando, Florida. The system is exclusively provided by Baron Services, Inc., of Huntsville, Alabama. GestureStorm interfaces with Baron Services' storm tracking and forecasting products, including FasTrac,® NexTrac,® and VIPIR.® By interpreting simple hand motions to facilitate Baron's products, GestureStorm provides an effective alternative to the traditional methodology for producing on-air weather spots.

GestureStorm™ is a trademark of Cybernet Systems Corporation.

FasTrac,® NexTrac,® and VIPIR® are registered trademarks of Baron Services, Inc.

UNDERSTANDING FIRE THROUGH IMPROVED TECHNOLOGY

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

By studying fire through the science of combustion physics, scientists and researchers from NASA, academia, and private industry find new ways to improve fire safety and increase fuel efficiency. Since gravity's effect on fire masks many details that occur during the combustion process, scientists can gain a better understanding of fire by studying it in microgravity.

Researchers from NASA's Microgravity Combustion program at Glenn Research Center use drop towers, which are long, vertical shafts, to study how fire behaves in microgravity. Experiment packages are dropped from the top of the tower, enabling them to achieve microgravity through freefall. As part of their work to measure fire behaviors, the NASA researchers needed a laser capable of high sensitivity trace gas detection at unique wavelengths. While diode lasers are suitable for tests in the drop towers because they are rugged, small, and low power, existing laser models did not have the capability to produce the necessary range of wavelengths.

PARTNERSHIP

NASA granted Southwest Sciences, Inc., of Santa Fe, New Mexico, a Phase II **Small Business Innovation Research (SBIR)** contract to develop a diode laser that could meet the Microgravity Combustion program's very specific measurement requirements. As a result, the company developed a broadly tunable external cavity diode laser that offers unprecedented wavelength agility and tuning speed.

Although the Aztec laser is not the first external cavity diode laser, its increased capabilities mark a tremendous leap in the technology. Dr. Nancy Piltch, a NASA optical physicist for the Microgravity Combustion program, described the technology advance as "equivalent to switching from mechanical to electronic tuning."

The Aztec™ laser's detection capabilities may lead to improved fire safety both on Earth and aboard the Space Shuttle.

PRODUCT OUTCOME

Aztec™ is the commercial name for Southwest Sciences' laser. The laser has coarse tuning ranges of 10 nanometers (nm) to 30 nm at wavelengths ranging from 630 nm to 2,300 nm, making it the only commercially available external cavity diode laser with wavelengths beyond 1,650 nm. The laser's high-speed tuning in both coarse and fine wavelength regimes allows for increased trace gas detection. With the automated coarse tuning option, the Aztec sweeps through its wavelength range in less than 1 millisecond. While some diode lasers can only detect one type, or species, of a trace gas, the Aztec's broad wavelength tuning provides access to multiple trace gas species.

The Aztec has a wide range of applications for both NASA and commercial users, from protecting astronauts in space to improving combustion processes on Earth. It may serve as a new tool for planetary exploration, as it can detect a wide range of multiple gas species in planetary atmospheres. The laser could optically detect gaseous indicators of incipient fires on the International Space Station and Space Shuttle, as well as detect low concentrations of potentially toxic gases in spacecraft crew habitats. The laser could also provide more accurate fire detection in aircraft cargo compartments. Since the Aztec can detect several gases that only evolve during an actual fire, its implementation could reduce the large number of commercial aircraft landings that currently occur due to false alarms. Other applications include environmental and industrial process monitoring.

Aztec™ is a trademark of Southwest Sciences, Inc.

APPROACHING SUSPICIOUS SUBSTANCES SAFELY

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

A mineral identification tool that was developed for NASA's Mars Rover Technology Development program is now serving as a powerful tool for U.S. law enforcement agencies and military personnel to identify suspicious liquid and solid substances.

PARTNERSHIP

In 1998, NASA's Jet Propulsion Laboratory awarded a **Small Business Innovation Research (SBIR)** contract to EIC Laboratories, Inc., to develop a portable Raman spectrometer and fiber-optic probe that could be used on a Mars exploration rover. Raman spectroscopy, an analytical technique for identifying molecules in gases, liquids, and solids, uses a laser to scatter light from a targeted sample. The Raman spectrometer detects the returned light in order to identify the sample's makeup. NASA needed this tool to be easily integrated into a Mars rover to provide chemical identification of Mars soil and mineral samples. Spectrometers such as this one are part of a cluster of instruments in the rover that combine traditional field tools with the equipment typically found in geological laboratories.

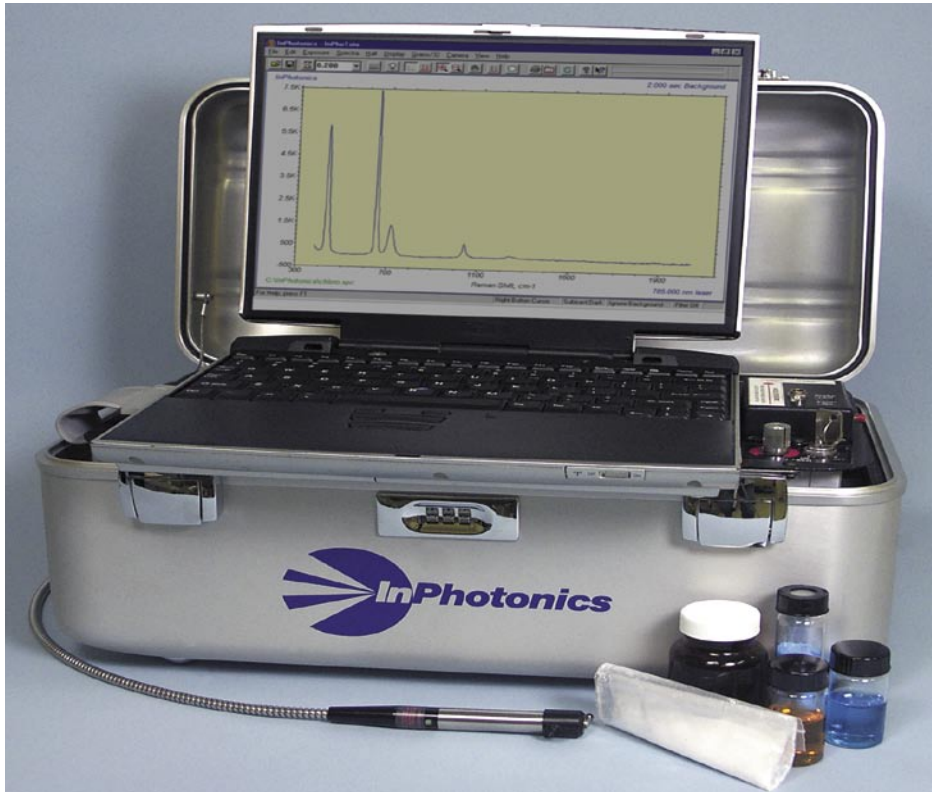
EIC Laboratories' work on the NASA project resulted in a portable Raman spectrometer with dual wavelength illumination that could obtain full-range spectra of mineral samples. The company also developed instrument control software for the system and a database of the Raman spectra of minerals for Mars exploration. The entire spectrometer fits inside a "suitcase" roughly 24 by 16 by 8 inches, and employs a fiber-optic probe 4 by 0.5 inches in diameter that can be integrated into the rover arm.

PRODUCT OUTCOME

The U.S. Army had been using EIC Laboratories' high-resolution Raman spectrometer for applications such as identifying chemical agents in sealed glass vials, and was interested in buying a man-portable version of it for use in field analysis. At the same time, the U.S. Federal Bureau of Investigation (FBI) began setting up mobile laboratories to ascertain potential threats at high-profile events such as the Democratic National Convention in 2000 and the Presidential Inauguration in 2001. Just like the Army, the FBI needed a portable Raman system with high sensitivity and sufficient spectral resolution to identify unknown chemical substances with confidence.

In response to this need, the basic spectrometer originally built for NASA was repackaged for forensic and military applications. The commercial product, the InPhototе,™ is manufactured and distributed by InPhotonics, Inc., a spinoff company of EIC Laboratories, co-located in Norwood, Massachusetts. The portable InPhototе is a complete Raman spectrometer system contained in a 16- by 9- by 8-inch aluminum case, weighs approximately 22 pounds, and can be set up in a matter of minutes.

The tool can measure unknown substances through glass and plastic packaging materials with the RamanProbe™ focused fiber-optic probe. The probe length can be extended up to 200 meters to enable users to analyze potentially dangerous substances at a safe distance. In many cases, the spectrometer and personnel are kept in a safe zone while the probe is positioned next to the sample being analyzed. Being able to identify chemicals in remote locations also saves users time and labor, since otherwise the samples



The portable InPhototе™ stems from technology developed for the chemical identification of Mars soil and mineral samples.

The InPhototе™ can measure unknown substances through glass and plastic packaging materials with the RamanProbe™ focused fiber-optic probe.

would need to be collected, transported, and prepared prior to measurement in the laboratory.

One of the major advantages of Raman spectroscopy over other analysis techniques is its ability to measure through clear and semi-clear containers. Other techniques cannot analyze samples without manipulating or contacting them in some way. Raman spectroscopy, which is very specific to molecular structure, can also be used to identify a wide variety of organic and inorganic compounds as long as there are intramolecular bonds present. InPhotonics is working on expanding its Raman database, which currently contains 243 compounds of explosives and precursors, to include pesticides and other toxic chemicals. According to the company, many of the InPhototе's users have created their own libraries specific to their application in order to rapidly identify unknown substances in the field.

InPhotonics has seen an increased demand for the InPhototе following the terrorist attacks against the United States on September 11, 2001. Since the system can rapidly identify a wide range of potentially hazardous materials, it is currently of interest to law enforcement and security agencies worldwide. The InPhototе continues to undergo engineering changes to improve detection limits, reduce size and weight, and minimize power consumption for long-term operation off an internal battery.

While the ability to rapidly identify chemicals onsite is more important than ever before, the company is also exploring non-forensic applications. Chemical and pharmaceutical manufacturing facilities would like to bring the laboratory to the sample, rather than transfer a sample to the laboratory and wait for the results. A portable instrument could also be used for quality control of incoming materials or finished products. The latter can be measured through packaging materials as a final step before shipment.

In response to other market needs, InPhotonics recently repackaged the portable system into a laboratory spectrometer known as the VERAX.™ This product meets the needs of customers who want the performance specifications of the InPhototе product but do not require the portable package. The company is targeting the VERAX for process development in the pharmaceutical industry as well as for general analytical and research applications.

InPhototе,™ RamanProbe,™ and VERAX™ are trademarks of InPhotonics, Inc.

FIGHTING CORROSION

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

Reinforced concrete structures such as bridges, parking decks, and balconies are designed to have a service life of over 50 years. All too often, however, many structures fall short of this goal, requiring expensive repairs and protection work earlier than anticipated. The corrosion of reinforced steel within the concrete infrastructure is a major cause for this premature deterioration. Such corrosion is a particularly dangerous problem for the facilities at NASA's Kennedy Space Center. Located near the Atlantic Ocean in Florida, Kennedy is based in one of the most corrosive-prone areas in the world.

In order to protect its launch support structures, highways, pipelines, and other steel-reinforced concrete structures, Kennedy engineers developed the Galvanic Liquid Applied Coating System. The system utilizes an inorganic coating material that slows or stops the corrosion of reinforced steel members inside concrete structures. Early tests determined that the coating meets the criteria of the National Association of Corrosion Engineers for complete protection of steel rebar embedded in concrete. Testing is being continued at the Kennedy's Materials Science Beach Corrosion Test Site.

PARTNERSHIP

Cortec® Corporation, of St. Paul, Minnesota, has licensed the NASA-developed technology and markets it under the brand name GalvaCorr.™ The company manufactures and supplies corrosion protection solutions to the petrochemical, metalworking, electronics/electrical, utility, construction, military/government, marine, basic metals, automotive, and equipment maintenance markets. GalvaCorr is a compliment to Cortec's line of Migrating Corrosion Inhibitors.™

PRODUCT OUTCOME

GalvaCorr is a room temperature liquid coating that can be sprayed or hand applied to concrete structures. It is applied easily to vertical, horizontal, and overhead surfaces, and to structures of many shapes. The coating contains particles of magnesium and indium, as well as moisture-attracting compounds that facilitate the protection process. After the coating is applied to the outer surface of reinforced concrete, an electrical current is established between the metallic particles and the surfaces of the embedded steel rebar. This electrical current is responsible for providing the necessary cathodic protection for the embedded rebar surfaces. Without this protection, the embedded steel may continue to deteriorate until failure.

GalvaCorr is a breakthrough technology with great commercial value for the transportation, infrastructure, marine infrastructure, civil engineering, and construction industries. Without this technology, embedded steel structures will continue to corrode and deteriorate until failure occurs, costing companies billions of dollars to repair their infrastructures. Cortec recommends GalvaCorr for parking decks, ramps, and garages; commercial and civil engineered structures; bridges and concrete piers; offshore platforms; and utility poles above water line.

The GalvaCorr™ liquid coating is applied to concrete structures such as this bridge in order to protect the structures from corrosion.

Cortec® is a registered trademark of Cortec® Corporation.

GalvaCorr™ and Migrating Corrosion Inhibitor™ are trademarks of Cortec® Corporation.

SPREADING THE WORD ON SAFETY

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

Beginning with the Apollo Program in the early 1960s, the NASA White Sands Test Facility (WSTF) has supported every U.S. human exploration space flight program to date. Located in Las Cruces, New Mexico, WSTF is part of Johnson Space Center. The facility's primary mission is to provide the expertise and infrastructure to test and evaluate spacecraft materials, components, and rocket propulsion systems to enable the safe human exploration and utilization of space.

WSTF stores, tests, and disposes of Space Shuttle and International Space Station propellants. Since aerospace fluids can have harmful reactions with the construction materials of the systems containing them, a major component of WSTF's work is the study of propellants and hazardous materials. WSTF has a wide variety of resources to draw upon in assessing the fire, explosion, compatibility, and safety hazards of these fluids, which include hydrogen, oxygen, hydrazine fuels, and nitrogen tetroxide. In addition to developing new test methods, WSTF has created technical manuals and training courses for the safe use of aerospace fluids.

PARTNERSHIP

As part of NASA's goal to transfer technology to industry and the commercial sector, WSTF partners with standards organizations such as the American Society for Testing and Materials (ASTM) and the American Institute of Aeronautics and Astronautics to document results in technical papers and safety manuals, develop and deliver safety courses, and perform hazards/failure analyses. Through these partnerships, private industry can purchase the safety manuals and training courses.

NASA safety manuals and training courses are available for purchase through several standards organizations.

PRODUCT OUTCOME

One of the main WSTF courses that ASTM markets is "Fire Hazards in Oxygen Systems," which is intended for anyone who operates, maintains, or manufactures any type of oxygen system. The course benefits engineers, scientists, technicians, and others who are involved in the production or use of liquid or gaseous oxygen by teaching them to identify and evaluate hazards in oxygen systems. Other topics in the course include oxygen compatibility, appropriate material selections, and good practices for oxygen systems operations and maintenance.

The oxygen safety courses developed by WSTF served as models for the creation of other courses, such as a hydrogen safety course that is marketed through Wendell Hull & Associates, Inc., also of Las Cruces. This course offers valuable information as WSTF continues to work with the private sector to develop safety measures for the hydrogen industry.

WSTF's technical manuals have become industry standards, and the training courses are taught worldwide. While WSTF's courses and manuals benefit the development of technologies in the aerospace community, they also apply to other fields that use aerospace fluids. For example, the hydrogen manual and course can be applied to the development of fuel cells and hydrogen-powered vehicles. The oxygen training material benefits advances in medicine, gas production, chemical processing, and home health care.

SUPERIOR SENSOR MAKING SENSE IN MILITARY, MEDICINE

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

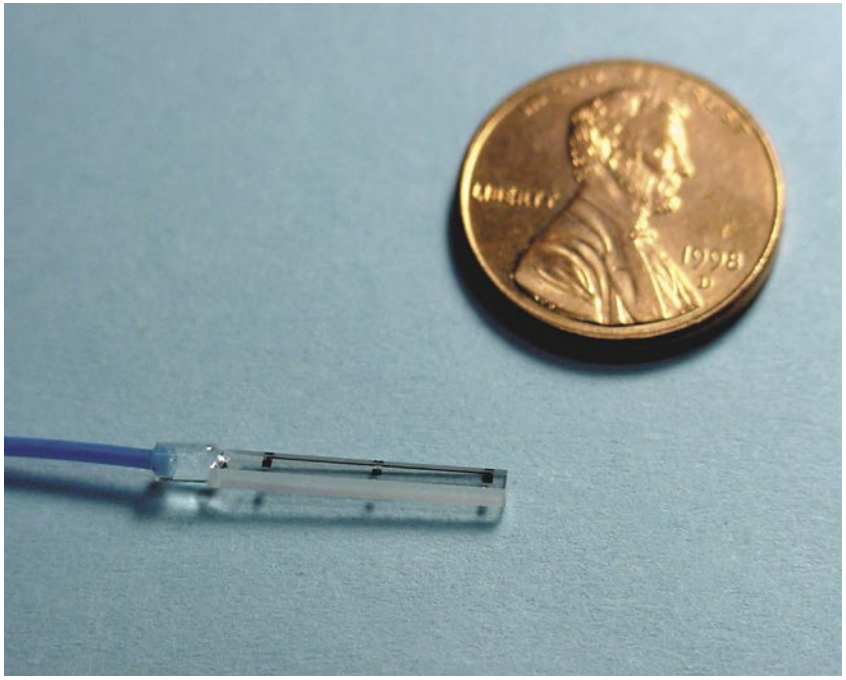
A fiber-optic voltage sensor developed a decade ago for NASA's aircraft and space power systems has been the building block for a string of new sensor products offering safe, accurate detection and measurement for electrically noisy and hazardous environments.

Srico, Inc., a Columbus, Ohio-based photonics engineering company, created the original voltage sensor in cooperation with NASA's Glenn Research Center under a **Small Business Innovation Research (SBIR)** contract, and successfully marketed it as a solution for fiber-optic communication systems, noncontact probing of high-speed integrated circuits, biomedical engineering and instrumentation, and lightning detection in avionics and mining. The technology has since been propelled to a higher level to address electrodiagnostics, patient monitoring, and functional magnetic resonance imaging (the ability to study the brain's function, not just its structure, like traditional magnetic resonance imaging), as well as physiological monitoring of military pilots and combat personnel.

PARTNERSHIP

In developing the follow-on optical sensing products, Srico was also awarded a generous grant from the Garrett Morgan Commercialization Initiative, established by Glenn Research Center to assist small, minority- and women-owned businesses in taking NASA-derived technology to market. This initiative is managed by the Great Lakes Industrial Technology Center (GLITeC).

"Our company is very honored and grateful to receive such a prestigious award," says Dr. Sri Sriram, Srico's chief executive officer. "This grant is very timely, because the worldwide demand for our optical components is very high, yet the supply is limited."



The Photrode™ all-optical sensor manipulates light to measure the electrophysiological signals produced by the body (penny shown for scale).

PRODUCT OUTCOME

Srico's small lithium niobate photonic electrode, or Photrode,™ represents a paradigm shift in technology for sensing electrophysiological signals, particularly electroencephalography (EEG) and electrocardiography (EKG) signals. While current methods for executing EEG and EKG measurements require the attachment of electrical wires to a patient's scalp or chest, Srico's Photrode invention manipulates light to measure the electrophysiological signals produced by the body, otherwise known as biopotentials. Unlike conventional electrodes, Photrode measurements do not require skin preparation or the use of adhesives or conductive gels. This makes the technology ideal for dry-contact sensing of low-level EEG signals and noncontact sensing of high-level EKG signals (EKG readings can be taken directly over clothing with the Photrode).

The basic Photrode system consists of a laser source, optical input and output fibers, an optical chip, an optical receiver, and signal-processing components. When a Photrode sensor picks up a biopotential signal, light from a continuous wave laser source enters the sensor and becomes modulated by the signal. The optical receiver then detects and digitizes the voltage output of the Photrode.

With NASA technology at its core, the Photrode was developed for the U.S. Army Aeromedical Research Laboratory to assess the physiological- and flight-readiness of Army pilots, and for the Walter Reed Army Institute of Research's departments of neuropsychiatry and surgery, for ambulatory alertness-monitoring and triage applications, respectively. Ongoing research and development was extended to the U.S. Army, enabling it to monitor in real time the alertness levels of its personnel and to assess their cognitive performance and sleep/wake status in sustained operational settings. Previously, the Walter Reed Army Institute of Research demonstrated that soldiers who have

Photrode™ sensors, shown here mounted on a helmet, use Srico, Inc.'s proprietary technology for improved, hassle-free, noncontact electrocardiography and dry-contact electroencephalography measurement.

been awake for 48 to 72 hours rapidly lose their ability to make correct judgments. This lack of sleep has been suggested as a possible cause of friendly fire casualties and loss of expensive equipment. Other studies have supported this notion, further indicating that both sleep (low-frequency EEG) and alertness (high-frequency EEG) measurements are critical in determining a soldier's level of performance and in avoiding incidents that are due to a decline in cognitive function.

With the Photrode, it is now possible to integrate the low-frequency domain of sleep with the high-frequency domain of active brain-functioning into one compact, pocketsize ambulatory system. Photrode introduces the potential to acquire the full range of EEG signals, thereby facilitating the possibility of creating an alertness/drowsiness index for evaluating performance capability in both military and civilian operational settings—where awareness is vital.

Subsequent research and development efforts made possible by grants from the National Institutes of Health demonstrated that Srico's Photrode sensor is viable for magnetic resonance imaging. According to Sriram, it is currently not possible to safely monitor a patient's brain activity when a magnetic resonance scanner is turned on, because the traditional electrical leads used to monitor the EEG interfere with the high radio frequency fields in the magnetic resonance environment. "This not only can distort the images, but it can also cause severe burns to a patient," he adds. By enabling uninterrupted capture of all of the brain's activity, the Photrode system combines the high temporal resolution of the EEG signals with the exquisite spatial resolution of magnetic resonance images. There is no interference with the radio frequency and magnetic fields of the scanner, and there is no risk of thermal or electrical burns.

The sensor technology, a recipient of R&D Magazine's esteemed R&D 100 Award, could be used for any type of electrophysiological measurement in airline pilots, unmanned aerial vehicle control station operations, heavy machinery operators, nuclear power plant employees, truck drivers, and many other occupations that demand high levels of alertness and performance over a long duration.

Srico also markets NASA-influenced wideband integrated optic modulators and fiber-optic microwave links for voltage testing/measurement and signal transmission in industrial fields. These low-drive voltage, high-damage threshold products are well-suited for cable television systems; antenna remoting; automotive and medical electronics testing; aircraft testing; and wireless, satellite, and fiber-optic communications.

Photrode™ is a trademark of Srico, Inc.

LEAVING A PRINT ON SAFETY

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

Pattern-recognition technologies developed by NASA to identify spacecraft and other objects in space have helped in the development of new, biometrics-based security solutions on Earth that recognize individuals to grant access to protected facilities, equipment, or information.

PARTNERSHIP

The general principles of the pattern-recognition methods used at NASA's Johnson Space Center for spacecraft and object tracking have helped to direct the technology of Bioscrypt, Inc., a leading provider of identity-verification products. Dr. Colin Soutar, chief technology officer of Bioscrypt, worked at Johnson Space Center between 1992 and 1994 as a National Research Council Research Fellow. He worked in the Tracking and Communications Division with Johnson's Robotic Vision Manager, Dr. Richard Juday, on optical correlation systems and advanced research concepts based on pattern recognition, including autonomous rendezvous and capture of spacecraft, and autonomous, unmanned landings on Mars. The pattern-recognition skills that Soutar developed for optical correlation and space-related conceptual projects are applicable to his current position with Bioscrypt, as the company uses pattern-based processing to accomplish the task of fingerprint verification.

PRODUCT OUTCOME

Headquartered in Ontario, Canada, with a U.S. office in Van Nuys, California, Bioscrypt has installed over 70,000 fingerprint readers worldwide. The pattern-based templates behind Bioscrypt's fingerprint products have been carefully designed to produce one of the most robust fingerprint-verification algorithms in the world, as evidenced by the company's first-place performances at the 2002 and 2004 International Fingerprint Verification Competitions (held every other year). Bioscrypt's pattern-based approach filters, smoothes, and conditions an image to produce a high-quality representation, or template, of a fingerprint's "ridge pattern." Features such as creases, cuts, abrasions, and pores that appear inconsistently are removed. This way, the data that Bioscrypt use for comparison are the entire ridge pattern, which remains unchanged throughout a person's lifetime.

The Bioscrypt technique estimates and removes the relative distortion between the candidate fingerprint and the prevously enrolled fingerprint template. Every ridge of the candidate is then aligned with every ridge of the template image to provide maximum use of the entire fingerprint

The V-Smart™ two-in-one reader combines the high security of Bioscrypt, Inc.'s proven fingerprint-matching technology with a contact-less "smart" card that hosts an encrypted template of a user's fingerprint. The reader instantaneously matches the fingerprint to the template stored on the card, allowing for fast throughput.

image. Subsequent to the removal of the distortion, the ridge patterns are correlated, emphasizing areas in which the images are clean and highly complex and downplaying areas where the images are "noisy" and "bland." For example, noisy parts of the fingerprint would be where the ridges of the print are "broken up" due to poor imaging, and bland portions are typically where the information content of the print is low, such as at the tip of the finger where the ridges are generally straight lines.

This sophisticated methodology for enrolling and validating fingerprint images is at the heart of all Bioscrypt product offerings. Known as Bioscrypt Core,™ the methodology is available for licensing and has been selected by various fingerprint sensor manufacturers, including Atmel Corporation and AuthenTec, Inc., and application developers such as Sense Technologies, Inc.

One of the company's most successful products is a practical two-in-one reader known as V-Smart.™ V-Smart combines the high security of Bioscrypt's proven fingerprint-matching technology with a contactless "smart" card that hosts the mathematical template of a user's fingerprint. Personal information remains perfectly secure with V-Smart, since fingerprints are embedded within encrypted chips on the smart cards, and not on the reader or in a company database. The smart card allows a user to retain control of his or her template fingerprint. To access a facility protected by V-Smart, a user must place on the reader the pad of the finger that matches the previously created fingerprint template, while waving the smart card in front of the reader. The reader will instantaneously match the fingerprint to the template stored on the card, allowing for fast throughput.

The V-Smart two-in-one method provides safety and security for both the user and the establishment being protected. For example, if an employee of a company safeguarded by V-Smart loses his or her smart card, no one else could gain access to the workplace should they happen to find it, since the fingerprint would not match up. In addition to employee identity theft, companies can snuff out security-threatening situations such as equipment theft, vandalism, unauthorized access to restricted areas, and "buddy punching," when an employee clocks in or out another employee who is not present at the time. Employers also rack up significant costs attributed to replacing lost or stolen building keys or access cards, and correcting time and attendance issues—all of which can be eliminated with the V-Smart access system.

Bioscrypt's largest deployments of V-Smart readers include sensitive entry points at American Express worldwide headquarters in New York, New York, and the New York Police Department headquarters. At the police department, thousands of officers and government workers have been issued new badges containing digital copies of their fingerprints. According to one Bioscrypt official, the high-tech security system may soon be embraced by more than 200,000 New York City and State government employees.

Airports around the world are experiencing the benefits of Bioscrypt's advanced fingerprint technology as they implement new security systems to combat international terrorism. In 2004, Indiana's Fort Wayne International Airport selected V-Smart to verify individual access to sensitive areas. Little Rock National Airport in Arkansas has deployed over 100 V-Smart readers for approximately 5,000 users. In the Eastern Hemisphere, Russia's largest and foremost airport, Domodedovo International Airport, has installed V-Smart to control access to "staff-only" areas of the facility.

The technology had officially come full-circle when NASA implemented it to protect the Triana Science and Operations Center at the University of California in San Diego. The NASA-funded facility, a part of Scripps Institution of Oceanography, installed eight Bioscrypt units, one for every entry point and office. The facility uses Bioscrypt readers in conjunction with door controllers to protect the offices and work areas of employees engaged in developing a leading-edge Earth-imaging spacecraft. The Triana spacecraft has been completed and stored until a viable flight opportunity has been identified. NASA's intentions for the spacecraft are to transmit data back to the Triana center, where the information will be processed to provide scientists throughout the world with new insights into how our planet's climate works as an integrated system.

Bioscrypt's goal is to replace traditional access methods such as passwords, personal identification numbers, keys, and entry cards with its fingerprint-verification technology to enhance user convenience and security. As one assured customer puts it, "You can loan someone your card and personal identification number, but not your finger."

Bioscrypt Core™ and V-Smart™ are trademarks of Bioscrypt, Inc.

The airport industry continues to demonstrate that it is a first mover in the adoption of commercial biometric technology, having secured many critical access points with Bioscrypt products. The urgency to increase security within these facilities is perhaps greater than in any other environment.

SIZING UP THE SITUATION

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

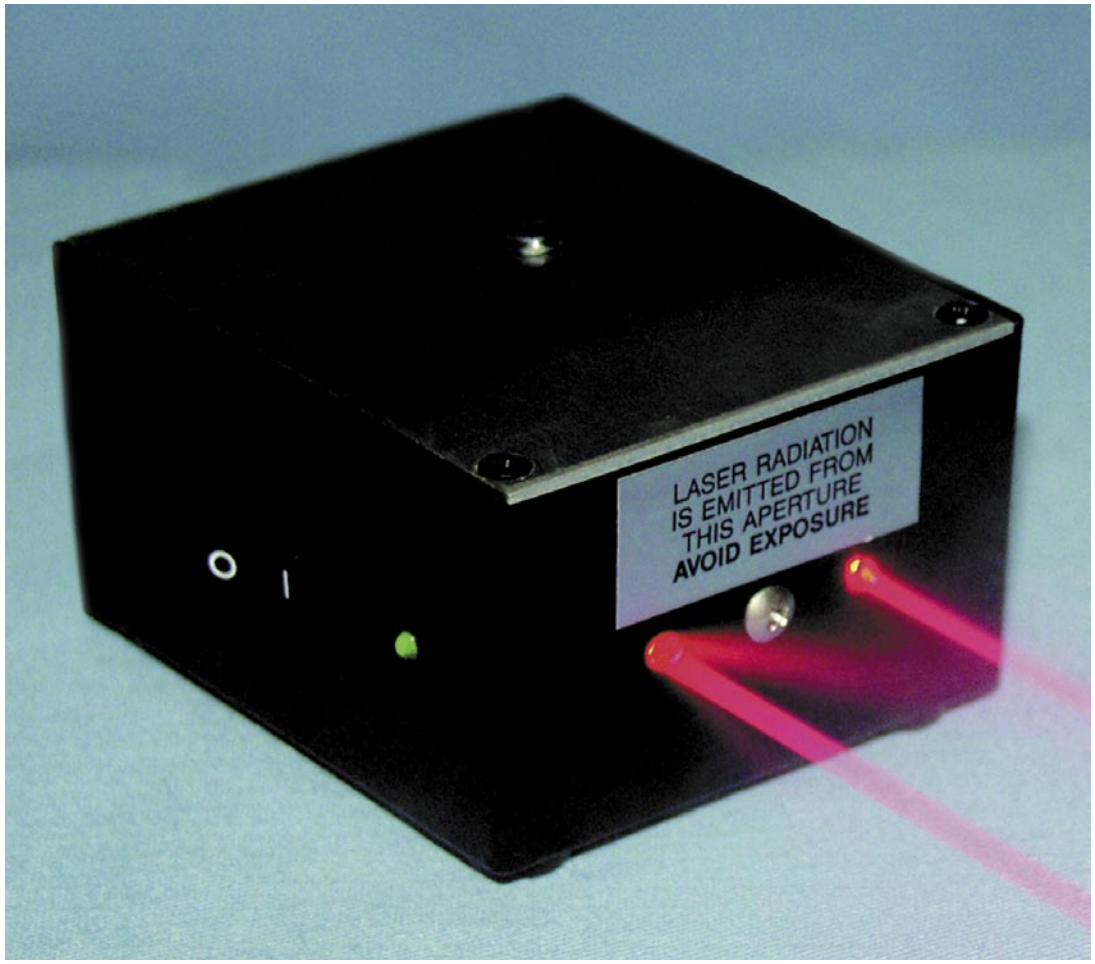
Hailstorm damage to the Space Shuttle's External Tank inspired a NASA innovation with extensive photography applications. In order to measure the defects caused by the storm, Kennedy Space Center used telephoto lenses to zoom in on the tank and view the damage clearly. However, since there was no reference object in the image, the engineers could not determine the scale of the damage.

In photographic situations similar to this, an object, such as a ruler, is placed within the field of view. This allows a person to look at a photograph and have a visual indication of the scale of the objects in it. In the External Tank situation, however, this procedure was not possible.

As a solution, Kennedy developed the Scaling and Measurement Device for Photographic Images, which provides a non-intrusive means of adding a scale to a photograph. In addition to meeting Kennedy's needs, scaling images is extremely important in crime and accident scene investigations, oil and chemical tank monitoring, and aerial photography.

The innovation consists of a tool that attaches directly to a camera or charge coupled device using a standard screw. Two lasers fitted to the device provide parallel beams that are set 1 inch apart. These lasers enable the device to project a pattern into the field of view. When a photograph is taken, the image of the laser pattern appears, along with the image of the object under investigation, allowing the viewer quantifiable information as to the size of the object. The laser beams are accurate to approximately 200 feet.

Windows®-based software was developed to work with the scaling device tool. The software provides further techniques to measure objects in photographs and digital images. By using the software, any object in the image can be measured diagonally, vertically, and



The Laser Scaling Device, developed at Kennedy Space Center, attaches directly to a camera and projects a pattern of dots into the field of view. The image of this pattern appears in the photograph along with the image of the object under investigation, enabling the viewer to measure the size of the object.

horizontally. The device and its software enable the user to determine two-dimensional measurements within a photograph.

PARTNERSHIP

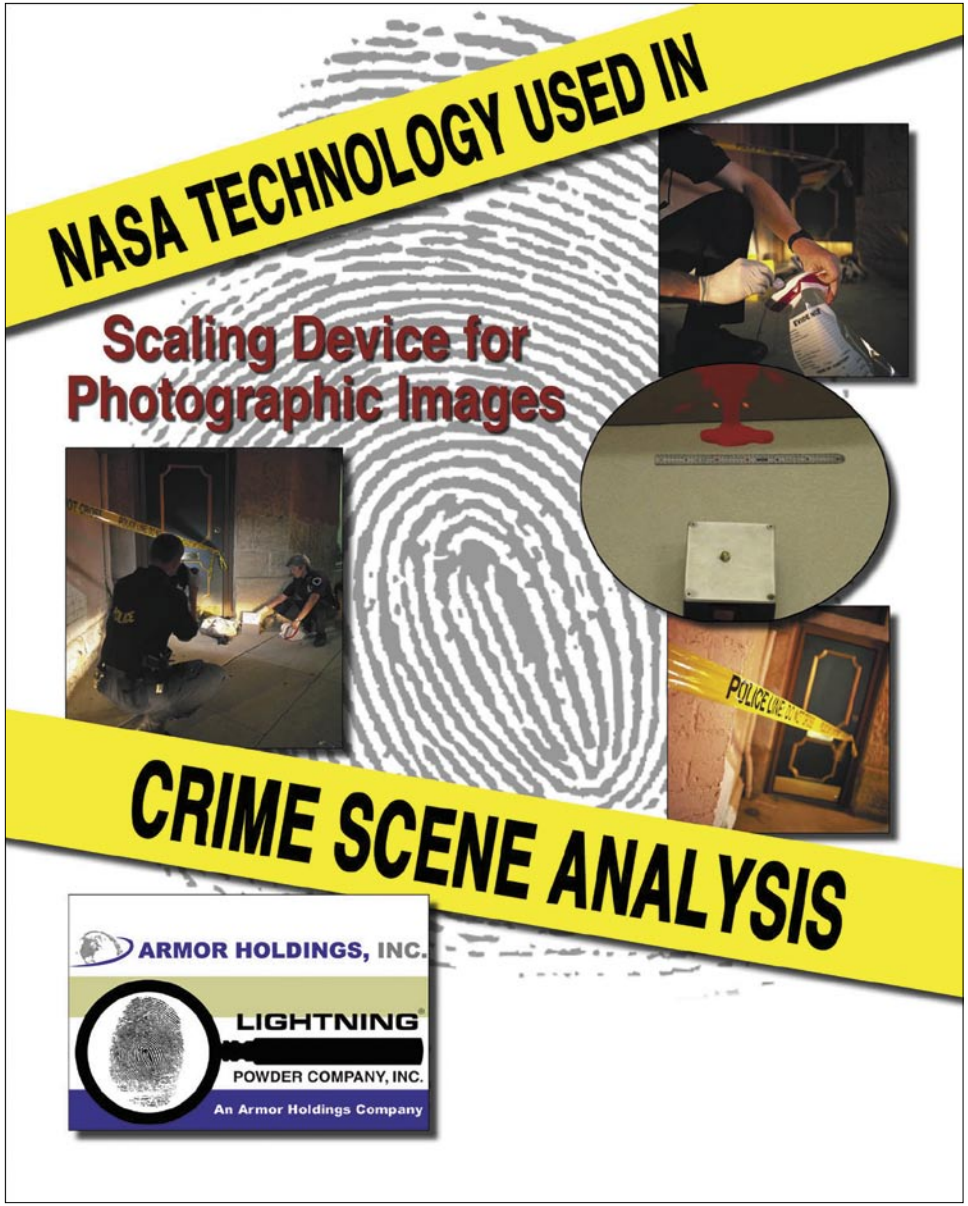
Armor Holdings, Inc., a leading manufacturer of crime scene investigation accessories, signed a non-exclusive license with Kennedy for the rights to both the scaling device and its accompanying software. Based in Jacksonville, Florida, Armor Holdings provides the forensics industry with tools needed to perform a job efficiently and safely.

PRODUCT OUTCOME

Armor Holdings' new Laser Scaling Device benefits crime scene investigators, photographers, and surveillance personnel. Information on the device is being distributed to crime laboratories around the world. Law enforcement photographers that take pictures of crime scenes can use the Laser Scaling Device to shoot scaled photos of blood-spatter patterns, graffiti, or other components of crime scenes that can be portrayed in a two-dimensional medium. In other applications, industrial photographers can use the device to shoot scaled photographs of large items that are not easily accessible by means of ladders or lifts.

The small tool weighs approximately half a pound and is powered with one replaceable nickel-cadmium battery. The device can be easily turned on and off to allow a photographer to provide the valuable scaling information within a picture. The software program included in the package allows the user to import the photograph, benchmark the two laser dots, and provide scale to the photograph. The user can then apply a measuring component in the program to determine the distances or size of items within the photograph.

Windows® is a registered trademark of Microsoft Corporation.



By enabling users to measure the size of an object in a photograph, the Laser Scaling Device helps crime scene investigators analyze information.

DEVELOPMENT OF A DIGITAL IMAGE MEASUREMENT SYSTEM

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

An unexpected tragedy took place on April 28, 1988, when the roof of an Aloha Airlines 737 aircraft ripped open at 24,000 feet, killing a flight attendant and injuring eight people. The in-flight structural failure of Aloha Flight 243's 19-year-old aircraft prompted NASA Langley Research Center to join with colleagues at the U.S. Federal Aviation Administration and the U.S. Air Force to initiate the Nation's first Aging Aircraft Research program.

One of the program's essential goals was to develop reliable, predictive methods for assessing the residual strength of aging aerospace structures. Dr. Charles E. Harris, the NASA director of the Aging Aircraft Research program, realized that the complex distortions and large, three-dimensional (3-D) warping observed in thin, lightweight aerospace structures during the failure process simply could not be measured by existing methods. In response to the need for a new method, Harris provided support to research scientists at the University of South Carolina (USC) from 1992 to 1996 to develop the first method capable of making the required, full-field measurements.

Correlated Solutions, Inc.'s three-dimensional measurement system utilizes two digital cameras and associated hardware to obtain pairs of stereo images.

Over the course of this effort, the USC researchers developed Digital Image Correlation, a data analysis process which uses a proprietary mathematical correlation method to analyze digital image data taken while samples are subjected to mechanical stresses. Consecutive image captures taken during the testing phase "show" a change in surface characteristics as the specimen is affected by the mechanical stresses imposed upon it. This type of technology is known as computer vision, the automated extraction of information regarding the objects or scene in one or more images.

The researchers first worked on a two-dimensional (2-D) image correlation method that could be applied to planar specimens that experienced only small out-of-plane displacements during loading. Extending their work on 2-D computer vision, the researchers then developed a 3-D measurement system using stereo-vision principles, in which two images taken simultaneously from two different angles are brought together into one image for 3-D perception. The new system proved to be robust, accurate, and effective in measuring the complete 3-D shape and deformations of thin, warping aerospace structures. In addition to being used for laboratory experiments, the system was portable and effective under field conditions. When deployed on a concrete tarmac, it successfully measured the response of selected sections of a commercial jet fuselage being subjected to internal pressure loading. Upon completion of the initial development phase, the technology continued to be improved and upgraded.

PARTNERSHIP

In 1999, USC licensed a key component of the technology it developed through the Aging Aircraft Research program. As a result, Correlated Solutions, Inc. (CSI), of West Columbia, South Carolina, was formed to focus on the improvement, development, and marketing of advanced measurement systems using the principles of computer vision. Soon after, CSI received contracts from NASA Langley to build systems capable of making specific

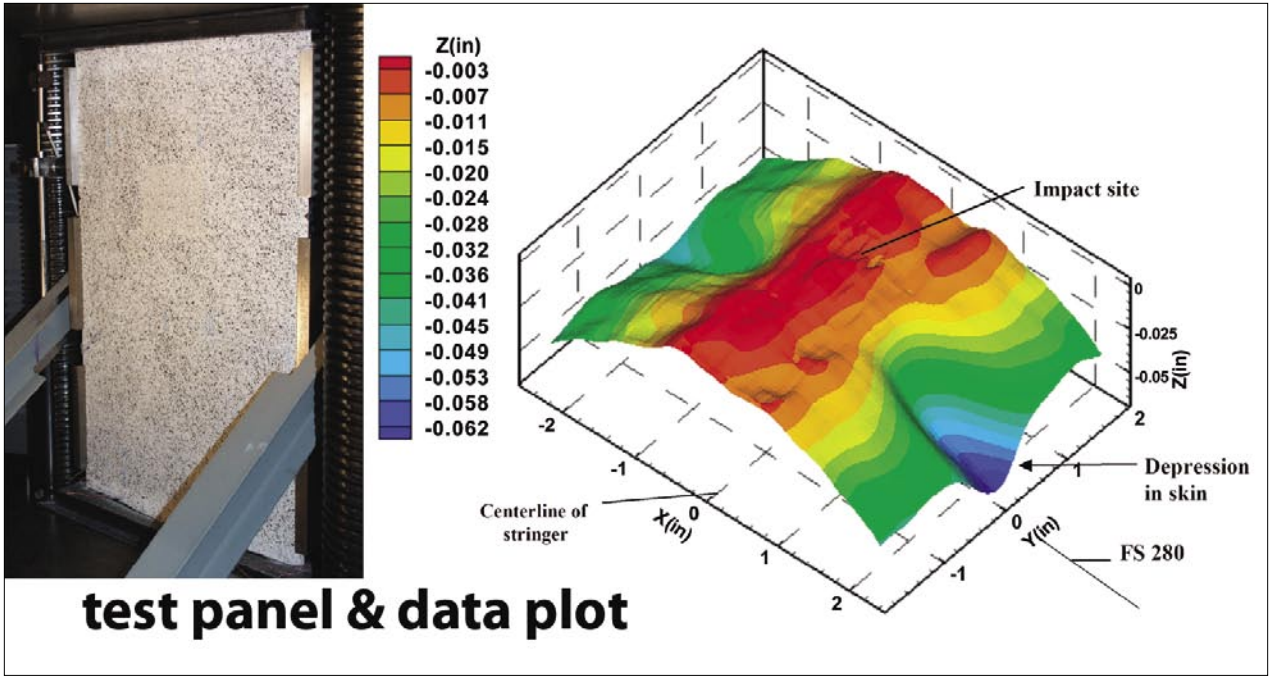


Image courtesy of Don Baker, "Experimental Results from Stitched Composite, Multi-Bay Fuselage Panels Tested Under Uniaxial Compression"

A typical data analysis from Correlated Solutions, Inc.'s three-dimensional system can be seen in this figure, which shows work on the characterization of advanced materials for the aircraft industry by NASA Langley Research Center's Don Baker. The picture is of the complete sample and the plot is a local area profile.

measurements of interest to NASA This prompted CSI to convert the working academic system to a viable commercial product.

PRODUCT OUTCOME

While the basic principles employed to develop the original stereo-vision measurement system remain essentially unaltered, CSI has improved and expanded the applicability of all aspects of the technology. It offers both 2-D and 3-D measurement systems. The 2-D digital image correlation system allows for the measurement of full-field, in-plane displacements. The method is easy to use, accurate, and fast. It requires only one camera to take the images and a computer to run the analysis.

CSI's 3-D system consists of two digital cameras and associated hardware for the cameras to obtain the necessary pairs of stereo images; a computer-based image acquisition and analysis system to record and process the images to obtain full-field data; and software to convert the images into measurements of 3-D displacements. The software, known as VIC-3D, provides a wide array of presentation options for viewing and displaying the data.

The VIC-3D software package offers a user-friendly, Windows®-based environment for image acquisition, camera calibration, image analysis, and data presentation. It has been developed and tested by both CSI engineers and beta-users, resulting in continuous improvements in its effectiveness. Recently, CSI developed and implemented a patent-pending calibration methodology within VIC-3D to ensure that the images can be easily analyzed for maximum measurement accuracy. Based on rigorous mathematical principles, the calibration technology completely eliminates the need for precision translations, precision targets, or precision rotations, resulting in the most robust and efficient calibration process currently available in the imaging industry.

CSI's 2-D and 3-D measurement systems are available to industry, government, and academia. The company's marketing representatives in Europe, Asia, and the United States offer custom measurement systems for clients, as well as standard configurations for typical applications. CSI provides full technical support for designing, configuring, and utilizing their measurement systems in virtually any application environment. In support of customer needs, CSI personnel work with each individual to select the appropriate lenses, cameras, lighting, data acquisition hardware, software, and accessories for the application of interest.

The 3-D image correlation technique can be applied to any field requiring an understanding of material deformation when subjected to external influences. Applications include aircraft fuselage and wing analysis, rubber tire analysis, biomedical research, and crash testing. The technology has recently extended its applications to optical stereo-microscopy, scanning electron microscopy, and atomic force microscopy. These new systems allow for the characterization of bio-engineered and nano materials.

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ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

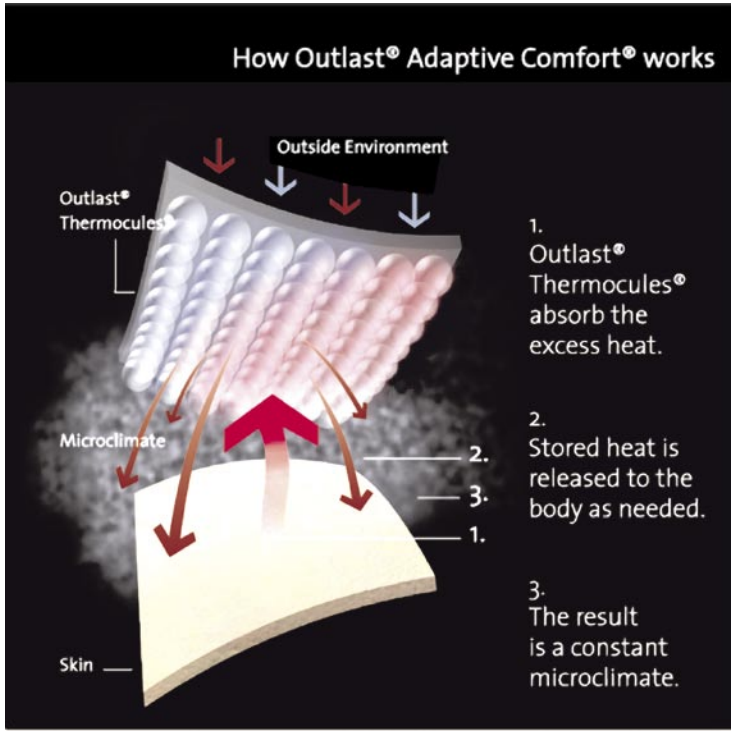
In 1988, NASA began working with private industry to develop thermally adaptive phase-change materials that could be applied to astronauts' suits and gloves for better protection against the bitter cold and scorching heat encountered in space.

PARTNERSHIP

Triangle Research and Development Corporation, of Research Triangle Park, North Carolina, participated in a Phase I **Small Business Innovation Research (SBIR)** contract with Johnson Space Center to assist in the creation of phase-change materials for NASA. Prior to this contract, the company demonstrated the value of manufacturing textile fabrics and fibers containing impregnated, microencapsulated phase-change materials for the U.S. Air Force. This work, also carried out under a Phase I SBIR contract, explored the necessity of such materials to protect pilots from temperature extremes.

PRODUCT OUTCOME

Three years after the completion of the NASA contract, a Boulder, Colorado-based firm acquired from Triangle Research and Development Corporation the exclusive patent rights for incorporating phase-change technology in commercial fibers and fabrics. Ed Payne and Bernard Perry, the founders of Gateway Technologies, saw the potential for using phase-change technology to enhance the comfort levels for individuals with active outdoor lifestyles. In 1997, Gateway Technologies changed its name to Outlast Technologies, Inc., and subsequently introduced the world to the first line of commercial gloves and footwear incorporating Outlast® Smart Fabric Technology.™



Outlast® Thermocules® work with the body to regulate temperature and humidity better than fabrics or insulation alone. The result is a microclimate that is optimized for individualized comfort.

Beginning with the very first set of Outlast gloves, each Outlast product contains a lining that continuously interacts with the unique microclimate of the human body and the environment to moderate temperature from being too hot or too cold to being just right. Traditional clothing systems trap heat in during high activity. The human body naturally sweats to cool the skin, reducing the ability of clothing to keep the body dry and comfortable. Outlast technology, conversely, will keep individuals comfortable by absorbing body heat when too much is created, thereby diminishing the amount of moisture in their clothing. The clothing essentially stays drier and maintains its effectiveness. A "comfort zone" can also be sustained in cold-weather environments, as Outlast garments will release stored heat back to the body when it begins to chill or shiver.

Within the Outlast products there are millions of microcapsules called Thermocules® that recycle stored energy by absorbing and releasing excess body heat to balance temperature. To insure durability against the rigors of everyday wear and tear, phase-change materials are placed into these Thermocules, which are very much like miniature ping pong balls, but much smaller at 1/2 to 1/20th the diameter of a human hair. Not only are Thermocules small but their shells are very stable, since they are made to be inert and not melt. Once the phase-change materials are microencapsulated into Thermocules, they can be blended into compounds suited for fabric, fiber, and foam coatings.

From head to toe, Outlast Technologies is covering the everyday consumer with pure comfort. Boots, socks, underwear, shirts, pants, jackets, gloves, and hats have been made "smart" with the addition of Outlast Thermocules. Even bedding has successfully adopted the temperature-controlling technology. The company's Adaptive Comfort® Bedding has been the answer to a restless night's sleep for

many people around the world. Recently named one of TIME magazine's "Coolest Inventions," the Adaptive Comfort Bedding line of mattress pads, pillows, and comforters helps to buffer temperature swings throughout the night, creating an environment where one is less likely to wake up from coldness or overheating. It takes just 90 seconds for the Thermocules to adapt to the body, helping to maintain an optimum temperature for rapid eye movement sleep. Thermal compatibility between sleep partners also increases, creating an individual "cocoon" around each sleeper. The Outlast phase-change materials can be found in Spring Industries, Inc.'s Wamsutta® EvenTemp® line and Serta, Inc.'s Sensifiber™ line.

In 2003, Outlast Technologies paired up with Gold Toe Brands, Inc., to roll out the new Gold Toe ADC™ (All Day Comfort) and Gold Toe MAX™ sock lines. As the first and only line of men's dress/casual socks to feature Outlast phase-change fabric technology, Gold Toe ADC absorbs excess body heat to prevent clammy feet and overheating. The Gold Toe MAX line consists of athletic socks that keep even the most active feet comfortable, cool, and dry. To promote the new products, Gold Toe Brands launched the first national advertising campaign in the company's 80-plus-year history. As part of this campaign, Gold Toe Brands recruited New York Yankees' pitcher Mariano Rivera for an in-store promotion at Macy's department stores.

Other sports celebrities have professed just how valuable Outlast products are in their training, including professional snowboarders Keir Dillon and Victoria Jealouse, and Iditarod champion and record-holder Mike Curiak. "The technology allows optimum performance," says Dillon. "You can stay focused when you're not overheating or freezing."

"I can't ride when I'm cold. I get scared, timid," adds Jealouse, who spends much of her time in cold places such as Alaska. "This technology really works. You can't believe you're warm when it's crazy cold outside, and then in the spring I don't overheat."

With Adaptive Comfort® Bedding, there is likely to be less tossing and turning to get comfortable during the night, and less need to pile blankets on the bed when the weather is cold.

The list of products does not stop here. Outlast Technologies has entered strategic partnerships with over 200 premium-brand leaders in North America, Europe, and Asia, such as: Adidas, Bugatti, Burton, Kenneth Cole, Lands' End, Nordstrom, Rainforest, The North Face, Timberland, and Weatherproof. Expanding beyond consumer apparel, Outlast material has been considered by General Motors as the material of choice for leather bucket seats in the conceptual design of future Hummer H2 sports utility models.

Meanwhile, hundreds of miles above the Earth, Outlast apparel is making space exploration more comfortable for astronauts. NASA will continue to test new Outlast gloves and footwear in order to make those living and working in space feel "more at home."

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Smart Fabric Technology™ is a trademark of Outlast Technologies, Inc.

Wamsutta® and EvenTemp® are registered trademarks of Spring Industries, Inc.

Sensifiber™ is a trademark of Serta, Inc.

Gold Toe ADC™ and Gold Toe MAX™ are trademarks of Gold Toe Brands, Inc.

HOT AND COLD THERAPY EASES PAIN

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

In the 1960s, NASA civil servant Tom Hughes worked for Marshall Space Flight Center's Quality Control Laboratory as a systems engineer. Reporting directly to Dr. Wernher von Braun, Marshall's first director, Hughes was assigned as a NASA representative for quality control at the Michoud Assembly Facility in New Orleans, Louisiana, to oversee the Saturn V rocket project. During this time, Hughes invented several technologies to improve the safety of the rocket, earning several commendations from von Braun. He also gained technical expertise in microwave technology, as NASA researched it to determine its relationship to radar.

As Hughes read and studied NASA's microwave reports, his job requirements also led him to gain experience in packaging materials. NASA sent Hughes to the School of Military Packaging Materials at Aberdeen Proving Ground, in Maryland, which trained NASA personnel as well as military personnel. At the school, Hughes discovered heat-sealing packaging materials that were developed for NASA applications. This type of material eventually became an element of Hughes' invention, a heating and cooling pad that utilizes a thermal ceramic compound.

PARTNERSHIP

The microwave expertise Hughes gained during his employment with NASA led him to develop the unique thermal ceramic compound. Drawing upon NASA's research studies, Hughes experimented with various clay materials to determine which were microwave-reactive, meaning they would absorb heat, and which were microwave-invisible, meaning the microwaves have no affect. Before long, Hughes developed the soft and pliable ceramic material, which is capable of absorbing heat through microwaves and retaining it for an extended period of time. The clay-based substance also retains the cold when placed in the freezer.

The pack containing the Thermal Ceramix® material for the ThermiPaq™ is enclosed in a soft, washable cover.

PRODUCT OUTCOME

After patenting the material as Thermal Ceramix,® Hughes joined with four partners to form Thermionics Corporation, and worked to bring the technology to the commercial market. Originally based at Clemson University's Center for Applied Technology, the company is now located in Springfield, Illinois.

Thermionics' products incorporate the Thermal Ceramix's ability to retain heat and coldness and release them slowly at a stable temperature over several hours. The company's most prominent product is the ThermiPaq,™ a therapeutic pad that provides hot and cold therapy for pain caused by ailments such as arthritis, muscle pain, swelling, sunburn, sinus headaches, cramps, and sprains. Within the ThermiPaq, the Thermal Ceramix compound is contained

in the heat-sealing packaging material that Hughes learned about at the School of Military Packaging Materials. The reusable pad cools in the freezer and heats in the microwave, while maintaining its flexibility at any temperature. This flexibility allows the ThermiPaq to conform to the affected area of the body. The product incorporates a soft, washable cover, as well as a VELCRO® strap to hold the pad in place on the sore area.

For hot therapy, users heat the ThermiPaq in the microwave for a few minutes as detailed in the instruction manual. For cold therapy, the pad is ready after being placed in the freezer for an hour. The ThermiPaq retains its therapeutic temperature for 30 minutes, and then remains at a comfortable hot or cold level for an additional hour and a half. The Thermal Ceramix material within the pad is environmentally safe and nontoxic, and is easy to use without any electrical cords, messy gels, or hot water bottles and ice bags to fill.

The Thermal Ceramix technology in ThermiPaq capitalizes on the efficiency of radiant energy, offering distinct advantages over the convective energy used in gel/liquid-based products. While convective energy transfers immediately, leading to rapid temperature loss and the potential for hot spots, radiant energy is transferred slowly and evenly, allowing the ThermiPaq to penetrate deeply and more effectively. Also, unlike products that incorporate gels or chemical liquids, the ThermiPaq does not need to be rejuvenated by boiling it or soaking it in water.

Thermionics' product line also includes the Wine Tote,™ which incorporates the Thermal Ceramix technology to chill and safely transport up to three bottles of wine. The tote's reusable chill pack can be stored in the freezer and then slipped in between the bottles of wine to keep them cold. Another product, Quick Chill,™ is a bottle wrap that is cooled in the freezer and then placed around a beverage bottle, chilling it in 10 minutes and keeping it cold for up to 3 hours. The wrap's VELCRO closure adjusts to most bottles, making it perfect for soda, water, wine, and other beverages.

The ThermiPaq™ provides hot and cold therapy for pain caused by ailments such as arthritis, muscle pain, swelling, and sprains.

Another Thermionics product is Teddy WarmHeart,® a special stuffed bear that radiates a gentle warmth from his own thermal ceramic "heart." Originally developed for hospital use, the toy bear comes complete with a "hibernation" sleeping bag. After taking a short, 1 minute nap in the microwave, Teddy WarmHeart emerges ready to share his warmth with children of all ages. Remaining warm for up to 4 hours, the bear is soft, hypo-allergenic, and does not require any batteries or wires.

Thermionics' products are available in retail stores, pharmacies, and through the company's Web site. The ThermiPaq recently became available through select Wal-Mart stores.

Thermal Ceramix® and Teddy WarmHeart® are registered trademarks of Thermionics Corporation.

ThermiPaq,™ Wine Tote,™ and Quick Chill™ are trademarks of Thermionics Corporation.

VELCRO® is a registered trademark of Velcro Industries B.V.

DAMPING GOES THE DISTANCE IN GOLF

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

In the late 1980s, Dr. Benjamin Dolgin of NASA's Jet Propulsion Laboratory developed a concept for a high-damping graphite/viscoelastic material for the Strategic Defense Initiative (popularly referred to as "Star Wars"), as part of a space-based laser anti-missile program called "Asterix." Dolgin drummed up this concept with the intention of stabilizing weapons launch platforms in space, where there is no solid ground to firmly support these structures. Without the inclusion of high-damping material, the orbital platforms were said to vibrate for 20 minutes after force was applied—a rate deemed "unacceptable" by leaders of the Strategic Defense Initiative.

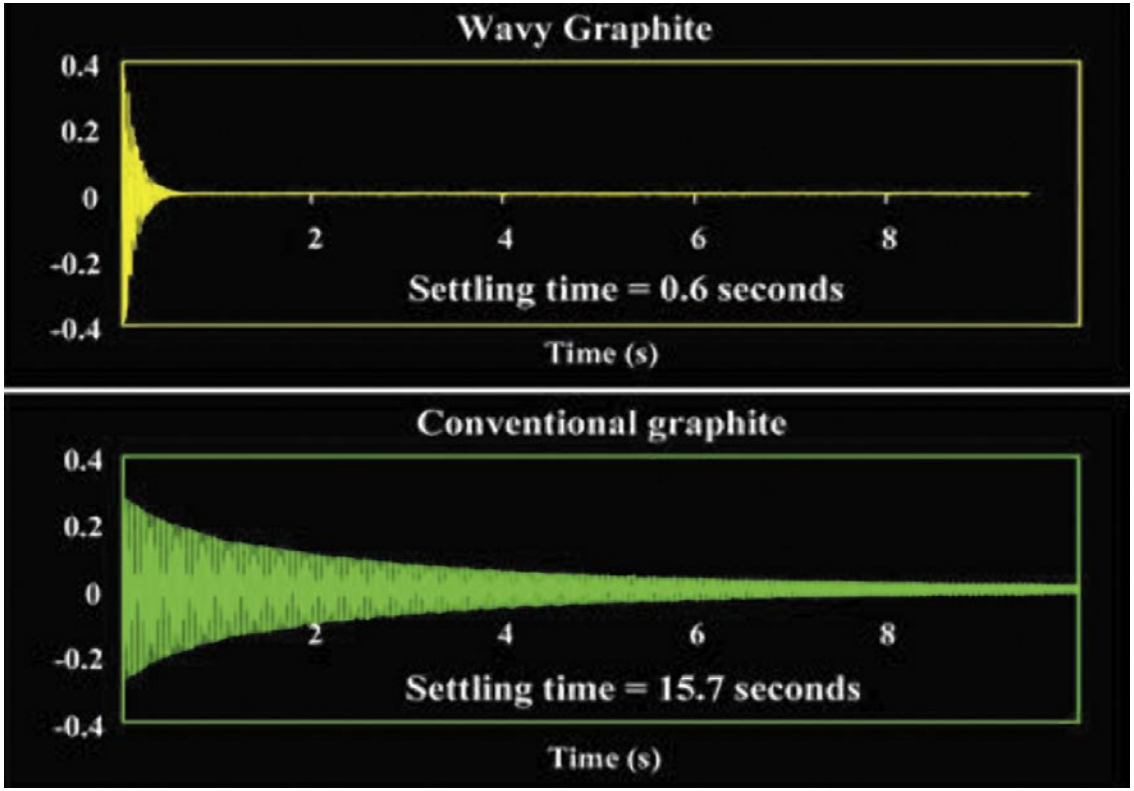
PARTNERSHIP

Dolgin's proposal for a high-damping graphite/viscoelastic material actually lay dormant for nearly 5 years after he conceived it, until it became the topic of doctoral studies for Dr. William Pratt, a Brigham Young University scholar who would later head up Patterned Fiber Composites, Inc. Pratt took the concept to the next level and discovered a practical method for manufacturing "wavy" graphite composite technology to dampen, or restrain, structural vibration. In 1998, the U.S. Air Force awarded Pratt and his Pleasant Grove, Utah-based company a 3-year **Small Business Innovation Research (SBIR)** contract to further develop this research and come up with an improved means for dampening space structures. In addition, Pratt received an exclusive license to use the NASA concept invented by Dolgin for commercial manufacturing of graphite composite products.

PRODUCT OUTCOME

By combining his research with Dolgin's concept and using a machine he built for the U.S. Air Force, Pratt has created a progressive golf shaft that is helping golfers to hit the "long ball" even longer. The "Wave Shaft" golf shaft employs a viscoelastic layer sandwiched in between two opposing wavy-patterned graphite layers to create unparalleled stiffness and damping. The structure of the Star Wars-influenced shaft is as stiff as steel, but with thousands of times the damping, which results in less shock and vibration during a swing and ultimately cuts down on the stinging pain and discomfort typically incurred by avid golfers as a consequence of vibration.

When the shaft is placed under load, opposing waves from its wavy fiber composite layers cause a significant amount of shear stress in the viscoelastic adhesive sandwiched between these layers. This greatly enhanced shearing of the



The wavy composite used in the construction of the Wave Shaft contains damping that is thousands of times greater than conventional golf club shafts. When a conventional graphite shaft and the Wave Shaft are deflected the same amount, the vibrations in the Wave Shaft die out in only 0.6 seconds, while it takes at least 15.7 seconds for the vibrations in the conventional graphite shaft to die out.

viscoelastic is what causes high damping in the structure. The shearing action causes stretching of the long chain polymers in the viscoelastic to not only create the high-damping effect, but to generate heat and dissipate energy for longer drives off of the tee.

The Wave Shaft—the first of several golf products developed by Pratt under the NASA license—is currently available from New Revolution Golf, a spinoff company of Patterned Fiber Composites. When ball contact is made with a golf club featuring a Wave Shaft, it takes just 0.6 seconds for any vibrations to die out, compared with at least 15.7 seconds for the vibrations in conventional graphite shafts; steel shafts have even less damping and take at least twice as long as graphite shafts to stop vibrating. New Revolution Golf's Wave Shaft offers extraordinary damping in two directions: twist (torsion) and flex (bending). By the time a club breaks the horizontal on the downswing, the Wave Shaft's high damping has eliminated all the erratic twisting and bending, further preventing fluttering or wobbling in the club's head. This "self-adjusting stiffness" phenomenon allows for consistent, controlled contact between the club and the ball. The Wave Shaft still flexes and "whips" as one would expect, but at impact it stiffens as much as 17 percent to impart greater energy to the ball. The stiffness also prevents head lag during the impact, as well as any lag-induced backspin, and gives a driver more loft.

New Revolution Golf is also producing optimal-performance driver and wood heads that compliment its Wave Shaft. The company's drier heads are packed with 320 cubic centimeters (cc) of aircraft grade titanium, and feature a well-balanced perimeter design to match the dynamics of the Wave Shaft. The wood heads house 150cc and 140cc (3 wood and 5 wood, respectively) of stainless steel, and possess many of the same characteristics of the driver heads.

New Revolution Golf clubs are shaving strokes off of many golfers' games, including an editor for Golf Today magazine who recently tested two models and immediately found a "new love" for his golf bag. According to the editor, who experienced his longest drive ever when using New Revolution Golf's driver: "For the first time in my life, I felt the harder I would swing, the more 'kick' the shaft would create with no noticeable torque at all, even when I purposely hit the ball way out on the toe of the club head. It felt as though the club head accelerated past my hands at impact." While many golfers are recognizing the technology for its distance, others are touting it for its control, like a Professional Golfers' Association (PGA) head golf professional from Arizona, who claims that the ball flight after impact with a Wave Shaft-equipped club is the straightest he had ever seen, not only for himself, but others.

New Revolution Golf drivers and woods are designed to provide maximum distance, forgiveness, and accuracy, along with the unmatched feel of self-adjusting stiffness.

There are many other areas where the wavy composite material developed by NASA and Pratt could be successfully applied. Patterned Fiber Composites has proposed using the damping technology to eliminate resonance problems in helicopter drive shafts and in fan drive shafts for the F-35 Joint Strike Fighter. Pratt also has unfinished business in extending the technology to everyday consumers, as he is hard at work on a line of skis and a "quiet" hard disk drive for personal computers.

A NATURAL WAY TO STAY SWEET

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

A revolutionary, low-calorie sugar is now available to the food and beverage market, offering an all-natural alternative to table sugar and artificial sweeteners. Tagatose, a sugar that appears in nature in small quantities, began its unusual journey to the commercial market nearly 30 years ago, when Dr. Gilbert V. Levin invented a life detection experiment to place aboard NASA's Mars Viking 1 and Viking 2 landers. The experiment involved using radiation-laced nutrients to determine the presence of microbial life in Martian soil samples.

PARTNERSHIP

The experiment was one of the earliest projects for Biospherics Inc., the company Levin founded in 1967. NASA's planetary science program provided research and development support to the company, selecting Levin's experiment for its Viking missions in 1969. After the Viking 1 lander touched down on Mars to gather data, it would place Martian soil into a container with the radiation-laced nutrients. If microbes were present, they would eat the nutrients and release radioactive carbon dioxide, which is detectable by a Geiger counter.

In selecting the nutrients for the experiment, Levin first examined the conventional form of glucose, because every living organism on Earth eats this type of sugar. Levin then considered the principle that some complex molecules exist in "right-handed" and "left-handed" forms, known as enantiomers. In sugars, these forms are referred to as D and L, from the Latin dexter and laevus, and they only differ in the arrangement of their elements. While two enantiomers of a sugar molecule will respond identically in a chemical reaction, they will not have the same reaction in biological systems. Earth's microbes only eat and metabolize D-glucose. Since digestion could differ for the possible Martian microbes, Levin prepared both D-glucose and L-glucose for his experiment's nutrients, so that any possible life on the Red Planet was not missed. When technical problems prevented the use of glucose, he substituted another sugar, lactose, using both its D and L forms.

The results of Levin's experiment came back positive for the radioactive carbon dioxide. While the parameters of the experiment suggested life had been discovered on Mars, two other life detection experiments came up negative. A test for organic material, the precursor to all life, also was negative, leading NASA's scientists to conclude that Levin's test had been fooled by oxidants in the soil.

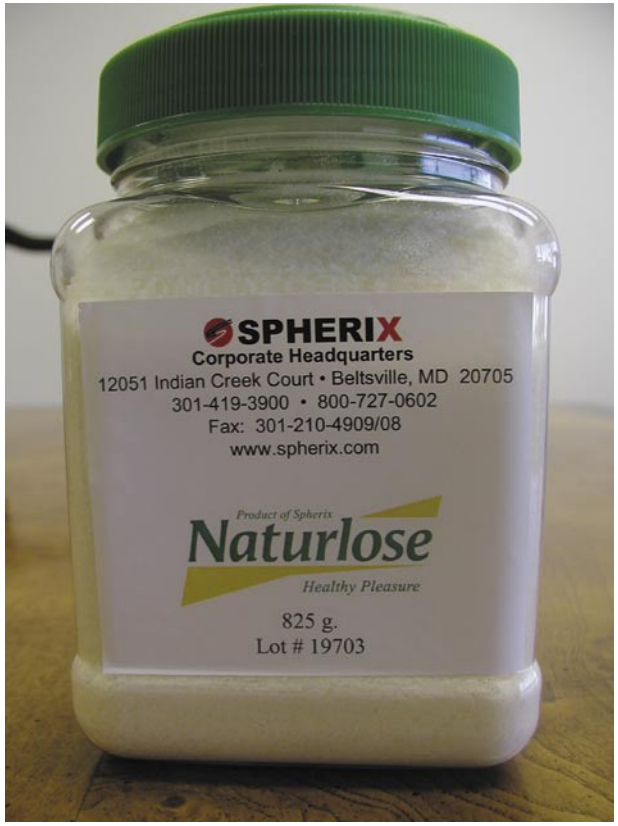
Tagatose, an all-natural alternative to table sugar and artificial sweeteners, has been introduced into 7-Eleven's Diet Pepsi Slurpee.®

PRODUCT OUTCOME

While the Viking experiment was not generally accepted as proof of life on Mars, Levin's exploration of the two different forms of sugar led him to realize that if the human stomach does not digest L-glucose, the sugar might be able to serve as a low-calorie sweetener. The main question was whether or not a left-handed sugar would taste as sweet as the right-handed sugar people consume. Levin established a taste panel at his Beltsville, Maryland-based company, which he renamed Spherix Incorporated. No one was able to tell the difference between the L and D versions of the sugar. He then patented the use of L-sugars as low-calorie sweeteners.

While L-glucose was an excellent candidate to be a low-calorie sweetener, Levin found that his company could not make it cheaply enough for commercial use. He continued to explore and patent other left-handed sugars for use in foods, such as L-fructose and L-gulose, but Spherix continued to find them too expensive to be viable. Levin then examined D-tagatose, which closely resembles L-fructose. The right-handed tagatose is similar enough to a left-handed sugar to cause the human stomach to digest only a small percentage of it, making it low in calories. More importantly, Spherix developed an inexpensive method to make tagatose, and patented the method in 1988.

Tagatose quickly proved its advantages as an alternative for regular sugar. Since it is 92 percent as sweet at table sugar, it can be used as a one-to-one sugar replacement. This gives tagatose the benefit of having the same bulk as table sugar, making it possible to be used in recipes for baked goods or any other recipe in which the bulk of the sugar is an important ingredient. Other low-calorie sweeteners on the market have high-intensity sweetness, and cannot be used for many recipes, since a tiny pinch achieves the necessary



The natural sugar taste of Naturlose™ makes it an excellent sweetener to improve the taste of non-food products such as toothpastes, throat lozenges, and cough syrup.

level of sweetness. Tagatose also browns like regular sugar during baking, and does not have an aftertaste like some of the high-intensity sweeteners. In addition to being low in calories, tagatose does not cause cavities or promote tooth decay. It also provides a safe sweetener for diabetics.

Spherix continued to develop tagatose until 1996, when the company exclusively licensed the use of the sweetener in food and beverages to Arla Foods Ingredients. Five years later, the U.S. Food and Drug Administration (FDA) deemed tagatose as "Generally Recognized As Safe," a status which is required for sales in the United States. This FDA action enabled Arla Foods to move forward with commercialization, as the company began building plants to manufacture the sugar.

In 2003, Arla Foods began successfully selling tagatose to food and beverage manufacturers under the brand name Gaio-Tagatose.® The sugar was introduced into 7-Eleven's Diet Pepsi Slurpee,® and diet fruit juices to be sold at Wal-Mart and other chains. Several other prominent food product companies are manufacturing their products with it and considering marketing them. These products include chocolate candy, soft and hard confectioneries, cereals, ice cream, frostings, and chewing gum. Tagatose may also be applied to health bars and dietary supplements, creating opportunities in the health food markets. Because the sugar has no impact on blood sugar levels, it is suitable for inclusion in low-carbohydrate diets. An early study commissioned by Arla Foods indicated tagatose's potential market in foods as valued at over $1 billion per year, depending on its suitability for a wide variety of products. The additional potential uses in diet sodas and health food could expand the market significantly.

While Arla Foods explores the food and beverage market for tagatose, Spherix has launched a sales and marketing campaign for Naturlose,™ the company's brand name for non-food versions of the sugar. Spherix received its first shipment of Naturlose from Arla Foods in December 2003, enabling the company to pursue commercial sales for toothpastes, mouthwashes, and cosmetics. Naturlose's natural sugar taste and low calories make it an excellent sweetener to improve the taste of these products and others such as throat lozenges and cough syrup.

Levin recently relinquished his chief executive office position to become Spherix's executive officer for science. He is leading the effort to prove Naturlose's medicinal value to drug manufacturers. The company's animal studies have indicated the sugar's ability to enhance fertility and treat anemia. Diabetics may particularly benefit from both the food and non-food applications of tagatose. A study funded by Spherix and the State of Maryland, conducted at the University of Maryland School of Medicine, showed that not only is tagatose safe for diabetics, but it also blunts the rise in blood sugar from regular glucose consumption. More importantly, it showed that tagatose could potentially be used to treat Type 2 diabetes, as the benefits for this all-natural sugar continue to get sweeter.

Gaio-Tagatose® is a registered trademark of Arla Foods Ingredients

Slurpee® is a registered trademark of 7-Eleven, Inc.

Naturlose™ is a trademark of Spherix Incorporated.

ARTIFICIAL MUSCLE KITS FOR THE CLASSROOM

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

Commonly referred to as "artificial muscles," electroactive polymer (EAP) materials are lightweight strips of highly flexible plastic that bend or stretch when subjected to electric voltage. EAP materials may prove to be a substitution for conventional actuation components such as motors and gears. Since the materials behave similarly to biological muscles, this emerging technology has the potential to develop improved prosthetics and biologically-inspired robots, and may even one day replace damaged human muscles. The practical application of artificial muscles provides a challenge, however, since the material requires improved effectiveness and durability before it can fulfill its potential.

PARTNERSHIP

In 2000, NASA's Johnson Space Center granted Environmental Robots, Inc. (ERI), of Albuquerque, New Mexico, a Phase II **Small Business Innovation Research (SBIR)** contract to develop a family of artificial muscle systems with robotic sensing and actuation capabilities for a wide spectrum of NASA space robotic and extravehicular activity (EVA) applications. As a result, the company developed two types of ionic polymeric artificial muscles: a bending, flexing, deforming type with sensing and actuation capabilities, and a fibrous electrochemical contractile type that is comparable to mammalian muscles.

PRODUCT OUTCOME

In order to bring artificial muscle technology to the attention of researchers, scientists, and engineers, as well as high school and college students, ERI began working on two educational outreach products as part of a Phase III SBIR contract with NASA Johnson. The company developed the Artificial Muscles Science Kit® and the Contractile Polymeric Artificial Muscles Science Kit® after designing a simple procedure to manufacture two electrically controllable strips of polymeric artificial muscle and package them in a safe, low-cost kit.

The two science kits contain the basic materials needed to safely create artificial muscles and test them for actuation and sensing.

The first kit focuses on the bending and flexing polymers with ionic polymer metal composites, while the second kit explores chemically or electrochemically activated polymers in the form of contractile fiber bundles. Both kits provide users with the basic materials and items necessary to safely create artificial muscles and test them for actuation and sensing. Materials in the kit include pre-treated ionic polymer strips, Chemical Material Data Safety Sheets, protective gloves, electrical wires, self-adhesive copper tape, and a pre-fabricated artificial muscle as a reference sample. The kits also contain detailed instructions and technical documents pertaining to all of the artificial muscle samples.

As part of its SBIR work, ERI also commercialized a biometric sensor and actuator element with attached electrodes, as well as an assortment of contractile and bending ionic polymeric artificial muscles. While ERI's science kits aim to promote the science and technology of artificial muscles, these other products have possible applications for NASA's space robotics, autonomous EVA actuation and sensing capabilities, and space robotic automation. The technology may also benefit nanosensing and nanoactuation applications.

Artificial Muscles Science Kit® and Contractile Polymeric Artificial Muscles Science Kit® are registered trademarks of Environmental Robots, Inc.

HEATING AND COOLING EFFICIENCY FOR HOMES

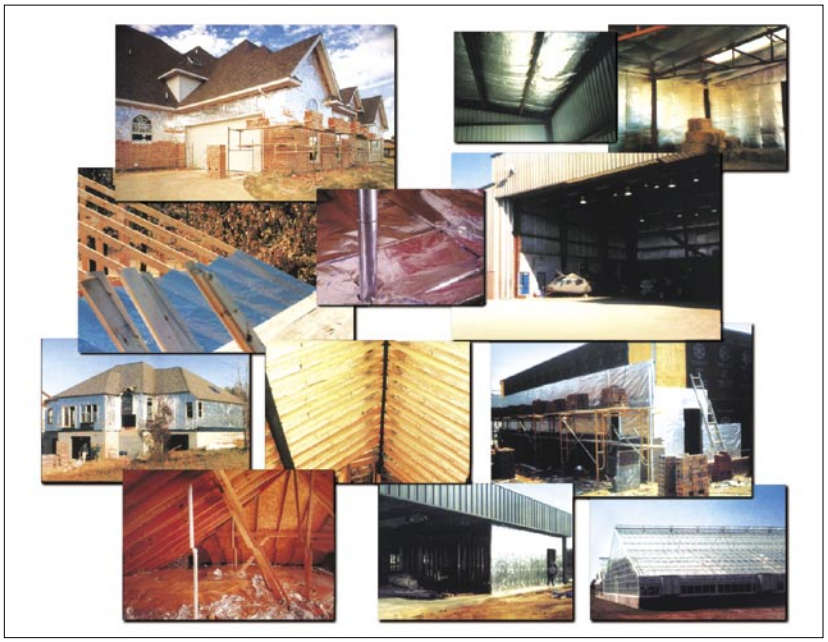
ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

Over 40 years ago, NASA developed Radiant Barrier technology to protect astronauts in the Apollo Program from temperatures that ranged from 250 °F above to 400 °F below zero Fahrenheit. This feat in temperature control technology enabled the astronauts to work inside the Apollo Command Module wearing short-sleeve shirts, with temperatures similar to those of a regular business office. The Radiant Barrier has been applied to virtually all spacecraft since then, including unmanned spacecraft with delicate instruments that need protection from temperature extremes. It is also applied to the astronauts' space suits, protecting them during space walks.

Made of aluminized polymer film, the Radiant Barrier both bars and lets in heat to maintain a consistent temperature in an environment where ordinary insulation methods will not suffice. The aluminization of the material provides a reflective surface that keeps more than 95 percent of the radiated energy in space from reaching the spacecraft's interior. In space suits, the thin and flexible material reflects the astronauts' body heat back to them for warmth, while at the same time reflecting the sun's radiation away from them to keep them cool. Using conventional insulation, a space suit would have required a 7-foot-thick protective layer.

PARTNERSHIP

Since the 1970s, private industry has had the opportunity to apply Radiant Barrier technology to various commercial applications. This NASA-developed, public domain technology has been applied to energy conservation techniques for homes and offices, and even specialty applications such as candy wrapping, thermos bottles, windshield covers for automobiles, fire suits, space blankets for forest rangers, race cars, and refrigeration trucks to name just a few.



The cost-saving benefits of Eagle Shield, Inc.'s Radiant Barrier product extend to a variety of applications where heating and cooling efficiency is desired.

PRODUCT OUTCOME

Eagle Shield is a Radiant Barrier product that can be installed directly on top of existing ceiling insulation in a home to reduce heating and cooling bills. Manufactured by Eagle Shield, Inc., of San Ramon, California, the product consists of two sheets of 99.5 percent industrial grade aluminum adhered together and tri-laminated to a thermal break to create a two-sided reflector. It is perforated with tiny holes that allow moisture to pass through so it does not create a moisture barrier for existing insulation. According to the company, installation takes an average of 2 to 6 hours based on difficulty and accessibility of the attic, walls, and crawl space interiors. Eagle Shield Radiant Barrier Insulation is not mechanical, therefore it cannot break down and it requires no electrical or plumbing connections in the installation process.

Eagle Shield cuts heating and cooling costs by lowering the amount of heat transferred into a home in the summer and out of a home in the winter. In the summer, heat waves generated by the home's roof decking are reflected by the Radiant Barrier before they have the opportunity to be absorbed by the ceiling insulation, thereby keeping the home cooler. In the winter, the radiated heat waves from within the home are absorbed by the ceiling and conducted up through the insulation into the attic. In this case, the down-facing side of the Radiant Barrier reflects the radiant heat waves emitted from the insulation back down toward the living area instead of allowing them to simply escape into the attic. This process eliminates heat loss through the ceiling, saving heating costs.

In addition to lowering bills and increasing the comfort level of the home, the improved temperature control achieved by the Radiant Barrier product can potentially extend the life of the home's heater and air-conditioning unit. Eagle Shield can also be applied to water heaters and ducts for improved energy efficiency. These applications show the continued benefits of Eagle Shield's mission of "Bringing Space Age Technology Down to Earth."

AMORPHOUS ALLOY SURPASSES STEEL AND TITANIUM

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

In the same way that the inventions of steel in the 1800s and plastic in the 1900s sparked revolutions for industry, a new class of amorphous alloys is poised to redefine materials science as we know it in the 21st century.

Welcome to the 3rd Revolution, otherwise known as the era of Liquidmetal® alloys, where metals behave similar to plastics but possess more than twice the strength of high-performance titanium. Liquidmetal alloys were conceived in 1992, as a result of a project funded by the California Institute of Technology (CalTech), NASA, and the U.S. Department of Energy, to study the fundamentals of metallic alloys in an undercooled liquid state, for the development of new aerospace materials. Furthermore, NASA's Marshall Space Flight Center contributed to the development of the alloys by subjecting the materials to testing in its Electrostatic Levitator, a special instrument that is capable of suspending an object in midair so that researchers can heat and cool it in a containerless environment free from contaminants that could otherwise spoil the experiment.

With an amorphous atomic structure that is unprecedented for structural metals, the Liquidmetal® alloy possesses superior elasticity and a high yield strength more than twice that of high-performance titanium alloys.

PARTNERSHIP

Prior to the discovery of the material that would eventually come to be known as Liquidmetal, Dr. Bill Johnson of CalTech had spent over 20 years studying the feasibility of creating new types of metals with liquid atomic structures. As a professor of Engineering and Applied Science, Johnson's motivation to study liquid-like metals was the work of a former CalTech materials scientist named Pol Duwez. In 1959, Duwez employed a rapid cooling process to successfully create a thin, gold-silicon alloy that remained amorphous at room temperature. This ribbon-like form of amorphous metal caught on, and is still being used today in transformer cores on power poles to reduce transmission losses.

As Johnson's studies continued over the years, he envisioned amorphous metals in thick, structural hunks that did not require rapid cooling for formation. In 1992, he and Dr. Atakan Peker—a graduate student at the time—patiently spent 10 months bringing this concept to fruition as part of their task for CalTech, NASA, and the U.S. Department of Energy. Using a complicated blend of elements (zirconium, titanium, nickel, copper, and beryllium) possessing varying chemical characteristics, Johnson and Peker were able to create a newly structured alloy that turned from a liquid structure or non-crystalline to a solid at room temperature, without having to subject the material to rapid cooling.

Over the next 6 months, the two-man team experimented with varying amounts of the chemical elements and several hundred resulting glassy alloys. They ultimately concocted a promising recipe they termed as "Vitreloy." There were no doubts cast over the amazing strength of Vitreloy. A 1-inch-diameter bar of the new material was capable of lifting 300,000 pounds, while a titanium bar of the same size

HEAD Racquet Sports has incorporated Liquidmetal® into a new tennis racquet line.

supported 175,000 pounds. Despite this superb achievement, Vitreloy was quite delicate, having the propensity to shatter like glass. Johnson explained that this shear failure would occur because Vitreloy lacked the crystals normally found in conventional metals that gather together to protect a surface area from imperfections and damaging forces. On the other hand, by not possessing crystals, amorphous metals are elastic, strong, and corrosion-proof.

Using methods resembling those employed to process plastics, Johnson and Peker in 2000 improved upon Vitreloy to create an extended family of Liquidmetal alloys with improved strength properties that do not inhibit the metal's flexibility to be shaped and processed into many different forms.

PRODUCT OUTCOME

Arguably the first major breakthrough in materials technology since the development of thermoplastics, Liquidmetal alloys offer superior mechanical properties compared to other highly engineered materials. Compared to crystalline metallic alloys, Liquidmetal is much more resistant to permanent deformation from impact, and 3 times more elastic or resilient. To demonstrate the elasticity phenomenon, three identical, polished, marble-sized balls made of stainless steel were each dropped into their own glass tubes from the same height and left to bounce. Each tube contained a different type of metal plate at the bottom: the first tube possessed a steel plate, the second tube a titanium plate, and the third tube a Liquidmetal plate. The ball in the steel-plated tube and the ball in the titanium-plated tube ceased bouncing between 20 and 25 seconds, while the ball in the Liquidmetal-plated tube continued to bounce for 1 minute and 21 seconds. Also, the plate made from Liquidmetal was the only plate containing enough elasticity to allow the ball to bounce completely out of the glass tube several times after the initial drop.

Liquidmetal Technologies, Inc., of Lake Forest, California, is the owner of the intellectual property rights for Liquidmetal, holding more than 40 worldwide patents and trademarks on the composition, manufacturing process, and usage of the technology. The company began manufacturing plates for golf equipment in 1996, and has since catapulted its business to a new level with many other applications built from Liquidmetal technology.

Scientists at Liquidmetal Technologies discovered that the inclusion of Liquidmetal alloys into a wide range of military products could significantly enhance the performance and safety levels of these items. The initial military product identified was the Kinetic Energy Penetrator (KEP), the most effective armor-piercing ammunition used by the

military. The KEP currently utilizes depleted uranium alloy rods, however, so the U.S. Department of Defense is searching for a new, environmentally safe KEP material that performs as well as this heavy metal, but without the potential hazards (depleted uranium is slightly radioactive and has chemical toxicity properties that, in high doses, can cause adverse health effects). Based on an initial testing occurring recently, the U.S. Army found the Liquidmetal refractory-based alloy composite to have unique characteristics that make it an improved material for use as KEP rods in advanced armor-piercing ammunition. As a result, the Department of Defense is working closely with Liquidmetal Technologies to develop a range of KEP rods that are suitable to replace the depleted uranium rods.

In 2003, HEAD Racquet Sports, a division of HEAD NV, incorporated the revolutionary metal alloy into a new tennis racquet line. HEAD has maximized the benefits of the alloy by applying it to four strategic areas of the Liquidmetal racquet's head. This allows all of the energy from ball impact to be used for a powerful return, so what a player puts into his or her swing is exactly what they get out. No energy is lost on ball impact due to the racquet's liquid atomic structure.

The HEAD Liquidmetal Radical, one of several HEAD racquet models featuring the alloy, was named one of BusinessWeek's and FORTUNE's 25 best products for 2003. This model is also considered the "weapon of choice" for tennis star Andre Agassi. "The power and maneuverability of the Liquidmetal technology is unparalleled," states Agassi, who ranked number one in the world in August 2003.

More recently, Russian tennis pro Marat Safin reached the finals at the 2004 Australian Open with his HEAD Liquidmetal Prestige racquet. On the women's side, Anastasia Myskina—also of Russia—was a quarter-finalist with her HEAD Liquidmetal Instinct racquet and Patty Schnyder of Switzerland was a semi-finalist with her HEAD Liquidmetal Prestige racquet.

Also in sports, Rawlings Sporting Goods Company, Inc., the leading manufacturer of baseball sports equipment and official supplier to Major League Baseball, is following up on the success of its inaugural line of Liquidmetal baseball and softball bats by signing an exclusive, multi-year agreement with Liquidmetal Technologies to develop the "next standard" in high-performance baseball equipment. The current Rawlings® Liquidmetal product group features a full range of metal performance bats in four categories: youth baseball, high school/collegiate baseball, senior league baseball, and fast pitch softball.

Liquidmetal is proving to be an attractive and effective casing for wristwatches and jewelry. Swiss luxury watchmaker TAG Heuer is featuring the high-performance alloy as the casing of a new, special edition, state-of-the-art chronograph timepiece. The digital movement timepiece was unveiled at the BASEL 2003 World Watch & Jewelry Show as the Microtimer Concept Watch. Built upon TAG Heuer's international reputation for precision, endurance, and technological innovation, it is fitted with the first Swiss electronic movement accurate to 1/1000 of a second.

The Liquidmetal® properties translate into a watchcase that is scratch-, dent-, and corrosion-resistant, and at the same time provides a high gloss that can be polished to a luxurious jeweler's finish. Swiss luxury watchmaker TAG Heuer is featuring Liquidmetal® as the casing of a new, special edition timepiece.

Rawlings Sporting Goods Company, Inc., and Liquidmetal Technologies, Inc., teamed up to develop the "next standard" in high-performance baseball equipment.

The Liquidmetal properties translate into a watchcase that is scratch-, dent-, and corrosion-resistant, and at the same time provides a high gloss that can be polished to a luxurious jeweler's finish. Furthermore, the ability of Liquidmetal alloys to be cast into precision net-shape parts offers additional opportunities and advantages for their application in unique and sophisticated jewelry designs. TAG Heuer, together with its parent company Moet Hennessy Louis Vuitton, have agreed to broaden their product portfolios utilizing Liquidmetal technology.

In telecommunications and electronics, Liquidmetal Technologies has created markets for scratch-resistant and slim-but-strong cellular phone casings. Vertu Limited, a luxury personal communication company, features the alloy in the bezel and battery cover of its new Vertu® Ascent Collection, available in fine jewelry and department stores worldwide. In an effort to answer consumer demands for smaller, thinner, and more aesthetically pleasing cellular phone designs, Samsung Electronics Company produced a Liquidmetal super-thin liquid crystal display screen frame component for its SCH-X199 mobile phone model. More recently, Samsung has focused on developing small, net-shaped parts such as hinge assemblies, and is incorporating these parts into cellular phones and other devices. The small, functional parts exploit the high strength and elasticity of Liquidmetal while using the alloy's ability to be "plastically processed" to obtain precision hardware at cost structures competitive with plastic parts.

In medicine, Liquidmetal Technologies is working with DePuy Orthopaedics, a division of Johnson & Johnson, to develop orthopedic implant products such as hip and knee replacement devices, as well as scalpel blades that are stronger and sharper than steel, less expensive than diamond, and longer lasting than modern blades.

For industry, Liquidmetal Technologies offers a complete line of alloy coatings and powders for equipment and machinery that provides the exceptional benefits of an amorphous surface in tough environments of high wear, temperature, and corrosion. These products possess the right properties to significantly extend part life, including low coefficient of friction, low shrinkage, wear resistance, and high-temperature performance. With established applications in oil drilling thousands of feet beneath the sea floor, refining, pulp and paper, food processing, and agriculture, the coatings are a dependable solution to everyday wear and tear.

Spinning back to the Space Program, NASA and Liquidmetal Technologies worked together on four Space Shuttle missions, enabling NASA scientists to study the alloy firsthand in the microgravity conditions of space. The technology is also being considered for several upcoming aerospace applications, possibly helping to get the 3rd Revolution even further off of the ground.

Liquidmetal® is a registered trademark of Liquidmetal Technologies, Inc.

Rawlings® is a registered trademark of Rawlings Sporting Goods Company, Inc.

Vertu® is a registered trademark of Vertu Limited.

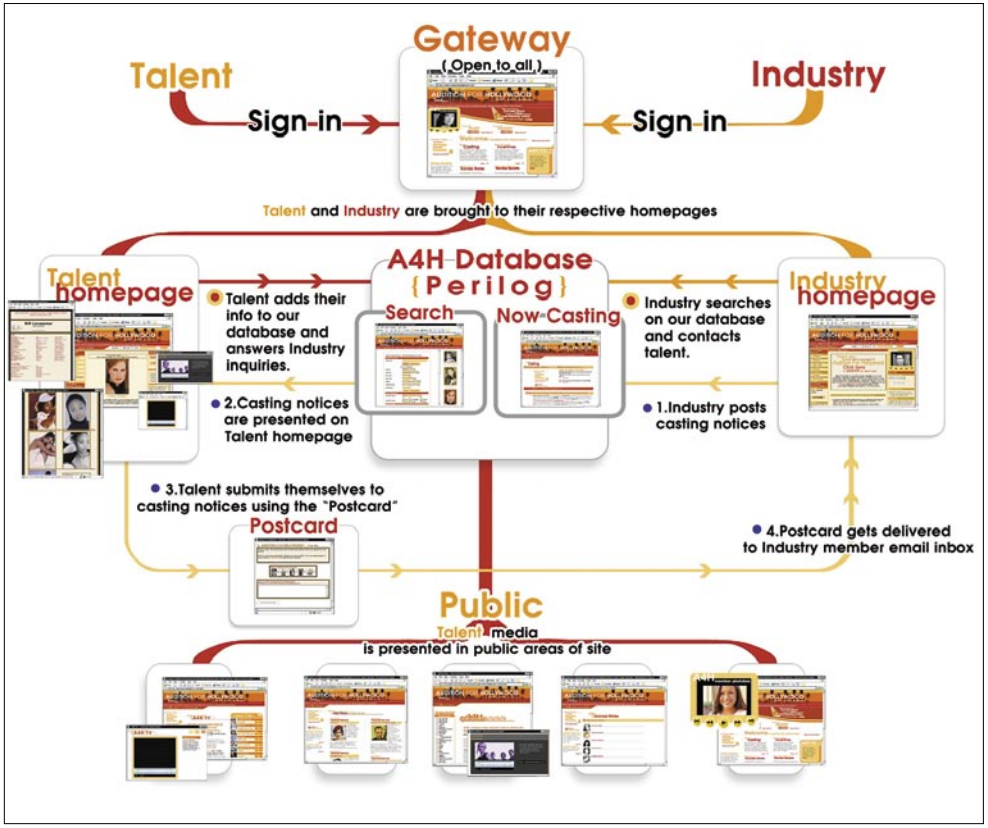
The new Vertu® Ascent Collection, featuring Liquidmetal® in its bezel and battery cover.

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

In today's fast-paced business world, there is often more information available to researchers than there is time to search through it. Data mining has become the answer to finding the proverbial "needle in a haystack," as companies must be able to quickly locate specific pieces of information from large collections of data. Perilog, a suite of data-mining tools, searches for hidden patterns in large databases to determine previously unrecognized relationships. By retrieving and organizing contextually relevant data from any sequence of terms—from genetic data to musical notes—the software can intelligently compile information about desired topics from databases.

Perilog was invented by NASA's Dr. Michael McGreevy, a principal investigator at the System Safety Research Branch under the Information and Computational Sciences Directorate at Ames Research Center. McGreevy applied his research on presence-based search engine and data-mining technology to analyze aviation safety incident reports from the Federal Aviation Administration (FAA). As part of NASA's effort to dramatically reduce the potential for commercial aviation accidents, Perilog was designed to support the FAA's Aviation Safety Reporting System (ASRS). This system receives, processes, and analyzes reports of unsafe occurrences and hazardous situations that are voluntarily submitted by pilots, air traffic controllers, and others in the airline industry. Perilog demonstrated its power on the ASRS's database of thousands of documents by drawing significant air safety connections out of the disparate data.

By unearthing relevant data to the research subject and then measuring contextual associations between term pairs within a text, Perilog produces models that capture the text's structure. The software then statistically compares these models to measure their degree of similarity to a query model, develops a ranking, and presents the search results to the user. Perilog also gives the user access to powerful query tools that can perform tasks such as generating search options automatically.

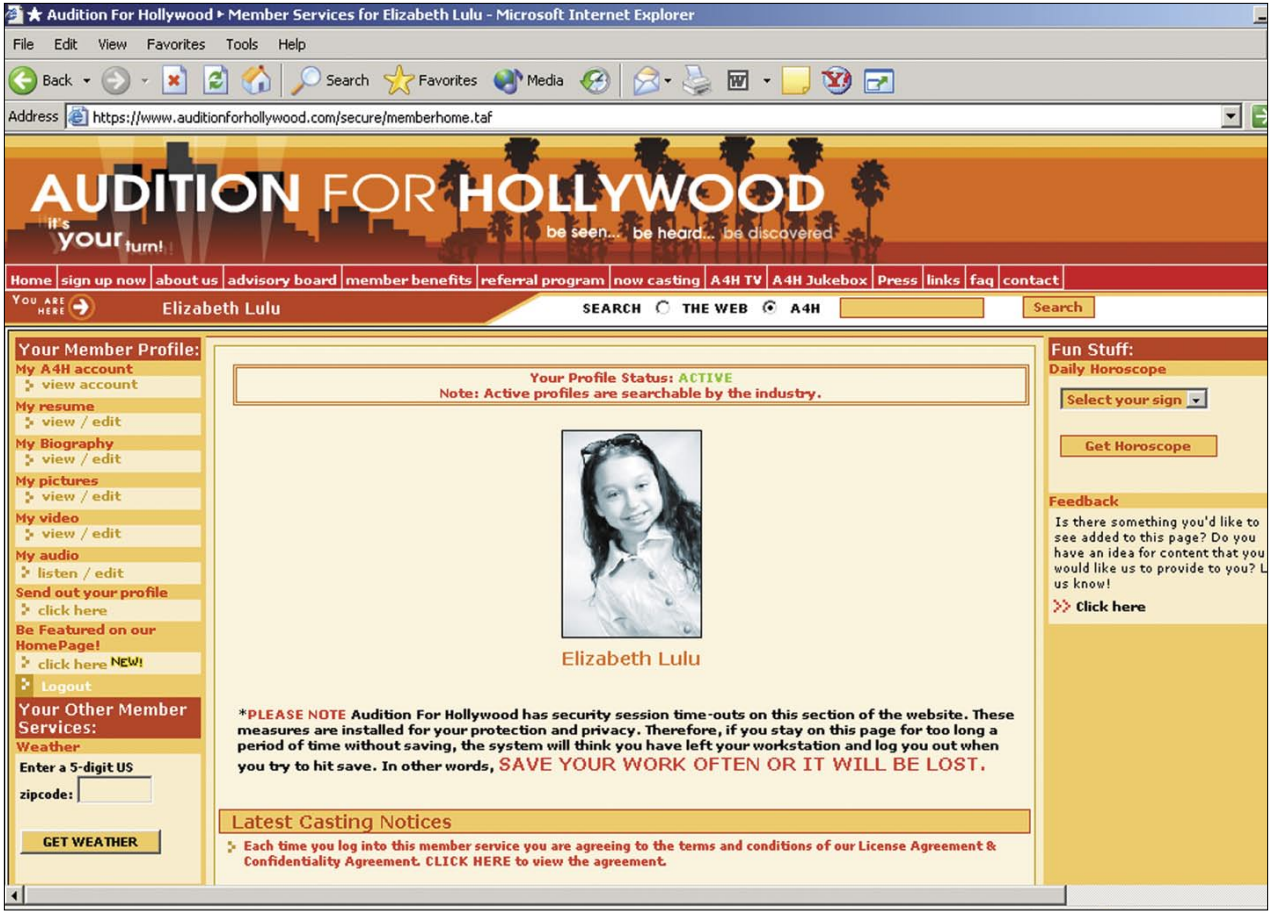


This diagram illustrates how Audition For Hollywood's Internet service connects talent with entertainment industry opportunities. NASA's data-mining technology, Perilog, plays a key role in the process.

PARTNERSHIP

NASA's Far West Regional Technology Transfer Center (RTTC) worked with Ames to promote Perilog and identify companies interested in obtaining a license agreement for the technology. Audition For Hollywood, an Internet company based in Los Angeles, California, attended Ames' licensing briefing for Perilog. Upon reviewing the technology's capabilities, the company determined that Perilog would be a good fit for its casting service, which is designed to match talent in the performance industry with high-profile entertainment executives. The Far West RTTC helped Audition For Hollywood prepare its license application and commercialization plan for NASA. The Ames Technology Partnerships Division then negotiated and executed the license.

David Lackner, Ames' Technology Partnerships manager, described the licensing agreement with Audition For Hollywood as "an unexpected but exciting opportunity to broaden our charter of making NASA's internally developed technology available to private sector companies." He continued to explain, "Typically, we license our inventions to companies in the medical or manufacturing fields.



Members of the Audition For Hollywood service see a personal profile page like this one when they log on to the system.

Our agreement with Audition For Hollywood is our first foray into the entertainment industry, and we are delighted that Perilog adds value to Audition For Hollywood's business strategy."

PRODUCT OUTCOME

Audition for Hollywood is using Perilog in conjunction with its own proprietary system in an effort to revolutionize the entertainment industry's casting process. The company's Internet-based service matches the requirements of entertainment industry decision makers with the skills of aspiring talent involved in all entertainment segments, including actors, musicians, dancers, models, and writers.

Perilog enhances the company's Application System search engine by integrating subjective criteria with objective criteria. For example, previous matching services could only identify objective information such as height, weight, and hair color. Perilog allows subjective information, such as personality and ethnicity, to factor into the search. According to the company, if a producer entered, "Exotic Pop Star," into the search engine, Perilog would be able to match the request to an actress's statement such as, "I am a Brazilian teenager with training in dance and the vocal range of Whitney Houston."

Since Perilog is not limited to locating "keywords" within structured database resumé fields, this refined and expanded search and match capability increases the likelihood of finding the right person for a role. It also enables matches for people that might have otherwise been overlooked. Casting directors benefit because they can narrow down a list of people who will truly qualify for a role. Perilog enables the person doing the searches to indicate how closely they want the results to match their criteria.

According to recent market surveys, there are approximately 200,000 television series, television shows, feature films, television commercials, documentaries, animated series, and other productions being created worldwide on an annual basis. Audition For Hollywood offers a unique opportunity for hundreds of thousands of aspiring actors, musicians, and models to be discovered for these opportunities through membership subscriptions to the company's online service. The service takes away the restrictions of geography between the aspiring talent pool and casting directors, as people across the globe can subscribe and be recognized for appropriate roles without having to travel to open casting calls. Entertainment professionals are taking notice of the cutting-edge technology. Within 6 months of the company's beta launch of its Web site, there were users from over 110 countries.

STUDENTS SOARING HIGH WITH SOFTWARE SPINOFF

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

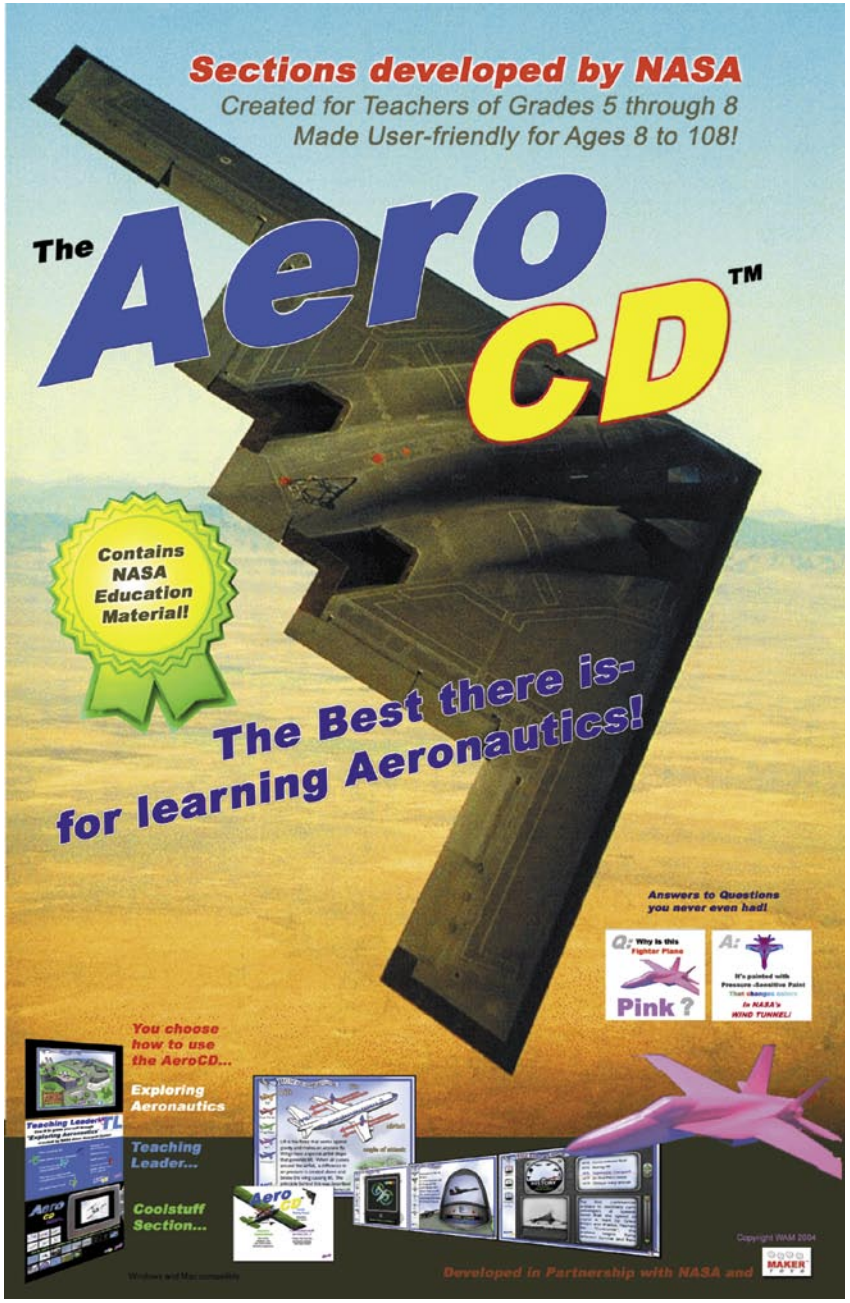
An educational software product designed by the Educational Technology Team at Ames Research Center is bringing actual aeronautical work performed by NASA engineers to the public in an interactive format for the very first time, in order to introduce future generations of engineers to the fundamentals of flight.

The "Exploring Aeronautics" multimedia CD-ROM was created for use by teachers of students in grades 5 through 8. The software offers an introduction to aeronautics and covers the fundamentals of flight, including how airplanes take off, fly, and land. It contains a historical timeline and a glossary of aeronautical terms, examines different types of aircraft, and familiarizes its audience with the tools used by researchers to test aircraft designs, like wind tunnels and computational fluid dynamics.

"'Exploring Aeronautics' was done in cartoon animation to make it appealing to kids," notes Andrew Doser, an Ames graphic artist who helped to produce the CD-ROM, along with a team of multimedia programmers, artists, and educators, in conjunction with numerous Ames scientists. In addition to lively animation, the software features QuickTime® movies and highly intuitive tools to promote usage of NASA's scientific methods in the world of aeronautics.

PARTNERSHIP

Bill Maecker, the president of Silvercreek, New York-based MakerToys, came to NASA looking for materials and images so that he could create an educational CD-ROM "learning toy" to add to his company's product line. Ames had a perfect match for Maecker with its "Exploring Aeronautics" CD-ROM, and licensed it to his company. According to Maecker, "It just made sense to license what the educators at Ames called affectionately 'the Aero CD,' and the rest is history."



MakerToys' AeroCD™ incorporates elements of NASA educational software to introduce students to aeronautics and the fundamentals of flight.

PRODUCT OUTCOME

MakerToys chose to use "AeroCD" for the name of its spinoff software product. The AeroCD™ retains the graphical user interface developed by Ames as one means to navigate the large amount of material on the CD. As a bonus, the company added two more interfaces to simplify use. The first additional interface, a proprietary "Teaching Leader" component, lets an individual student enjoy the commercial version of the NASA program without direction from a teacher, by providing voice-overs when the student rolls his or her mouse across text on the computer screen. The second additional interface is a "Coolstuff" screen that provides short NASA "movie" samples for users to select and determine if they are interested in continuing on to a particular longer-length QuickTime clip on the disc. The Coolstuff screen is intended to be a simplified navigation tool so that young students do not accidentally skip over important and interesting information stored on the AeroCD.

MakerToys also developed a second CD as a companion to the AeroCD called AeroLP. Its purpose is to provide a database of NASA facts about how things fly for people who want to teach small groups—such as teachers, pilot instructors, and scout leaders—or for individuals who just want to have a reliable information source for their own knowledge. For those who simply want to learn the basics, MakerToys has simplified titles and created a bookmark system for quick access to specific subjects, like aircraft types, classifications of aircraft by speed, and flight regimes, for example. In all, the AeroLP gives users 887 pages of printable material to create their own curricula.

MakerToys has met with numerous science/education distributors, museums, and mass-marketers to create a distribution plan for the AeroCD, thus catering to the needs of the target market. The Evergreen Aviation Museum in McMinnville, Oregon, is one of many U.S. museums raising money to support its programs, tours, and exhibits by selling the AeroCD in its gift shop. Evergreen Aviation Museum is home to the "Spruce Goose" Hughes Flying Boat that was built during World War II and tested shortly thereafter. The AeroCD is also available to the general public at the Smithsonian Institution's National Air and Space Museum, in Washington, DC, where MakerToys' flying toys have been among the top selling novelty items for years, according to the company.

The "Coolstuff" screen provides quick and convenient access to short NASA "movie" samples.

QuickTime® is a registered trademark of Apple Computer, Inc.

AeroCD™ is trademark of MakerToys.

WATER TREATMENT SYSTEMS MAKE A BIG SPLASH

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

In the 1960s, NASA's Manned Space Center (now known as Johnson Space Center) and the Garrett Corporation, Air Research Division, conducted a research program to develop a small, lightweight water purifier for the Apollo spacecraft that would require minimal power and would not need to be monitored around-the-clock by astronauts in orbit. The 9-ounce purifier, slightly larger than a cigarette pack and completely chlorine-free, dispensed silver ions into the spacecraft's water supply to successfully kill off bacteria. A NASA Technical Brief released around the time of the research reported that the silver ions did not "impart an unpleasant taste to the water."

NASA's ingenuity to control microbial contamination in space caught on quickly, opening the doors for safer methods of controlling water pollutants on Earth.

PARTNERSHIP

Carefree Clearwater, Ltd., of Cornelia, Georgia, obtained NASA's permission to manufacture a modified version of the Space Agency's patented Electrolytic Silver Ion Cell for numerous commercial and industrial applications, including swimming pools, hot water spas, decorative fountains, ponds, manufacturing processes, and evaporative water cooling towers.

PRODUCT OUTCOME

The Carefree Clearwater systems based on NASA's Apollo-era technology electronically release copper and silver ions into the water to destroy bacteria and algae—which are then filtered out. Unlike chlorine, the ions do not dissipate from heat and sunlight, therefore they are capable of providing a very stable sanitizer residual. The ionization technology substantially reduces the demand for chlorine so that fewer chloramines are formed and fewer chemicals are consumed. This cuts down on undesirable side effects realized in swimming pool environments, such as burning eyes, odor, and bleached or dry skin and hair. Furthermore, the ions pose no health risks, as scientists contend that chlorine can react chemically with organic materials in water to form a class of carcinogenic substances called trihalomethanes.

Numerous independent laboratory tests from NASA, health departments, and universities, and many years of field testing have confirmed the exceptional sanitizing ability of copper/silver ionization. Studies further show that using a combination of copper and silver can be effective against *E. coli, Pseudomonas, Legionella Pneumophila* (Legionnaires' disease), *Staphylococcus, Streptococcus, Salmonella,* and other pathogens—some of which have proven to be resilient even to high levels of chlorine.

Carefree Clearwater's automatic water purification ionizers employ a safe, low direct current, like that of several common household batteries, that passes through a set of copper and silver alloy electrodes. As the water supply traverses the ionizers' sealed chamber, metallic ions are generated to purify the water. When these ions encounter bacteria and algae, they destroy them through an alteration in their enzyme processes. All of the charged particles then flock together, only to be pulled out by a filter. The ions uphold a stable sanitizer residual until they are completely used up by this process.

The company markets several water purification products, including the Model 1200 State-of-the-Art Commercial Rated Electrolytic Ionizer and the Model 1100 Automatic Purification System. The Model 1200, which purifies 15,000 to 45,000 gallon swimming pools, features a rugged and durable design to protect its solid-state electronics from moisture, corrosion, and harsh environments; simple operating controls; light-emitting diode displays

Using NASA technology, Carefree Clearwater, Ltd.'s automatic purification systems electronically release copper and silver ions into the water to destroy bacteria and algae.

for power, polarity, and anode status; self-cleaning anode design; and an ion test kit. Variations of the Model 1200 are available for even larger swimming pools that range from 45,000 to 125,000 gallons. The Model 1100 offers many of the same features of the Model 1200, but at a lower price, since it is designed to purify spas and swimming pools up to 25,000 gallons.

Carefree Clearwater asserts that its commercial purifier quickly pays for itself by eliminating the need to spend thousands on chemical sanitizers, algaecides, and clarifiers. Operating costs for the ion generator's electrical consumption average less than 25 cents per month. Periodically oxidizing the water to break down organic contaminants from rain, wind, body oils, and leaf debris and maintaining a low halogen level and a normal pH balance are all that are needed when a Carefree Clearwater purifier is installed. Savings are also realized with a Carefree Clearwater purifier by eliminating bleaching and other damage to hair, swimsuits, pool equipment, and nearby plants and flowers. In addition, consumers save time, as daily testing and chemical handling are not required with a Carefree Clearwater product.

The company's purification systems have been installed in thousands of residential and resort pools and spas, YMCA facilities throughout the country, and at many major university indoor/outdoor pools, including the University of Virginia, the University of Texas, Purdue University, and Wake Forest University. Decorative fountains at Disney World, the Centers for Disease Control and Prevention in Atlanta, the John F. Kennedy Center for the Performing Arts in Washington, DC, and Kellogg's Cereal City in Battle Creek, Michigan, are kept sanitized with Carefree Clearwater purifiers, not to mention the largest decorative fountain in the world, the Fountain of Wealth in Suntec City, Singapore. Furthermore, the Cincinnati Zoo is tapping the technology for its sea lion tank, walrus pool, and arctic bird exhibit; Zoo Atlanta is utilizing it for its tiger and hoof stock exhibits; and Alligator Adventure in North Myrtle Beach, North Carolina, is employing it in its habitat for UTAN, the largest crocodile ever to be exhibited in the United States.

The Fountain of Wealth in Suntec City, Singapore—the largest decorative fountain in the world—employs a Carefree Clearwater purifier system.

Outside of recreational use, the electrolytic ionizer has proven to be invaluable for industry, especially in the areas of heating, venting, and air conditioning, and where cooling towers are relied upon to remove heat from a stored water source so that the water can be recirculated and reused or safely discharged to a natural body of water, like a river. Currently, there are more than 15 million cooling towers in the United States alone. This number will continue to increase significantly with the construction of new commercial and industrial facilities.

Water is the most commonly used coolant medium, and an open recirculating system is the most common type of equipment for a cooling tower Compared with other coolants, water is plentiful and inexpesive, and can carry large volumes of heat without considerable expansion or contraction. On the other hand, water can create major problems. Algae and microbiological contamination in the cooling system can lead to troubles ranging from bacterial buildup and Legionnaires' disease, to costly, extended downtime for cooling system repairs and the premature deterioration of expensive capital equipment. The National Oceanic and Atmospheric Administration, the Stamford Plaza Hotel in Auckland, New Zealand, and the Wallops Flight Facility in Virginia are a sampling of the various entities using Carefree Clearwater products to purify their cooling towers and prevent potential contamination and breakdowns.

The list of applications and benefits from this NASA-derived technology continues to grow daily, validating Carefree Clearwater's mission to establish a solid foundation and a strong future for electronic water purification.

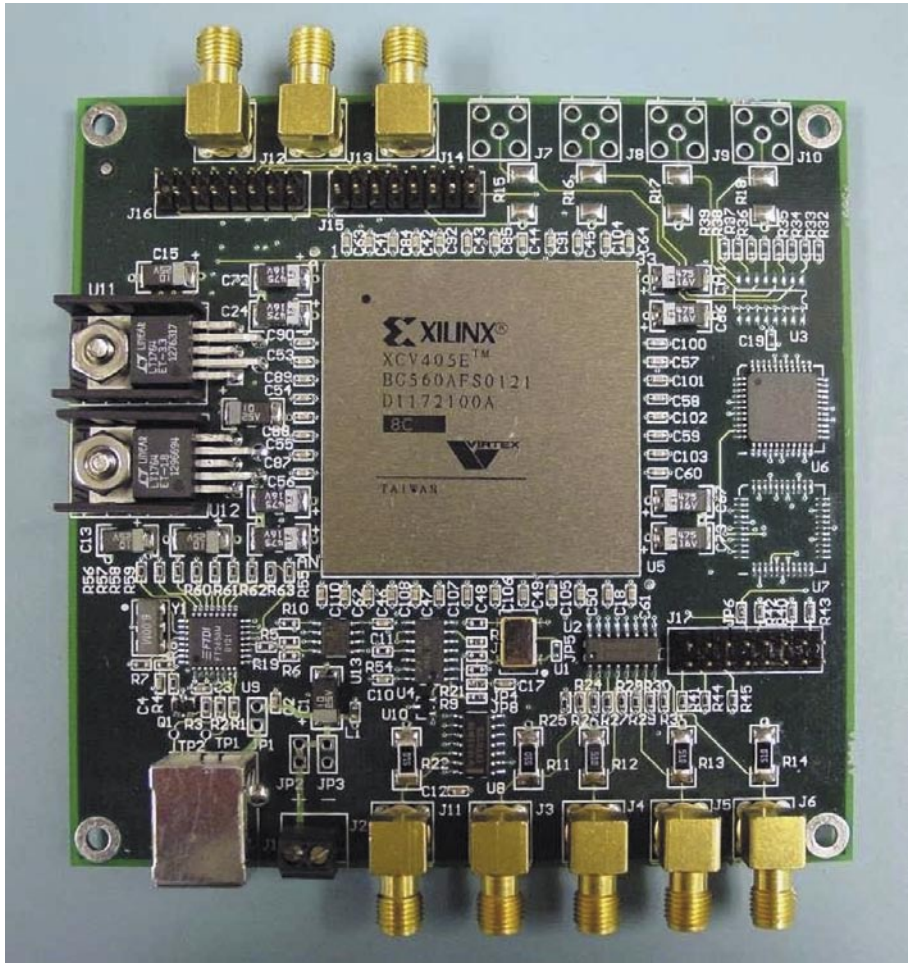
MULTI-CHANNEL SCALER CARDS IMPROVE DATA COLLECTION

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

Scientists interested in exploring the intricacies and dynamics of Earth's climate and ecosystems continually need smaller, lighter instrumentation that can be placed onboard various sensing platforms, such as Unmanned Aerial Vehicles (UAVs). Responding to a need for improved data collection for remote atmospheric measurement systems, ASRC Aerospace Corporation, of Greenbelt, Maryland, developed a series of low-power, highly integrated, multi-channel scaler (MCS) cards. The cards were designed to meet the needs of NASA's ground-based and airborne Light Detection and Ranging (LIDAR) photon-counting programs. They can rapidly collect thousands of data points during a continuous scan of the atmosphere.

PARTNERSHIP

Using **Small Business Innovation Research (SBIR)** funding from NASA's Goddard Space Flight Center, ASRC Aerospace improved upon its Advanced Multi-channel Scaler-5 (AMCS-5) card, which was already utilized in several Goddard-led projects. The company's two SBIR grants resulted in the AMCS-Universal Serial Bus (USB), AMCS-USB+, and Advanced Photon Counting System (APCS) cards. The adaptability, compact nature, and low power of these cards make them highly suitable for NASA's many ground-based and airborne LIDAR photon-counting systems.



The AMCS-USB card can rapidly collect thousands of data points during a continuous scan of the atmosphere. Applications include environmental monitoring data systems that study everything from clouds to pollution.

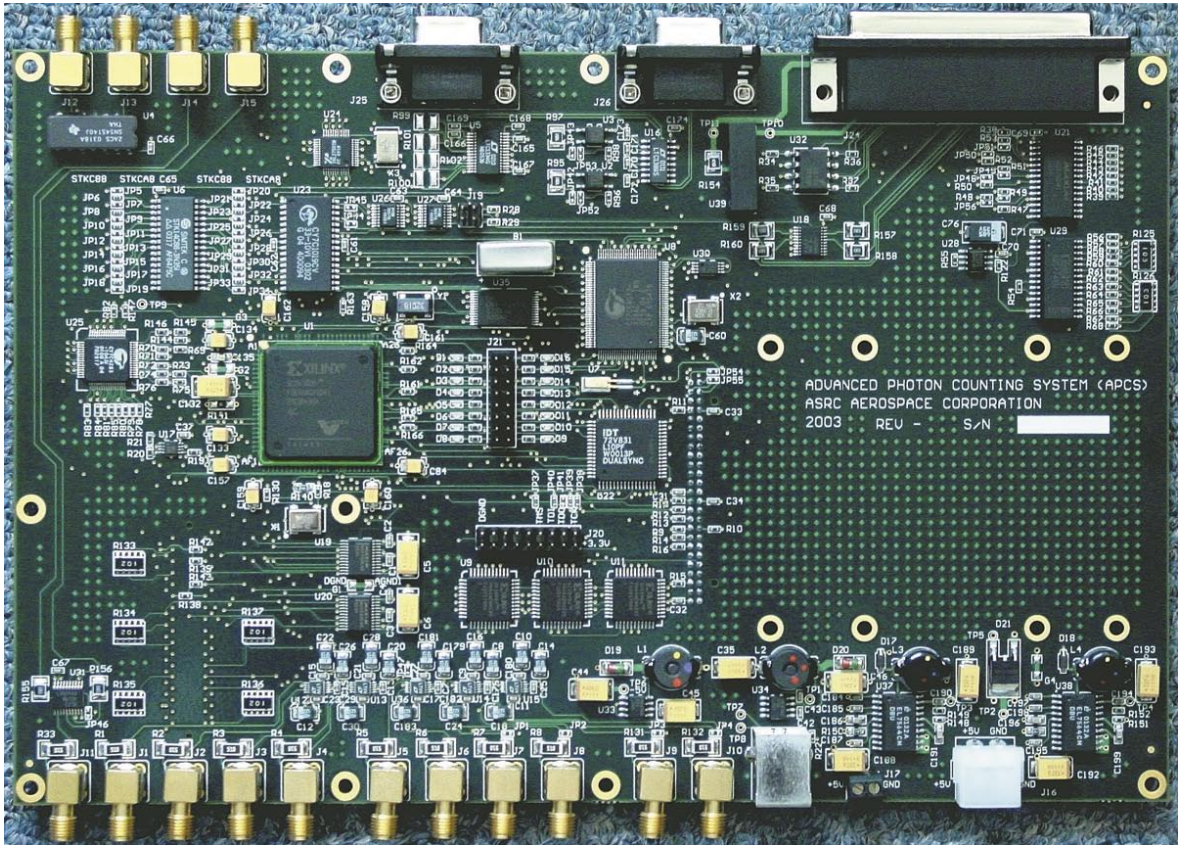
ASRC Aerospace's 4-input AMCS-USB and 8-input AMCS-USB+ cards provide a multi-channel scaler capability with a USB 1.1 interface. As systems began to use these cards, ASRC Aerospace discovered that many LIDAR systems often require the MCS function along with an analog-to-digital converter for housekeeping, serial communication ports, hard drive storage, time-tagging, and quicklook data capability. As a result, the company designed the APCS card, which serves as a complete data "system" on a single card. The APCS card includes all of these functions, along with a fast USB 2.0 interface and 10 MCS detector input channels. The serial ports allow for real-time quicklook data monitoring and navigational data capture, while the generic interface allows for a small laptop hard drive or rugged solid-state drive to be connected directly to the card. In addition, the company designed the APCS card with a daughtercard interface to create a very versatile system capable of high resolution. The APCS card is suited to both remotely deployed systems, such as in the UAV platform, as well as to laptop-based systems, where data can be readily monitored and controlled.

ASRC Aerospace also created a Windows®-based, graphical user interface (GUI) for the MCS cards that streamlines user interaction with the product. The GUI allows the user to write and read the MCS parameters, start acquisition with real-time, back-to-back integration and collection cycles, and log data to a text file for later review.

PRODUCT OUTCOME

The MCS cards rapidly collect thousands of data points during a continuous scan, and can be used in pulse-counting, integrating, and histogramming applications. In an airborne LIDAR application, for example, a laser is fired down to Earth from a high-flying aircraft. As the optical laser output moves downward, some of the light is reflected due to aerosols, clouds, and other particles in the atmosphere. Photon-counting detectors tuned to specific wavelengths detect the reflected light and output electrical signals indicating the presence of the reflected photons. The MCS card receives these electrical signals. By using a synchronization signal input, the card is aware of when the data acquisition starts. It divides the time-of-flight of the laser into time "bins" and records the number of reflected photons received in each bin. Once the desired number of lasers is fired, the card transmits collected data to the host computer. During the data collection by the software, the card continues to count and accumulate photons in a double-buffered memory to prevent data loss.

The AMCS-USB, AMCS-USB+, and APCS cards can be used in a variety of applications. The cards are highly integrated, in that all storage memory and multi-channel scaler functions are contained within a single chip on the cards. They can be adapted in the field, which allows the user to tailor the processor to suit the individual needs of the project. Parameters such as time resolution per bin, number of bins, accumulation delay, number of accumulations, and pulse polarity are set by the user through software control. The MCS cards transmit data to a host computer at the end of a completed integration cycle for processing and storage. All data transfers, such as commands from the host and acquired data from the card, are made through the USB interface. The cards can be used in any personal computer-based system, laptop, or desktop that has a USB port. In addition, the APCS card can store all of the collected data directly to an attached hard drive without the need for a host computer. This data can be read back at a later time with the use of a computer via the USB 2.0 interface.



The APCS card can store collected data directly to an attached hard drive without the need for a host computer.

Since the cards allow for many of their parameters to be configured via software, these products are attractive to industry, university, and government customers. The cards have been sold worldwide for use in advanced, high repetition-rate LIDAR systems. They can be used in environmental monitoring data systems that study everything from clouds to aerosols to pollution. The military could adapt the MCS cards for its smoke and chemical plume detection systems. The cards could also be used in non-LIDAR applications such as those for nuclear waste detection monitoring. Currently, the following LIDAR programs at NASA Goddard are benefiting from the MCS cards: Cloud Physics LIDAR, Thickness From Off Beam Returns LIDAR, Goddard LIDAR Observatory for Winds, 24-Channel Doppler LIDAR, Advanced Micropulse LIDAR, the Holographic Airborne Rotating LIDAR Instrument Experiment, and the Carbon Dioxide Detection Testbed.

Windows® is a registered trademark of Microsoft Corporation.

DIESEL GOES DIGITAL TO SAVE ENERGY, LOWER EMISSIONS

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

Forty years ago, actuators requiring constant energy to help power the Apollo spacecraft in space were replaced by magnetically holding and releasing, electronically controlled valves. Today, these same magnetic, electronic valves are on the verge of replacing entire camshaft systems in cars and trucks on Earth, thus leading to a whole new generation of low-emission engines.

PARTNERSHIP

NASA requires efficient and lightweight valves for controlling thrusters in spacecraft. While at Bell Aerospace in the 1960s, Eddie Sturman developed a very efficient valve control actuator that consumed little energy. Sturman's work resulted in five patents and systems that were extensively used throughout the Space Program. According to the Space Foundation, a non-profit organization aimed at advancing the exploration, development, and use of space, Sturman's valve control actuator likely was one of the energy-saving factors that enabled Apollo 13 to find the additional power it needed to return to Earth.

PRODUCT OUTCOME

Recognized by Popular Science magazine as the "Best of What's New" for 2000 and inducted into the Space Foundation's U.S. Space Technology Hall of Fame in 2003, Sturman's "digital valve" consists of a specially designed spool with a magnetic holding and releasing mechanism on its side and two opposing electromagnetic coils. The magnetic holding and releasing is commanded by sophisticated electronic processors, causing the spool to pass back and forth at tremendous speeds with remarkable precision to ensure accurate control of the pressurized hydraulic fluid that is pumped through the valve's opening. This allows the digital valve to open and shut extremely fast. Additionally, the valve can remain in the desired open/closed position due to magnetism from the component's electromagnetic coils. In effect, it saves energy, provides far greater fuel economy, and generates much less pollution than comparative valves.

Sturman had a plethora of non-aerospace uses in mind when he formed his own company, Sturman Industries, in 1989 to commercialize the digital valve initially developed for NASA and subsequently used in space. Original applications for the technology included implementation in battery- and solar-powered irrigation systems, but as Sturman continued to improve upon the design specifications for the valve, the company's focus shifted to making engines operate more efficiently.

From low-speed diesel to high-speed gasoline, and from heavy-duty trucks to standard passenger cars, Sturman

A big-rig truck equipped with a Hydraulic Valve Actuation system from Sturman Industries became the first camless vehicle to make it to the top and back of Pikes Peak without shutting down the engine.

A camless truck passes through Times Square on the tail end of its 10,000-mile trek across country to New York City, where Sturman Industries was presented with a "Best of What's New" award from Popular Science magazine.

Industries' Hydraulic Valve Actuation (HVA) system—controlled by the digital valve—provides the flexibility and precision required for clean, practical, and safe "camless" engine technology. Instead of using a traditional valve train consisting of a camshaft, push rod or cam chain, lifters, rocker arms, and valve springs, the camless engine utilizes HVA to open and close engine valves. HVA eliminates the mechanical linkage between the engine valves and the camshaft and allows for fully flexible engine valve operation.

In modern-day engines, the camshaft contains "lobes" (also called cams) that push against the engine valves to open and close them as the camshaft rotates. The size of these lobes determines the timing of the opening and closing of the valves, which allow the flow of fuel and oxygen into the engine's cylinders. This timing is critical and can have a great impact on an engine's performance at different speeds. In the Sturman camless system, however, timing is flexible and can be optimized for idle, acceleration, or full power, thus allowing the engine to "breathe easy" and perform well at all speeds. With a healthier respiration process, the camless engine offers cleaner emissions.

In 2000, history was made as a big-rig truck equipped with a Sturman HVA system became the first camless vehicle to make it to the top and back of Pikes Peak in Colorado without shutting down the engine. The accolade took place at the annual Pikes Peak International Hill Climb, the second-oldest motor race in U.S. history. One by one, vehicles race against the clock as they climb more than 12 miles to the top of the 14,110-foot summit, all while steering through 156 hairpin turns. In the same year, Sturman Industries successfully took a camless truck on a 10,000-mile tour across America. Even though camless engines are not yet considered mainstream on the automotive assembly line, the company's HVA system has been delivered to customers worldwide.

The digital valve has also been folded into fuel injectors, pneumatic valves, fluid transistors, airbags, suspension systems, and integrated electronic systems. Ford Motor Company's Power Stroke® 6-Liter OHV (overhead valve) V-8 turbo-diesel engine features the Sturman technology in the form of a hydraulic-assist direct fuel injection system. Sturman Industries' high injection pressures reduced the Power Stroke's nitrogen oxide emissions by 20 percent, compared to the Power Stroke's 7.3-liter predecessor, and greatly diminished the "clatter" that is associated with diesel engines. These improvements and others contributed to the Power Stroke being named one of 2003's "10 Best" engines by Ward's AutoWorld, a premier automotive magazine.

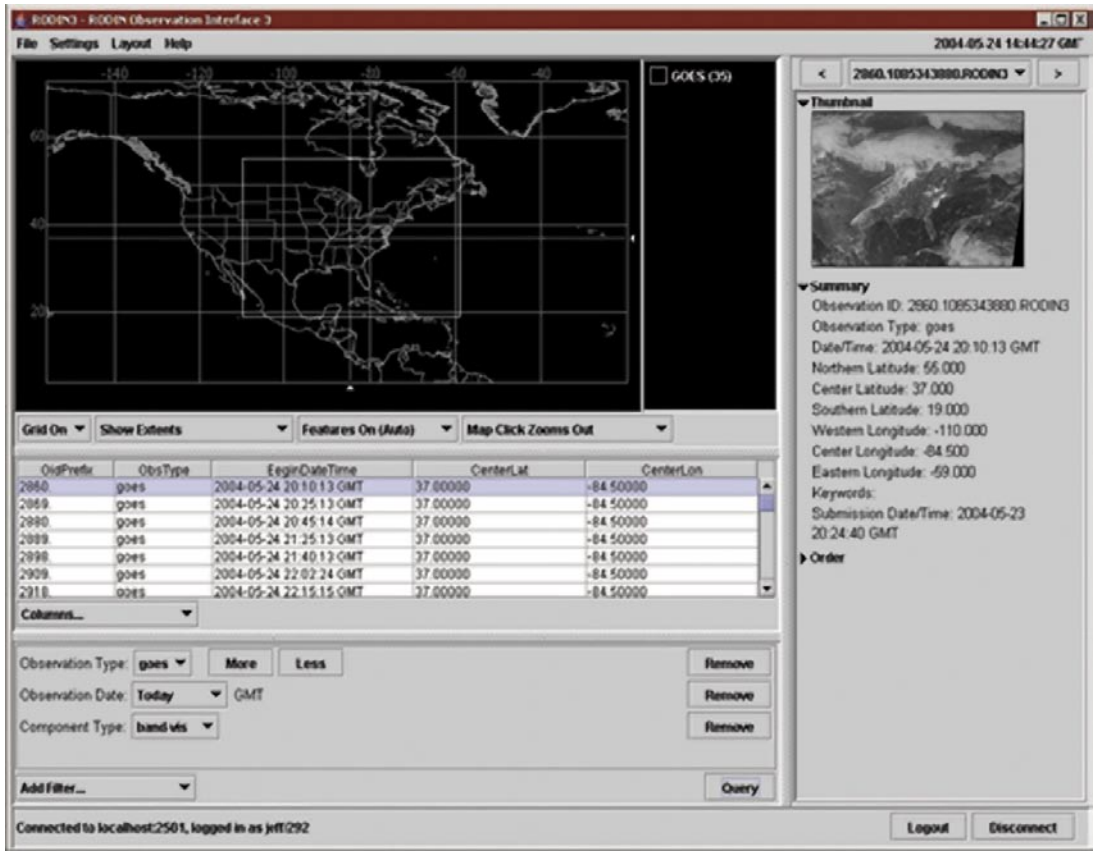
Non-automotive applications for the technology are numerous, ranging from carpet manufacturing to carbon dioxide-charged dispensers that prevent beverages from going flat.

Power Stroke® is a registered trademark of Ford Motor Company.

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

Since its founding in 1992, Global Science & Technology, Inc. (GST), of Greenbelt, Maryland, has been developing technologies and providing services in support of NASA scientific research. GST specialties include scientific analysis, science data and information systems, data visualization, communications, networking and Web technologies, computer science, and software system engineering. As a longtime contractor to Goddard Space Flight Center's Earth Science Directorate, GST scientific, engineering, and information technology staff have extensive qualifications with the synthesis of satellite, in situ, and Earth science data for weather- and climate-related projects. GST's experience in this arena is end-to-end, from building satellite ground receiving systems and science data systems, to product generation and research and analysis.

Among the company's advanced software designs is the Regional Digital Information Network (RODIN), which was originally designed under contract to NASA Goddard.



This screen shot shows the Regional Digital Information Network Observation Interface for the browsing and ordering client application.

RODIN is a Web-based information system that employs unique GST-developed methods for extracting, organizing, and searching metadata in such a way that allows fast retrieval and staging of stored geospatial data from different sources and in any format on the basis of time, location of the data, or other user-defined attributes. While providing a low-cost alternative to archive and retrieval systems based on fixed data formats, the RODIN framework provides much of the functionality of large, expensive data systems. RODIN offers the distinct advantage of not being bound by any one data format. In addition, it has the built in capability to automate the search, retrieval, and dissemination of data and data products over the Web.

PARTNERSHIP

GST developed RODIN for Goddard's Applied Information Sciences Branch as a core capability that would underpin the NASA Regional Applications Center (RAC) program. The RAC program was conceived to provide a nimble, locally implemented and controlled advanced data system that would enable universities, businesses, and local communities to jointly address environmental-related applications or issues of local or regional importance. While the RAC program is no longer actively supported by NASA, the RODIN software lives on through its transfer to private industry. Under a license from NASA, GST has continued to modify and develop RODIN as an add-on enhancement to the company's commercial products.

PRODUCT OUTCOME

Based on its earlier work with NASA's Applied Information Sciences Branch, GST introduced DirectMet® in 1999, a direct-readout Geostationary Operational Environmental Satellite Receiver and Workstation for the ingestion, processing, and analysis of geostationary satellite imagery. Used worldwide by professional meteorologists, DirectMet is employed extensively throughout the Caribbean and Pacific to support hurricane tracking among many other applications. The system allows automated user-defined

scheduling, subsetting, and product creation, and has unique built-in meteorological analysis functions.

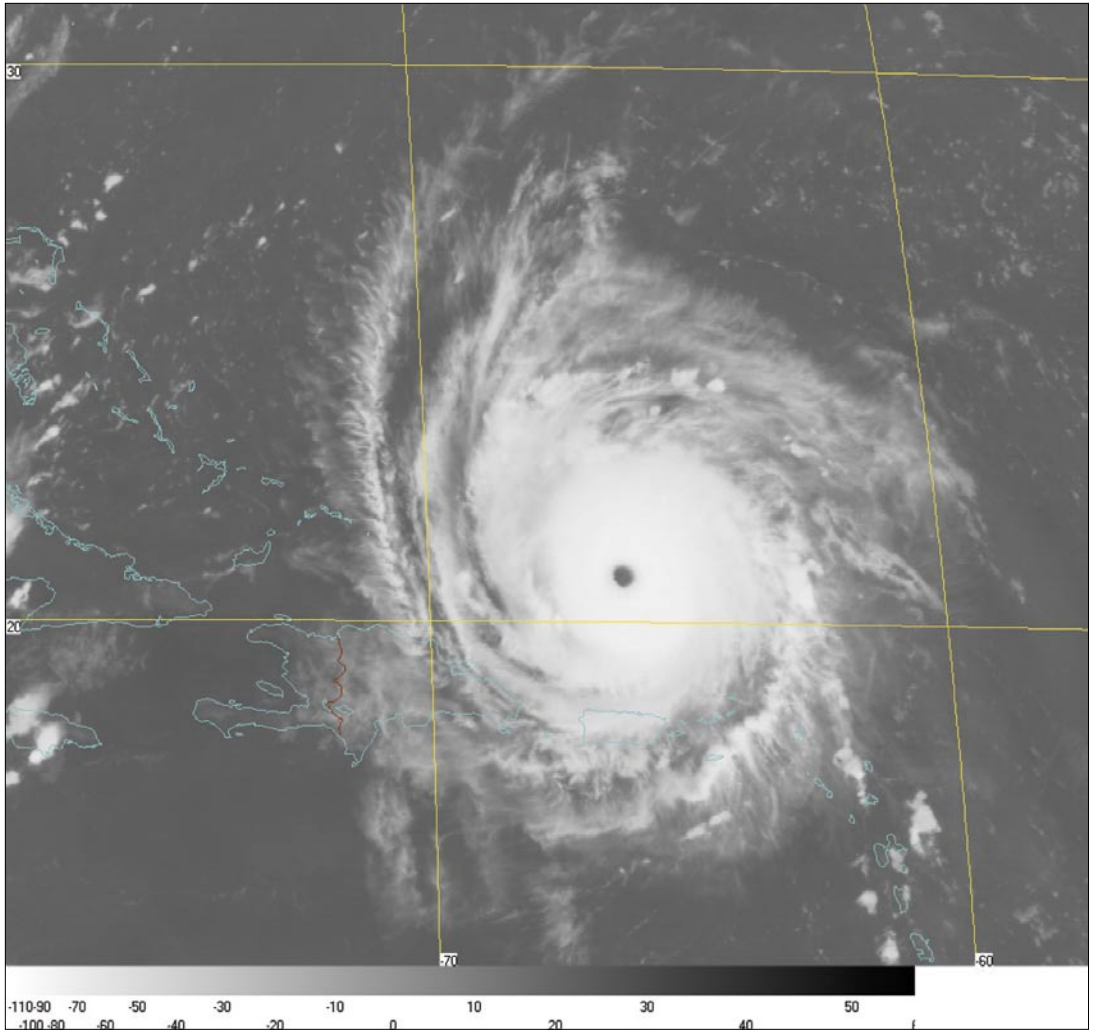
A new DirectMet archive based on the RODIN technology provides DirectMet with a scalable, expandable archive system that allows both directed and automated archiving of raw and processed data, imagery products, and project files. Data are fully retrievable by time, location, area, product, and spectral band.

Another application of RODIN is through MetLab,™ a "next-generation" meteorological workstation developed by GST in partnership with 3DI, Inc., in 2002. MetLab was recently adopted by the U.S. National Weather Service as its internal World Area Forecast System Aviation Weather Terminal. Deployed from Hawaii in the Pacific to the Caribbean and South America, the workstation provides comprehensive data and toolsets for the professional forecaster. GST is developing a RODIN-based archive system for MetLab's weather data that will be marketed as a comprehensive local meteorological data archive system to support local climate and weather studies. This archive system is needed by small countries around the world that do not have immediate or reliable access to the vast NASA or National Oceanic and Atmospheric Administration data holdings that are accessible to the U.S. community at various data centers.

RODIN's unique design has applications that extend beyond those of immediate interest and use to NASA and the weather communities. GST plans to develop RODIN-based archive and retrieval systems that will enable it to serve as a powerful, stand-alone archive for virtually any Earth science-related data system.

DirectMet® is a registered trademark of Global Science & Technology, Inc.

MetLab™ is a trademark of Global Science & Technology, Inc.



The DirectMet® GOES-GVAR system captured Hurricane Frances, a Category 4 storm, as it headed towards the Bahamas in August 2004. One of Global Science & Technology, Inc.'s many customers in the Caribbean depended heavily on the DirectMet system as the storm approached.

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

The Robot Systems Technology Branch at NASA's Johnson Space Center collaborated with the Defense Advanced Research Projects Agency to design Robonaut, a humanoid robot developed to assist astronauts with Extra Vehicular Activities (EVA) such as space structure assembly and repair operations. By working side-by-side with astronauts or going where risks are too great for people, Robonaut is expected to expand the Space Agency's ability for construction and discovery.

NASA engineers equipped Robonaut with human-looking, dexterous hands complete with five fingers to accomplish its tasks. The Robonaut hand is one of the first being developed for space EVA use and is the closest in size and capability to a suited astronaut's hand. As part of the development process, an advanced sensor system was needed to provide an improved method to measure the movement and forces exerted by Robonaut's forearms and hands.

Astro Technology, Inc., of Houston, Texas, rose to the challenge by developing a new sensor system that could measure the bending of the fingers, tactile forces at the finger tips, and tendon forces in the forearm. The company based the sensors on fiber-optic sensing technology and developed a small, high-rate data signal conditioning and acquisition system. With this new system, measurements that could not be accomplished with conventional methods were now possible.

Astro Technology's Fiber-Optic Sensor System (FOSS) overcomes the technical limitations of the previous method of using conventional strain gauges, such as susceptibility to electrical noise, difficult attachment techniques, cable handling limitations, and the need for a large data acquisition system to support a large number of sensing elements. The fiber-optic sensors are immune to electrical noise since the sensing element and cable require a light source rather than an electrical current. Cabling needs are significantly reduced, requiring fewer cables to pass through the wrist and forearm where space is limited. The small size of the fiber-optic sensors provides superior attachment methods relative to conventional sensors, and the miniaturized data acquisition system can reduce the size and weight for space flight and operation with the Space Shuttle and International Space Station.

PARTNERSHIP

NASA Johnson granted Astro Technology a Phase II **Small Business Innovation Research (SBIR)** contract to develop the FOSS, which will be used to instrument the Robonaut hand aboard the International Space Station. The contract followed Astro Technology's completed Phase I SBIR contract with Johnson, which tasked the company with applying the technology to robots used on the Space Shuttle. Astro Technology's advancements from its Robonaut development efforts paved the way for the application of new sensing methods in the oil and gas industry.

PRODUCT OUTCOME

Astro Technology engineers miniaturized and ruggedized the FOSS to meet the needs not only of NASA's Robonaut program, but for solid rocket motor testing applications and oil and gas subsea monitoring as well. The company has contracted with major oil companies to apply its FOSS technology to evaluate fatigue on subsea pipelines, risers, and offshore drilling and oil production rigs.

Astro Technology, Inc.'s Fiber-Optic Sensor System has applications ranging from deepwater drilling risers to the instrumentation of NASA's Robonaut.

Over the past decade, new oil reserves have been discovered in deepwater environments around the world. These deepwater reserves are capable of providing a constant stream of fossil fuel energy for many years, making their development increasingly important as energy consumption pressure increases.

Extensive technology requirements are necessary to develop the deepwater reserves, since many of the oil fields are in water depths of 7,000 feet or greater. Oil pipelines or risers must be greater than 1 mile in length and are unsupported from a well head to the water surface. Once the pipelines are in place, water currents flowing past the pipeline create a vortex-induced vibration that can cause the riser to fail from fatigue damage. Additional high-stress areas that could fail are located where the pipeline touches down on the ocean floor. Predictive monitoring is essential where failure could be catastrophic both economically and environmentally.

Astro Technology engineers adapted the FOSS technology to monitor and determine the service life of these subsea pipelines. The company developed risk management software to calculate real-time service life evaluations and cumulative fatigue using rain-flow analysis techniques. By calculating total fatigue based on the logged history of real-time strain measurements, the system is able to perform predictive failure analysis in order to determine which riser sections need to be replaced. As a result, costly repair and downtime are reduced and potential environmental contamination from hydrocarbon spillage is eliminated. Optimized for harsh operating environments, the sensor system has been deployed in deepwater fields in the Gulf of Mexico.

The FOSS technology is also suited for applications such as high-speed data acquisition systems for measuring strain and temperature in wind tunnel tests, structural monitoring of aircraft, and sensors in automobiles. In the meantime, the technology is bringing value to NASA, as Astro Technology's FOSS can be applied to both the current Robonaut version and its next-generation design.

One of the large oil rigs to which Astro Technology, Inc., is applying its sensor technology is now installed in the Gulf of Mexico.

The accurate, robust, and reliable sensors can integrate into a Robonaut hand with minimal interference with the mechanical design. The company's predictive failure analysis software could also be adapted to monitor space vehicle structures and subsystems, including propellant lines.

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

In order to deliver accurate geospatial data and imagery to the remote sensing community, NASA is constantly developing new image-processing algorithms while refining existing ones for technical improvement. For 8 years, the NASA Regional Applications Center at Florida International University has served as a test bed for implementing and validating many of these algorithms, helping the Space Program to fulfill its strategic and educational goals in the area of remote sensing. The algorithms in return have helped the NASA Regional Applications Center develop comprehensive semantic database systems for data management, as well as new tools for disseminating geospatial information via the Internet.

PARTNERSHIP

In 1996, NASA's Goddard Space Flight Center formally agreed to establish a Regional Applications Center at Florida International University through a NASA Institutional Research Award titled "High Performance Database Management with Applications to Earth Science" (NASA's Institutional Research Award Program provides minority institutions the opportunity to enhance their research capabilities in NASA-related fields). This collaborative effort has since expanded the practical applications of NASA satellite sensor readings—combined with other physical or logical data—to benefit U.S. Government at all levels, students and universities, and private companies.

PRODUCT OUTCOME

Didn't have a window seat when your plane flew over the Grand Canyon and the bright, colorful lights of the Las Vegas Strip? No need to endure another plane ride; now you can obtain a "bird's-eye" view of these wondrous landmarks and any others in the continental United States, all from the monitor of a personal computer.

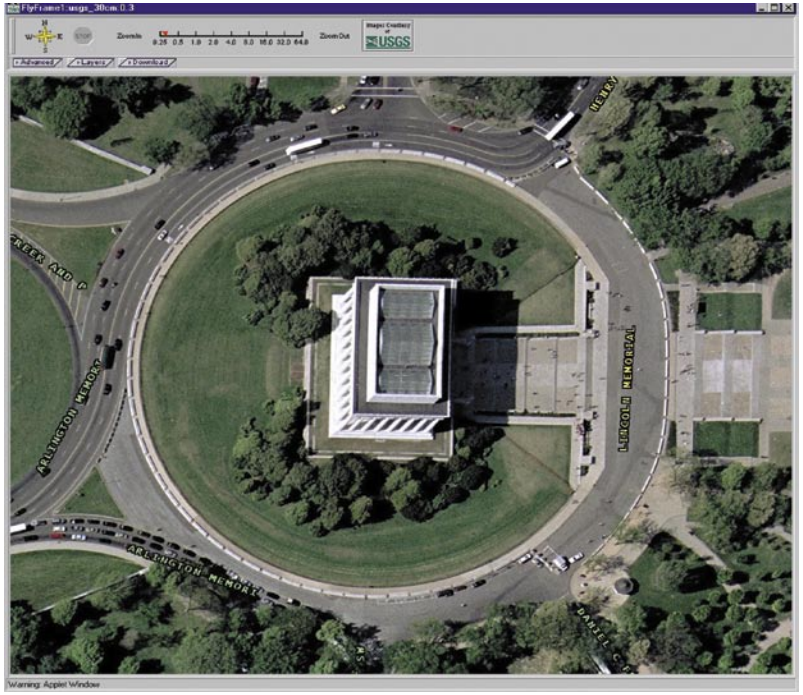
TerraFly—one of the projects to stem from the Goddard/ Florida International University collaboration—makes it possible for users to "fly over" vast areas of land using only an ordinary Web browser. TerraFly does not require the installation or downloading of any specialized geographic information systems software, unlike many other data systems.

The Internet-based technology was developed to make geospatial data more accessible to the average user, with nearly $30 million in funding from NASA, the National Science Foundation, the United States Geological Survey, and private companies such as IBM and Space Imaging. It is currently one of the largest publicly accessible image repositories on the Web, hosting more than 30 terabytes of data, including land, urban, and coastal imagery collected by satellites, aerial photography, and other means of remote sensing.

Whether it is sheer personal interest to navigate the American skies or map-planning for land development or zoning, TerraFly was designed to be a simple and convenient system for users of all levels (by simply typing in a street address or a zip code, one can obtain an overhead view of the desired location). TerraFly's database contains textual, remotely sensed, and graphical data which can be viewed and manipulated using any standard browser. Textual data is available for the description and location of specific areas of interest, while colorful graphical maps aid in the visualization of the data.

In flying over the imagery, the user can see various overlays, including road names, public buildings, and landmarks. The flight pattern over this spatial data is smooth and synchronized, so there are no pauses or interruptions as the user moves from one area to another, using a mouse cursor. "Compass Control" further allows for 360-degree

TerraFly users can enjoy the database system's "flying" capabilities via an ordinary Web browser, without having to install or download specialized geographic information systems software. By simply typing a street address or a zip code into the main page, one can obtain an overhead view of the desired location.



A zoomed-in, overhead view of the Lincoln Memorial in Washington, DC.

control of flight direction and speed. Even more, the user has the option of viewing the data at varying resolutions. For example, one can get close enough to see cars and trucks parked on the streets at 1-meter or better resolution, or far enough to view the land as it actually looks from high above the clouds.

By clicking on a point of interest on the TerraFly map—like a city block—the user can open a new browser window to access more specific information about the selected location, such as latitude and longitude; elevation; demographics (population and census information); number of residential homes; water usage; and proximity to the closest schools, hospitals, businesses, restaurants, and hotels. Much of this information is provided in URL links, so that the individual will only be a click away from retrieving even more information for a point of interest, such as the availability and rating of a hotel or the address and phone number of a restaurant.

All are welcomed to visit the TerraFly Web site and fly free of charge; however, flight time is limited so as not to jam up a network that hosts over 10,000 unique users per day. Florida International University offers monthly and yearly unlimited-flying subscriptions to individuals and organizations that intend to utilize the service more frequently than the casual user. Free subscriptions are available to staff members of TerraFly's government and industrial sponsors, as well as educators involved in NASA's Earth Sciences Program.

TerraFly users also have the option of purchasing images. By dragging the mouse cursor and creating a rectangle around an area of interest, a user can order prints of the marked area. Prints include digital aerial and satellite photos, topographic maps, panoramic posters, and glossy postcards.

With many government and commercial applications, TerraFly is estimated to generate large revenue for Florida International University. In one vertical application of the technology, the service has been tailored to the real estate industry to offer detailed property information and significant time and money savings for subscribers. For example, in just one sitting, real estate agents and their clients can access aerial pictures of properties; sales price history; tax information; property features; neighborhood information; extended demographics that include quality of life and schools with ratings data; and property reports detailing flood zones, hazards, and waste areas.

The Realtor Association of Greater Miami and the Beaches has subscribed its 9,000 members to TerraFly. Custom overlays for the Miami-based realtors include property lines and continuously refreshed multiple listings data.

In the fields of public health and epidemiology, Florida International University intends to draw correlations in lead poisoning cases affecting South Florida by overlaying incidences of lead poisoning, socio-economic data, and census information onto remotely sensed data. The university is aiming to scale the results to other geographic areas susceptible to this hazard.

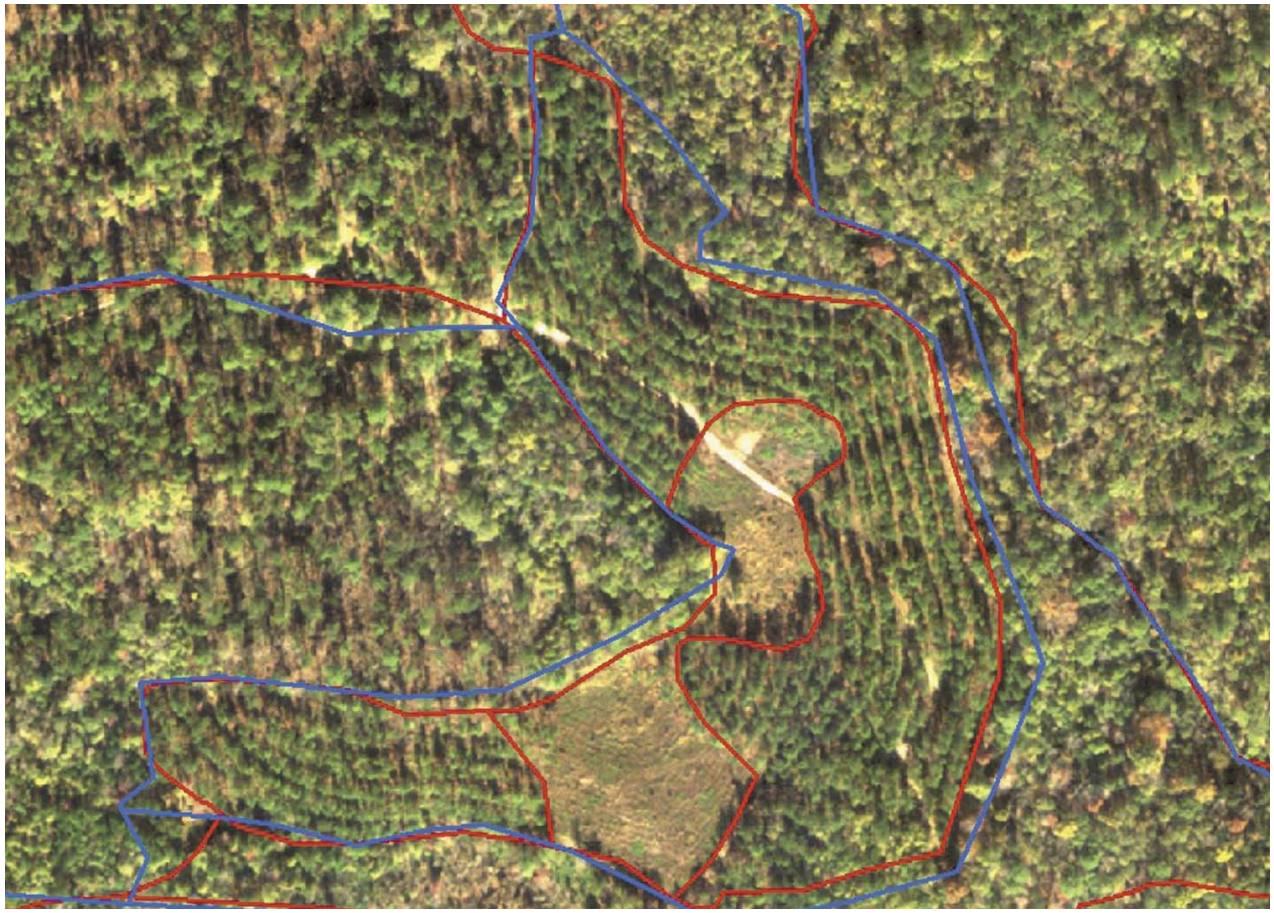
Elsewhere, TerraFly could serve as a valuable tool for government agencies working in the fields of homeland security, environmental protection, forestry, natural resources conservation, U.S. National Parks, and ecology. Visual data for the entire country is available to officials and emergency managers so that they can more effectively plan for, respond to, and mitigate bioterrorism or other man-made or natural disasters.

TREE-MENDOUS TIMBER EVALUATION

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

Funded and administered by NASA, the Affiliated Research Center (ARC) program transfers geospatial technologies from the Space Agency and participating universities to commercial companies, non-profit and trade organizations, and tribal governments. The origins of the ARC program date back to 1988, when NASA's Stennis Space Center initiated the Visiting Investigator Program to bring industry closer to spatial information technologies. The success of this trial program led to an expansion into the ARC program, whose goal is to enhance competitiveness of U.S. industries through more efficient use of remote sensing and related technologies.

NASA's ARC program served as the foundation for the development of International Hardwood Resources, which then grew into Falcon Informatics with the acquisition of a technology from a European software company and a change of business models. Doylestown, Pennsylvania-based Falcon Informatics is now a world-leading information services company that combines in-depth timber industry experience with state-of-the-art software to serve the needs of national governments, international paper companies, and timber-investment management organizations.



PARTNERSHIP

In 1997, Adam Rousselle founded International Hardwood Resources as a log-exporting and consulting company. Not long after, Rousselle found that it had become exceedingly difficult to find high-value pockets of timber (also known as timber "stands") to supply his company, so he decided to investigate the possibility of locating hardwoods through remote sensing. Essentially, Rousselle was looking to locate and purchase greater quantities of privately owned standing timber, because alternative sources—such as buying timber from auctions or other consultants—were prohibitively expensive. By locating, identifying, and evaluating trees through automatic interpretation of remote images, such as aerial photographs, Rousselle hoped to reduce the cost of pinpointing timber stands and increase the amount of cheaper, internally-sourced timber.

As a veteran of the Gulf War with experience in counter-intelligence, Rousselle was very familiar with the advances of satellite surveillance and high-resolution photography. This led him to NASA, where he learned about opportunities available through the ARC program. NASA granted him a research contract to perform a feasibility study to determine whether there would be potential for his concept to become commercially viable. The study was carried out at the School of Environmental Science at the State University of New York (SUNY), Syracuse, with guidance from the late Dr. Paul Hopkins, former director of the ARC program at this institution.

Boundaries are corrected by Falcon Informatics' automated image analysis (before and after; the blue lines represent the customer's boundary lines, established by conventional surveying techniques, and the red lines represent Falcon Informatics' corrected boundary lines).

During the research, Rousselle, Hopkins, and the ARC investigation team utilized Landsat Thematic Mapper imagery (30-meter ground sample distance) in a preliminary classification to define hardwood forest areas in the Allegheny Forest region of northwestern Pennsylvania. These regions were then classified to a higher level using Airborne Terrestrial Applications Sensor imagery (2.5-meter ground sample distance). Spatial analytical methods resident within a geographic information system were then added to the mix to define areas where logging might have been limited in the past due to the areas' high slopes. The remote sensing analyses were combined in the attempt to highlight areas that had a higher potential to contain valuable lumber.

The NASA-supported study at SUNY yielded encouraging results, showing that International Hardwood Resources could identify high-value hardwood trees using remote sensing, while additionally reducing environmental degradation by decreasing unnecessary logging and increasing the use of low-impact, selective harvesting techniques, such as helicopter logging. The company concluded from this project that it should invest time and capital in the development of a deductive logic system that renders an approximate value of a given timber stand, based on customer needs.

PRODUCT OUTCOME

In developing the logic system, Rousselle identified a "tremendous" opportunity to expedite the time-consuming task of manually interpreting the remotely sensed images. This occurred in June 2001, when Rousselle visited a Finnish company that developed a software application to detect individual tree crowns in aerial photography. The company was willing to sell the software to him because it had "never fully leveraged" its capabilities. Rousselle acquired the software and hired a software team to integrate it into the system that would be the nucleus of his revolutionary remote-sensing service. With the successive hiring of expert foresters and geographic information system (GIS) pros, Falcon Informatics was born.

Without ever setting foot in a forest, paper companies, real estate investors, government agencies, public forest managers, and many other entities can improve the accuracy and usability of GIS data through Falcon Informatics' services. In combination with traditional ground-sampling, Falcon Informatics can rapidly collect a wealth of timber inventory and management data. The company's innovative timber assessment services are based on the Forest Assessment and Classification Tool (FACT) software that automatically interprets aerial photography and satellite imagery, unlike the costly and arduous manual efforts of old. FACT enables Falcon Informatics to count and analyze each individual tree—hardwood or softwood—anywhere in the world. The process begins when the company flies over a selected geographic area, capturing a comprehensive, "bird's-eye" view of the landscape. FACT then performs an in-depth analysis of the captured imagery to identify viable timber stands and measure ground-sampled trees. The data resulting from this analysis are used to calculate the composition and volume of timber in the selected area.

Falcon Informatics' systematic approach eliminates many opportunities for human error and produces consistent and reliable results. The company can even correct existing, manually generated timber stand boundaries to reflect the correct geographic position. These services provide instant return on investment by improving the quality of the timber-management information, thereby accelerating the ability of forest managers to optimize growth and yield. Forestry teams can avoid costly mistakes and concentrate on improving productivity instead of spending wasteful hours trying to redefine forests.

"Foresters have studied the relationship between crown size and volume for a long time," Rousselle explains. "However, historically there has been no way to take advantage of this relationship. FACT makes this possible by allowing consistent crown measurements on a larger scale."

From an environmental standpoint, FACT helps to define stand-level health statistics, mitigate the threat of wildfires, and monitor the impact of insects and disease. Also, the proprietary tool can identify and document environmentally sensitive areas like Riparian buffers—areas of forested land adjacent to a stream, river, marsh, or shoreline which form the transition between land and water environments. Riparian buffers play an important role in maintaining the health of these waters by improving water quality and providing habitats for wildlife and fish.

In 2003, Falcon Informatics received contracts with the U.S. Army's Fort Benning, Georgia, and Fort A.P. Hill, Virginia, to deliver timber inventory and GIS data on over 250,000 acres of military base forestland, using FACT. The forest resource manager at Fort Benning was first introduced to Falcon Informatics' services in 2002 when Rousselle spoke to the committee of U.S. Department of Defense foresters at the Society of American Foresters' annual convention. "When I saw the work they were doing in other countries and here in the United States for several private companies, I was eager to learn more about how we could take advantage of it," the forest resource manager noted, adding that most people are not aware of how critical forest health is to the training and preparedness of U.S. soldiers.

Falcon Informatics has also formed strategic partnerships with several companies in order to create a larger pool of certified FACT users. Partners include Dendron Resource Surveys Inc., one of Canada's leading forestry consulting companies, and Emerge, a subsidiary of ConAgra, Inc., that supplies high-quality, digital, orthorectified, mosaic imagery products. The partnerships are focused on worldwide dissemination of Falcon Informatics' innovative hardwood and softwood analysis services.

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

In 1992, NASA and the U.S. Department of Defense jointly commissioned the research and development of a technology solution to address the challenges and requirements of communicating with their spacecraft. The project yielded an international consortium composed of representatives from the space science community, industry, and academia. This group of experts developed a broad suite of protocols specifically designed for space-based communications, known today as Space Communications Protocol Standards (SCPS). Having been internationally standardized by the Consultative Committee on Space Data Systems and the International Standards Organization, SCPS is distributed as open source technology by NASA's Jet Propulsion Laboratory (JPL). The protocols are used for every national space mission that takes place today.

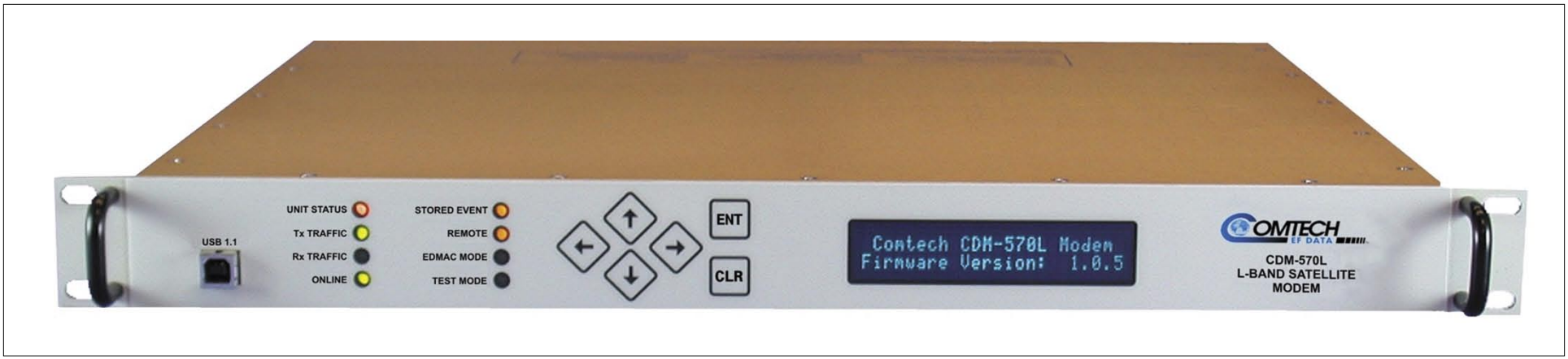
PARTNERSHIP

Engineers from Global Science & Technology, Inc. (GST), of Greenbelt, Maryland, were the principal developers of the SCPS suite of protocols. The company's chief engineer was the lead architect for the SCPS transport protocol, and GST personnel authored the SCPS Rationale Green Book. Many of the company's protocol engineers played integral roles in early SCPS development, including some of the first testing and operational deployments of the technology. Today, GST represents NASA at the Consultative Committee on Space Data Systems, and leads several international space networking consortia, including the Interplanetary Networking Research Group.

It was a natural extension of GST's business to take its SCPS research and development effort and transfer it into the commercial satellite and wireless markets. In 2000, the company began commercializing the transport protocol component of the SCPS suite. The development of this transport protocol was funded by NASA's Goddard Space Flight Center at the start of the original research and development project. This funding was critical in defining the need for the technology, crafting the specification for the protocol, and building the reference implementation that served as the blueprint for what eventually would become SkipWare,® the commercial implementation of the SCPS transport protocol.

While no formal technology transfer partnership between GST and NASA was necessary for the company's commercialization efforts, GST alerted all the relevant parties within NASA of its intentions to productize SCPS, and kept them apprised of its progress as the technology went to market. Recognizing GST's unique lineage with the technology, NASA showed great support for the company's intention to commercialize SCPS, and continues to support its efforts as the technology expands into new products and markets.

Today, NASA funds the maintenance of the SCPS reference implementation (an open-source blueprint of the code on which SkipWare is loosely based) through JPL, which serves to promote the SCPS technology within both the Federal technology sector and the commercial wireless market. Both JPL and Goddard generally promote SCPS within the space community, and wherever appropriate, will direct potential customers interested in the SCPS technology to GST and the SkipWare line. The company continues to work closely with interested parties at Goddard to keep them informed of SkipWare releases, new product features, and new market applications of the technology. GST also actively solicits input from NASA



Comtech EF Data, a satellite products company, distributes SkipWare® as an embedded service on its hardware platforms.

Comtech EF Data's *turbo*IP™ is the primary hardware platform bearing SkipWare® software.

regarding future requirements for space networking and how it can best develop its technology to meet the needs of the space community. The company maintains an ongoing dialogue with the space networking experts within NASA, and this affiliation promises to help promote and advance the SkipWare product.

PRODUCT OUTCOME

Global Protocols, Inc., an independent company spun off from GST for the purposes of commercializing its wireless protocol line, distributes SkipWare as a software license and as an embedded service on the hardware platforms of its partner, Comtech EF Data, a satellite products company based in Tempe, Arizona. SkipWare mitigates or eliminates the obstacles associated with wireless and satellite transport and provides efficient, reliable transmission over these media. Global Protocols has sold the technology to customers operating in the satellite, terrestrial wireless, and wireless telemetry markets, and its customer base includes major wireless Internet Service Providers both domestically and internationally, as well as every U.S. military branch.

Since being adopted as the military standard for stressed wireless networking, sales of SkipWare-enabled platforms in the military wireless market have increased substantially. The primary hardware platform bearing SkipWare is *turbo*IP,™ a rackmount accelerator manufactured and distributed by Comtech EF Data. Developed through a collaborative partnership between Global Protocols and Comtech EF Data, *turbo*IP represents a technology breakthrough in Internet-over-satellite platforms, combining high performance with open standards and network interoperability. These platforms sell at a rate of approximately 100 units per month, and generate significant support and engineering services revenues after each sale.

Offering both router mode and abridged mode (EasyConnect™), *turbo*IP provides unprecedented ease-of-installation while reducing maintenance (training) costs. Network availability is enhanced with *turbo*IP by addressing the single-point-of-failure issue using fail-to-wire technology. This technology ensures network connectivity in the event of any *turbo*IP failure including loss of power. Global Protocols and Comtech EF Data are continuing collaborative efforts and will, later this year, offer increased high-end features including Lempel-Ziv datagram compression and Selective Acceleration (patent pending).

Global Protocols has increased its engineering staff to meet the demand for its protocol engineering and integration services, and expects to continue to grow this business as new wireless media markets prosper. Having defined protocol engineering as a marketable service and having established SCPS as the standard in wireless data transport, several other companies have entered the market. Due in large part to NASA Goddard's vision and its forecasts for the need of high-performance protocols in wireless media, a new and prosperous business line is forming within the wireless communications market.

SkipWare® is a registered trademark of Global Protocols, Inc.

EasyConnect™ and *turbo*IP™ are trademarks of Comtech EF Data.

Selective Acceleration is patent pending Comtech EF Data.

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

In early 1995, NASA's Glenn Research Center (then Lewis Research Center) formed an industry-government team with several jet engine companies to develop the National Combustion Code (NCC), which would help aerospace engineers solve complex aerodynamics and combustion problems in gas turbine, rocket, and hypersonic engines. The original development team consisted of Allison Engine Company (now Rolls-Royce Allison), CFD Research Corporation, GE Aircraft Engines, Pratt and Whitney, and NASA. After the baseline beta version was established in July 1998, the team focused its efforts on consolidation, streamlining, and integration, as well as enhancement, evaluation, validation, and application. These activities, mainly conducted at NASA Glenn, led to the completion of NCC version 1.0 in October 2000.

NCC version 1.0 features high-fidelity representation of complex geometry, advanced models for two-phase turbulent combustion, and massively parallel computing. Researchers and engineers at Glenn have been using NCC to provide analysis and design support for various aerospace propulsion technology development projects. NASA transfers NCC technology to external customers using non-exclusive Space Act Agreements. Glenn researchers also communicate research and development results derived from NCC's further development through publications and special sessions at technical conferences.

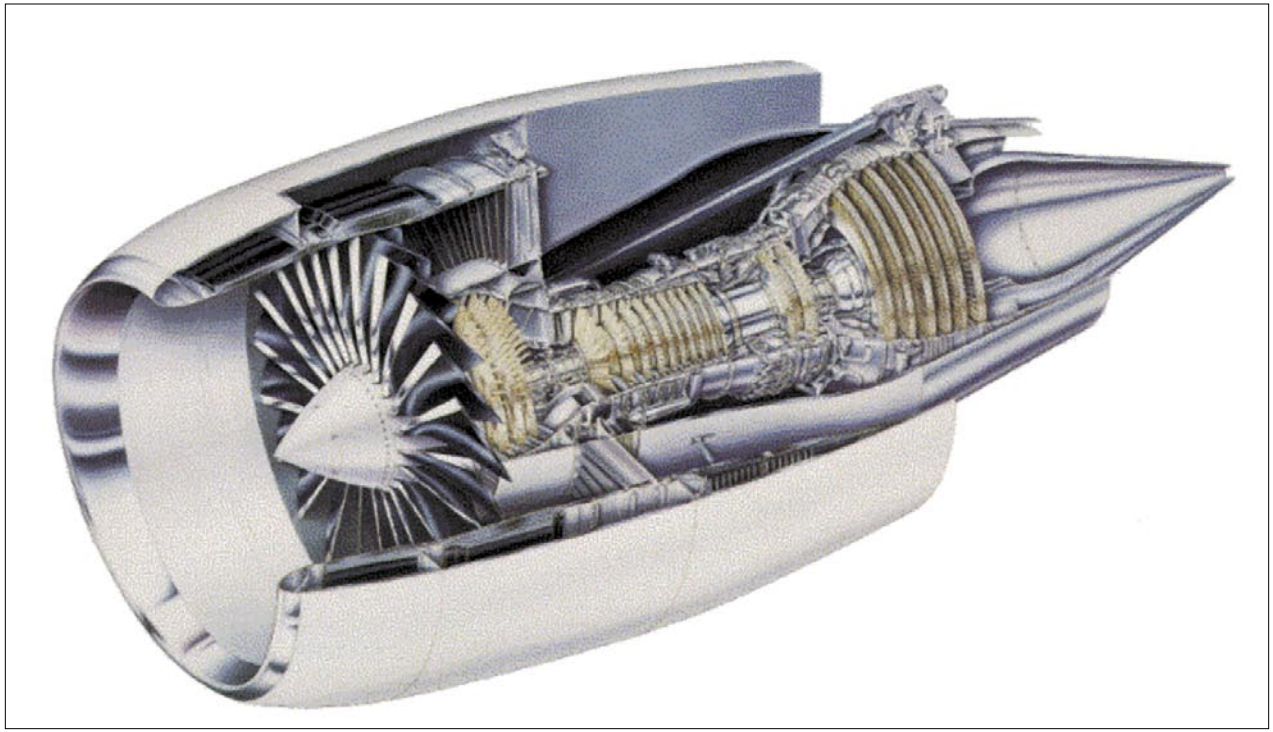
PARTNERSHIP

A Space Act Agreement between Glenn and Flow Parametrics, LLC, enabled the New Castle, Delaware-based company to commercialize the NCC. Engineers from Glenn's NCC team provided Flow Parametrics with technical support in accordance with the Space Act Agreement as the company developed its product, the FPVortex™ Computational Fluid Dynamics (CFD) Flow Solver. FPVortex particularly benefited from NASA's research efforts in the computation and simulation of propulsion system flow fields. Through the terms of the Space Act Agreement, the company's combustion and modeling engineers continue to frequently exchange technology and modeling ideas with Glenn's team, further improving the code.

PRODUCT OUTCOME

FPVortex provides design engineers and scientists with a detailed understanding of complex flow fields, leading to design and performance improvements in many types of flow devices. Flow Parametrics originally developed FPVortex to solve the flow fields in gas turbine fuel nozzles, combustors, diffusers, and augmentors. Due to the inherent geometric complexity of such devices, it was necessary to closely couple the flow solver with the types of geometry representations exported by computer-aided design, and to utilize the output of grid generators formerly used in the finite-element analysis field.

After this was completed, the company soon realized that the FPVortex code could be applied to a very wide range of flow problems, from low-speed laminar flows to hypersonic turbulent flows with chemical reactions, including liquid spray droplet tracking, evaporation, mixing, and combustion. Engineers added advanced numerical simulation methods to speed up the code execution, including parallel processing over networked computer processing units and a versatile grid adaption strategy for mesh refinement based on flow variable



FPVortex™ solves complex aerodynamics and combustion problems in engines.

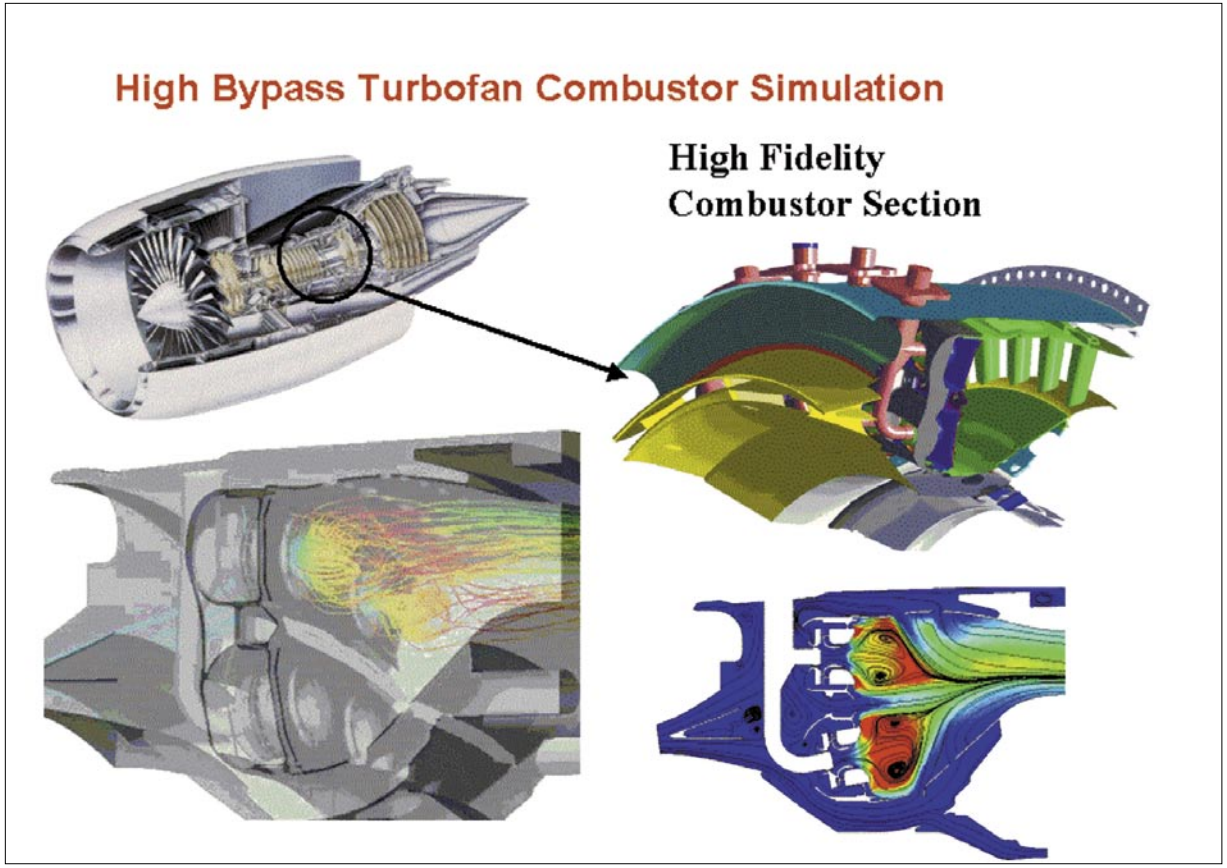
gradients, and near-wall grid clustering for improved resolution of boundary layers and heat transfer effects.

With the successful development of FPVortex, Flow Parametrics met its goal of providing a state-of-the-art computational combustion dynamics capability that meets designer requirements for geometric model accuracy, turn-around time for cases, and solution accuracy. While the product is targeted at PC computing hardware, UNIX versions of the code can be made available for special purposes. The code is easily coupled with commercially available pre- and post-processing tools, which together form a cost-effective solution to complex, large-scale flow simulation problems.

FPVortex has been successfully applied to design problems in the aerospace propulsion, automotive, and land-based power generation industries. In addition to solving complex aerodynamics and combustion problems in engines, FPVortex's applications extend to other market sector areas such as heat exchangers, particle separation machinery, land speed record vehicles, and medical devices, to name just a few. The code is being applied routinely in design analysis and optimization studies, as its capabilities continue to expand. New modeling capabilities include advanced finite-rate chemistry for hydrocarbon fuels, conjugate heat transfer for solving solid boundary temperature distributions, and automated liquid fuel spray cone parameter specifications. An increasingly popular use of the code is for unsteady flow analysis and design-oriented studies of pollutant emissions formation and transport.

FPVortex is available in executable form, under license from Flow Parametrics. The company provides full turn-key solutions for CFD-code application, including training in the use of its software, and has the flexibility to tailor FPVortex's use to specific applications, providing expert engineering consulting services to industry for advanced projects.

FPVortex™ is a trademark of Flow Parametrics, LLC.



By providing design engineers with a detailed understanding of complex flow fields, FPVortex™ facilitates design and performance improvements in many types of flow devices.

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

Ever wonder whether a still shot from a home video could serve as a "picture perfect" photograph worthy of being framed and proudly displayed on the mantle? Wonder no more.

A critical imaging code used to enhance video footage taken from spaceborne imaging instruments is now available within a portable photography tool capable of producing an optimized, high-resolution image from multiple video frames.

PARTNERSHIP

RedHawk Vision, Inc., a Costa Mesa, California-based subsidiary of Irvine Sensors Corporation, developed the "Real-Time Self-Contained Image-Motion Compensation for Spaceborne Imaging Instruments" algorithm with assistance from NASA's Marshall Space Flight Center under Phase I (1992) and Phase II (1998) **Small Business Innovation Research (SBIR)** contracts. By calculating the movement of a scene and then repositioning it back to the original position, the algorithm allows NASA to zoom and stabilize video footage without loss of detail, extract photo-quality still images, and even salvage dark, blurry, and jumbled video that is otherwise unusable. RedHawk Vision went on to complete another series of SBIR contracts with the U.S. Air Force, further advancing the video-to-photo software in preparation for commercialization.

Released to the public in 2000, RedHawk Vision's Video Pics™ was the first product to evolve from the NASA and U.S. Air Force collaborations. Video Pics demonstrated the capability to successfully extract 35-millimeter-quality photographs from continuous video and produce digital files compatible with image-editing software.

As the millennium progressed, so did digital technology, prompting RedHawk Vision to create a new line of video-to-photo software that could convert higher frame-rate video into optimal image prints.

PRODUCT OUTCOME

The new Paparazzi™ stand-alone video-to-photo processing software generates clear, high-quality images (300 dots per inch) from noisy, grainy streaming video, much in the same way that the human brain "sees" video content: scene by scene. Paparazzi takes the best parts of multiple frames of video and overlays them to create an image of superior quality in less than 10 seconds, unlike a frame-grabber, which extracts images from only a single video frame and at a much slower rate. As a result, Paparazzi catches extra details unattainable when using a frame-grabber, such as the exact time displayed on a wristwatch being worn by an individual in motion in a video.

In addition to combining video frames, Paparazzi adjusts pixel aspect ratio and corrects color. Controls for brightness, contrast, saturation, and hue let users fine-tune lighting as they would with any type of photo-editing software. Other features include zooming and cropping, optimized black & white processing, noise reduction, and 16:9 video

Stored on a "distribution unit" the size of an index finger, Paparazzi™ software generates clear, high-quality images from noisy, grainy streaming video.

support (16:9 is considered the new "standard" for digital television broadcasts).

The Paparazzi software and its supporting files are supplied on a Universal Serial Bus (USB) Flash drive "distribution unit" the size of an index finger, allowing for quick and easy transport of print-ready images between computer systems. To access the software, the user simply plugs the distribution unit into a computer's powered USB port and double-clicks on the associated icon in the drive's window. Paparazzi processes all video files that play on personal computers via the Apple QuickTime® downloadable media player.

In 2003, Paparazzi saved the day in a "one off" situation where a wedding photographer failed to make it to the church for a wedding ceremony. Brian Coe, the owner of an events videography firm just outside of Paris, France, named SQYnet Productions, purchased the video-to-photo software in order to supply stills to a "tearful bride" who inquired whether photos could be extracted from her wedding video. With Paparazzi, Coe was able to extract 40 high-quality photos from the video to satisfy the customer's request. SQYnet Productions has since incorporated Paparazzi images as an option for some of its standard wedding packages, leading to increased revenues for the company. With Paparazzi retailing at $279, Coe is happy to report that the software technology has already paid for itself.

Other applications for the technology include forensics, where crime investigators can use the software to decipher clues potentially caught on nighttime surveillance tapes, as well as astronomy, where astronomers can obtain sharp, distortion-free images with a combination of video recorder and a telescope.

Video Pics™ and Paparazzi™ are trademarks of RedHawk Vision, Inc.

QuickTime® is a registered trademark of Apple Computer, Inc.

Paparazzi™ locks on the subject above and combines multiple frames to capture video movement and excitement in precision still images. Other sports enthusiasts, such as the parachuter on the right, use the video-to-photo software to capture exciting action images.

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

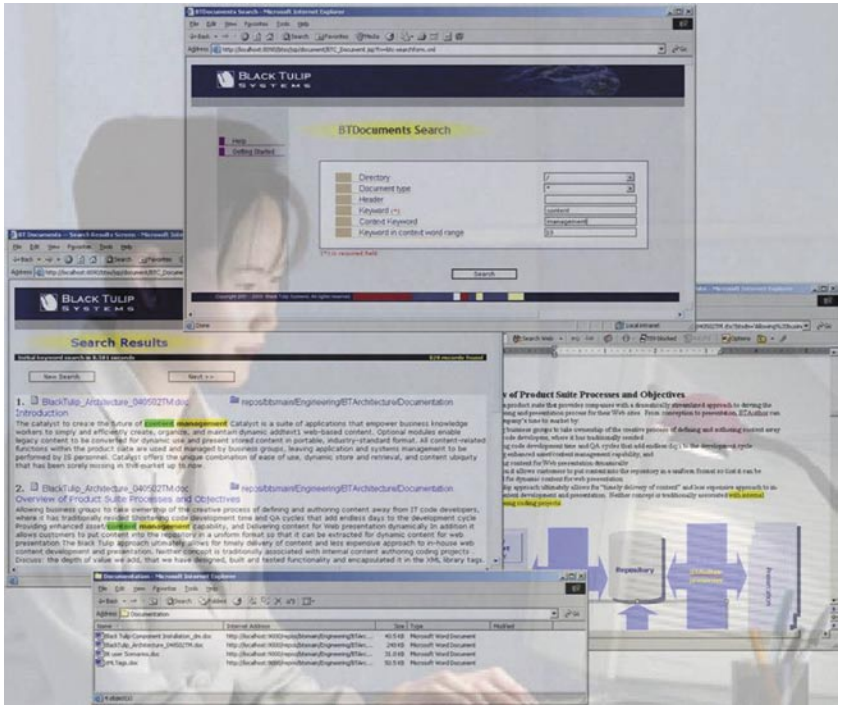
NASA software created to help scientists expeditiously search and organize their research documents is now aiding compliance personnel, law enforcement investigators, and the general public in their efforts to search, store, manage, and retrieve documents more efficiently.

Developed at Ames Research Center, NETMARK software was designed to manipulate vast amounts of unstructured and semi-structured NASA documents. NETMARK is both a relational and object-oriented technology built on an Oracle® enterprise-wide database. To ensure easy user access, Ames constructed NETMARK as a Web-enabled platform utilizing the latest in Internet technology. One of the significant benefits of the program was its ability to store and manage mission-critical data.

PARTNERSHIP

Black Tulip Systems Corporation, of San Jose, California, was given the opportunity to preview the NETMARK software in November 2002. Right away, the company knew that the NASA-developed technology would be the perfect complement to its current product offerings. The addition of the NETMARK technology could allow the company to grow the business and access a much larger unstructured document market.

Ames subsequently licensed the NETMARK software to Black Tulip Systems to make the tool available to people and organizations that need rapid searching of computer networks and systems. Black Tulip Systems has since enhanced NETMARK by adding more robust search tools and user-friendly interfaces, and by speeding up the processing time. "For non-technical users, the ease-of-use and increased speed will bring important evaluations to a faster conclusion," notes Black Tulip Systems' President and Chief Executive Officer Ted Munnich.



A NASA program that allows for rapid searching of computer networks and systems is the basis for BTDocuments,© a document index and search platform designed to convert unstructured and semi-structured documents into useful and easily accessed information.

PRODUCT OUTCOME

With the integration of NETMARK with Black Tulip Systems' existing document-processing practices, the company is bringing ownership back to content contributors by reducing the technology- and process-related complexities associated with retrieval and authoring. The outcome is being marketed as BTDocuments,© a revolutionary document index and search platform designed to convert unstructured and semi-structured documents into useful and easily accessed information. Indexed documents can be searched by keyword, keyword in context, and document type. Proximity and Boolean searches are built-in features of the search engine.

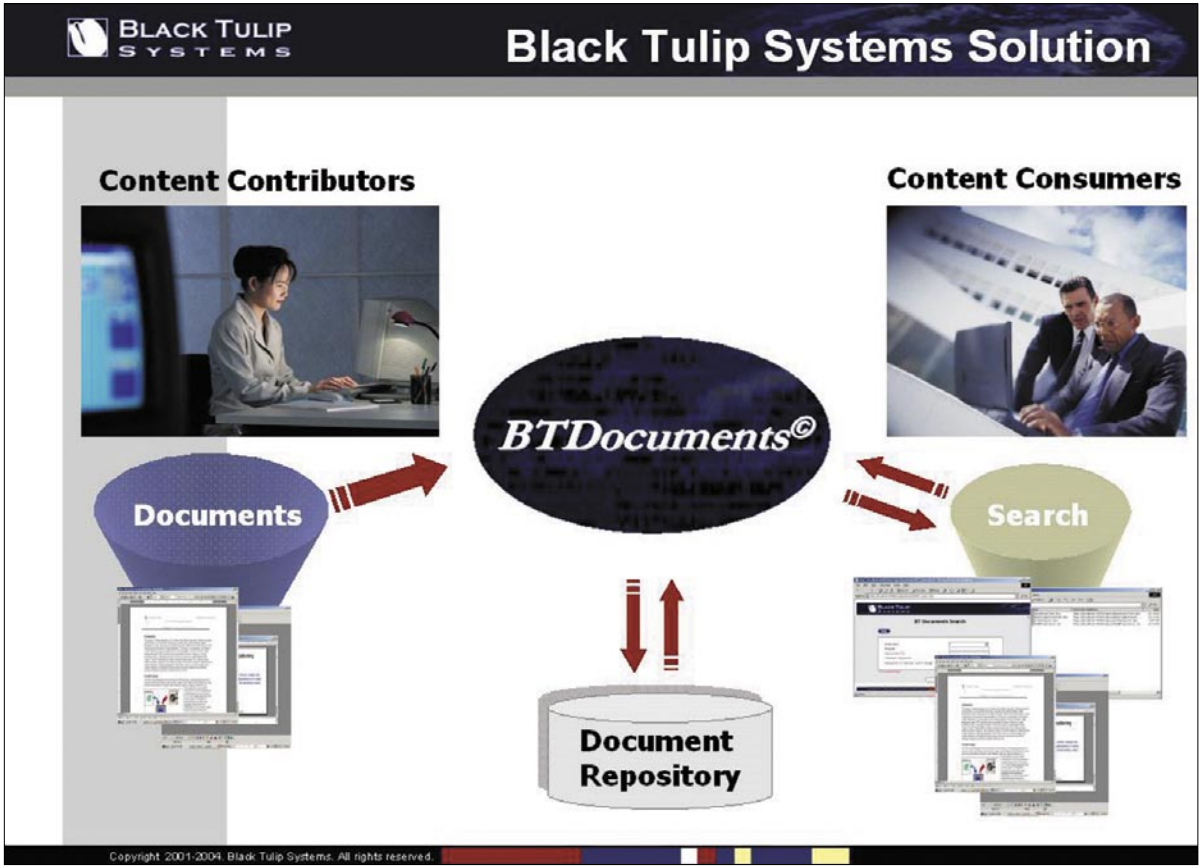
BTDocuments encompasses four key features that make document retrieval practical. The first feature "Sophisticated Search and Indexing" permits BTDocuments to search on anything from sections, titles, and headings to search strings, within locally stored documents. The second feature "Flexible Document Collection" lets BTDocuments support the most popular Microsoft® Office applications, like Word, Excel, and PowerPoint, as well as many other document formats. The third feature "Direct Navigation" lets users jump from the Web pages straight into the document, right to the paragraph they want. The fourth feature "Automated Target Document Assembly" allows BTDocuments to generate a new document from a search result set and store that document for future use.

As a business or document application grows, users can easily move from the desktop, to a network, and then all the way up to an enterprise with three scaleable versions of BTDocuments that are platform and database independent. For instance, a small professional group that starts out with one or two consultants or lawyers can easily maintain their document system and grow this system as their business grows.

A feature called BTEngine© is the underlying technology on which BTDocuments is built. BTEngine processes business logic combined with user-interface stored in eXtensible Markup Language (XML) files to present end-users' standard screens, represented as entry screens or result pages, ensuring accurate content storage and easy integration into the customer environments.

Also built on BTEngine, the BTAuthor© tool allows authors to create and store new content using native desktop authoring tools such as Word, so that their current processes or work environment are not interrupted. The authors are also capable of converting legacy documents of any type and format into useful knowledge bases.

Employing a unique approach called application encapsulation, BTAuthor enables business users across any enterprise to create and manage their own content in a small fraction of the time possible with existing Enterprise Content Management (ECM) technology, and without information technology (IT) involvement. According to Black Tulip Systems, ECM products have primarily concentrated on data storage and presentation. The company added that the content-authoring functionality provided by these products involves the use of programming or scripting languages such as Java,™ Practical Extraction and Reporting Language (Perl), or tool command language (TCL) to create authoring applications. This activity requires IT development to produce the content-authoring interfaces. Black Tulip Systems notes that a separate authoring interface is required for each type of content authored, with each taking an IT department about 5 days to design, code, and test. The company, which has whittled this time down to a matter of minutes with the Black Tulip "Solution Suite," asserts that the complexity behind this interface-production process leaves the enterprise "in the unenviable position of spending significant capital per year supporting content contributors on a recurring basis."



BTAuthor,© enables business users to create and manage their own content in a small fraction of the time possible with existing Enterprise Content Management technology, and without involvement from the information technology department.

"Existing solutions essentially remove the author's ownership and creativity and place these activities in the IT department's hands," according to Munnich. "This transfer results in a skills mismatch within a group not chartered or staffed to ensure quality for a wide range of content delivery media, including the organization's most visible symbol, its Web site."

Black Tulip Systems' solutions have proven to substantially improve productivity. The company has keyed in on publishing and public relations firms, health care providers, insurance groups, law enforcement offices, educational institutions, and government entities as valued customers. The simplicity and cost-effectiveness of the software has made it a welcomed addition for general users, as well.

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Microsoft® is a registered trademark of Microsoft Corporation.

Java™ is a trademark of Sun Microsystems, Inc.

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

I/NET, Inc., is making the dream of natural human-computer conversation a practical reality. Through a combination of advanced artificial intelligence research and practical software design, I/NET has taken the complexity out of developing advanced, natural language interfaces. Conversational capabilities like pronoun resolution, anaphora and ellipsis processing, and dialog management that were once available only in the laboratory can now be brought to any application with any speech recognition system using I/NET's conversational engine middleware.

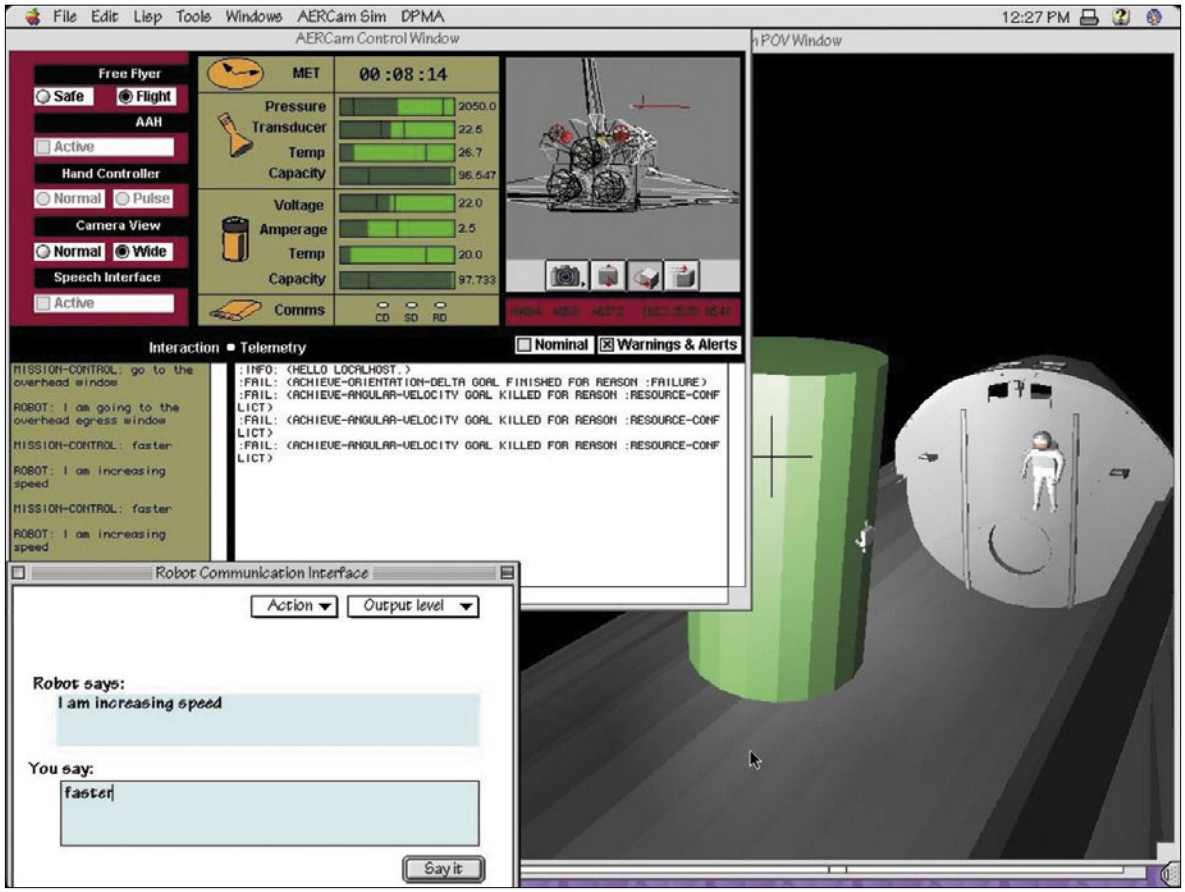
The conversational interface technology allows people to control computers and other electronic devices by speaking everyday natural language. Unlike voice recognition systems that substitute sounds for isolated commands, a conversational interface system enables extended conversations with a shared, changing context. For example, while driving, a person might ask the car, "What song is playing?" When the car responds with the name of the song on the CD player, the driver might say, "Turn it up." The car needs to infer that "it" means the volume of the CD player even though the CD player has not been explicitly mentioned. If the driver then says, "That's too much," the car needs to realize that its volume adjustment was too large and it should be turned down a bit.

PARTNERSHIP

In 1995, Dr. R. James Firby's work on robot control and natural language at the University of Chicago attracted the attention of Jon Ericson, a NASA engineer working on the Extra Vehicular Activity (EVA) Retriever project at Johnson Space Center. The next year, Johnson granted Neodesic Corporation, the company Firby cofounded, a **Small Business Innovation Research (SBIR)** contract to build a natural language system for robotic assistants in space.

Neodesic developed the Dynamic Predictive Memory Architecture (DPMA) system, which was used experimentally in conjunction with NASA's Advanced Life Support System Water Recycling project after the EVA Retriever project was cancelled. In 2001, Neodesic sold the language technology to I/NET, Inc., of Kalamazoo, Michigan. Firby and several of his Neodesic colleagues joined I/NET, and NASA Johnson granted the company an SBIR contract to further develop the conversational interface technology. Under this contract, I/NET worked to make the DPMA system easier to use and enable it to run on small systems such as hand-held pocket digital assistants.

In order to make the DPMA technology more readily accessible to software developers, I/NET is developing a suite of Conversational Interface Domains (CIDs). Programmers need a system that hides difficult language issues like inferring pronoun references, managing conversational context,



I/NET, Inc.'s conversational interface technology emerged from an effort to build a natural language system for robotic assistants in space.

and creating dynamic dialogues. Each CID is a prebuilt library that handles these complex processes automatically in a specific domain. Programmers describe their systems' functions and terminology with simple, declarative forms and the CID library manages context, inference, and dialog creation to allow users to carry on natural language conversations with the system. Two CIDs with wide applicability are the Device Control CID and the Messaging CID. The Device Control CID is perfect for building conversational interfaces for systems made up of devices and properties. Examples of these include: automobile controls, stereo systems, life-support systems, machine tools, and robotic systems. The Messaging CID is tailored to systems that manage collections of messages such as alarms, e-mail, or checklists.

For example, if a heating, ventilation, and air conditioning (HVAC) automation supplier wants to add a conversational interface to an environmental control room, the Device Control CID can be readily adapted to control environmental components. The specific details about the HVAC machines need to be supplied by the developer, but the language for turning them on and off and adjusting parameters are already encoded in the library.

Similarly, the Device Control CID can be used in automotive environments, where its wide language scope enables drivers and passengers to use varied forms of the same request, such as "Turn down the volume," "Turn the volume down," "Turn down the sound," and even "It's too loud!" The library also manages context and extended dialogues to help the system understand driver requests. For example, if the driver asks the car to "Turn on the seat warmer," the CID library does a number of things. First, it checks to see which seat warmer the driver might mean. This check can take into account external context such as which seat warmers have people sitting on them and which seat warmers are already on, as well as conversational context such as whether the driver was just talking about a specific seat warmer. If the library cannot infer a specific seat warmer, then it will ask the driver which seat warmer to turn on. The driver might respond with a phrase like "The driver's" or "Mine." The library then has to infer that the driver means the driver's side seat warmer.

PRODUCT OUTCOME

I/NET has commercialized its conversational technology and CID libraries for incorporation into a wide variety of systems. The Embedded Conversational Interface (CI) Toolkit and Converse Server serve as complimentary development platforms for clients to incorporate the conversational interface technology into their own products.

The CI Toolkit is written in Java™ for embedded systems such as hand-held devices and cell phones. Initially designed for the automotive telematics market, it supports all I/NET CID libraries in a very small package. The CI Toolkit was recently licensed by a company building accessible systems for the handicapped.

I/NET's Converse Server is designed for a wide variety of computers running a number of different operating systems, and it supports many more interface options. Converse Server enables natural language applications to be deployed through Web browsers, instant messenger, wireless Web, telephone, text messaging, and custom application interfaces.

I/NET has also built its own products that use the CID libraries. The Phone Automation Manager (PAM) is an application for interacting with remote, automated systems over the telephone. It has found wide application in factory and machine tool monitoring. When a factory system issues an alarm, PAM can call a maintenance technician on the phone and explain the problem. The technician can then work with PAM using plain English to ask for more details about the alarm, check on the system status, and reset machinery if necessary without needing to come to the factory first. By working through PAM, a technician can be on call without leaving home, increasing the individual worker's flexibility and decreasing the company's staffing needs. PAM can also be customized to support additional requests—even to provide warehouse, stock, and order information. Thus, PAM can be used as a management tool as well as a maintenance assistant. The system was recently tested at an auto parts factory in Tennessee during a crucial maintenance period and received rave reviews.

As increasing computational power allows embedded devices to grow smaller and more powerful, it also allows voice recognition to become more reliable. I/NET believes that conversational interfaces are perfect for controlling embedded devices because they require no display and, when well crafted, help the user discover and take full advantage of each device's capabilities. I/NET's CID libraries offer powerful, easy-to-implement building blocks for constructing modular, user-friendly, conversational interfaces. I/NET is putting advanced interface technology to work today.

Java™ is a trademark of Sun Microsystems, Inc.

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

In 1984, researchers from Ames Research Center came together to develop advanced human interfaces for NASA's teleoperations that would come to be known as "virtual reality." The basis of the work theorized that if the sensory interfaces met a certain threshold and sufficiently supported each other, then the operator would feel present in the remote/synthetic environment, rather than present in their physical location.

Twenty years later, this prolific research continues to pay dividends to society in the form of cutting-edge virtual reality products, such as an interactive audio simulation system.

PARTNERSHIP

Throughout the 1990s, virtual reality technology was applied to multiple areas, from video games to military equipment. William Chapin founded AuSIM, Inc., in 1998 to develop three-dimensional (3-D) audio products for mission-critical applications, such as those originally proposed by NASA.

Prior to launching his Mountain View, California-based company, Chapin joined NASA partners and researchers to develop several iterations of increasingly more-detailed, physically-based acoustic room simulation models. Over a 4-year period, they would develop three successively more accurate models of acoustic simulation.

When AuSIM came to be in 1998, Chapin would further fortify his ties with NASA. Dr. Stephen Ellis, a member of Ames' Human Information Processing Branch, was conducting research on perceptual issues relating to latency in visual displays, along with Dr. Dov Adelstein and Dr. Elizabeth Wenzel—one of the NASA researchers who helped to develop the original virtual reality interfaces for Ames. AuSIM assisted Ellis, Adelstein, and Wenzel by integrating aural and visual displays so the three could study the inter-relationship of latency. Ames contracted with AuSIM to provide the synchronization control in the aural and visual display systems. This work would lead to a series of annually renewed contracts between Ames and AuSIM.

Meanwhile, across the country at NASA's Langley Research Center, Dr. Stephen Rizzi of the Structural Acoustics Branch needed an auralization architecture on which he could develop his own models. Rizzi and AuSIM collaborated to make a version of the company's technology in which sub-models could be replaced with a "plug-in" design. This "open kernel architecture" collaboration continues through 2004, with support from Phase I and Phase II **Small Business Innovation Research (SBIR)** contracts. Additionally, Rizzi and AuSIM produced joint research papers based on their studies of advanced propagation models and structural acoustics.

PRODUCT OUTCOME

While audio simulation technology has been called "3-D sound," this same title has been applied to spatialized sound and surround sound, which are simpler technologies

The 3-D Voice Communication Interface System, AuSIM, Inc.'s latest hardware product, connects to a network via ethernet. Each participant uses one system, and the headset is tracked in orientation and global position. Derivatives of this system are being developed for wearable and vehicle applications.

attempting to leverage traditional sound production techniques. Spatialized sound and surround sound are great for creating a theatre effect in one's living room, but they do not help distinguish multiple alarms in a nuclear power plant control room, for example. AuSIM's interactive audio simulation, on the other hand, can make a distinction between these alarms, give a fighter pilot the natural cue for an approaching threat, or allow air traffic controllers to better associate pilot voices with the planes in the airspace and taxi-ways surrounding them, according to the company.

In noisy environments such as restaurants and lobbies, people are well-adapted to tuning into desired sound and tuning out noise, a perceptual phenomenon referred to as the "cocktail effect." Humans perceive signatures in sound from the propagation and from the source to their ears, and hence create a mental image of the environment that allows them to discriminate independently originating sounds. AuSIM notes that traditional audio technologies do not simulate the propagation of sounds through a medium and therefore present false aural signatures.

AuSIM's solutions to help humans differentiate between simultaneous sounds are based on NASA-influenced audio simulation techniques that create and preserve the perceptual spatial clues in electronically transmitted sound. The solutions apply to military, industrial, voice telecommunications, and academic research projects.

As the company's core technology, AuSIM3D™ gathers dynamic acoustic properties, 3-D position, and 3-D orientation of all objects to drive complex models based on the physics of sound waves. Applied to real-world tasks, AuSIM3D reduces fatigue with naturally presented information, maintains more efficient and productive workers, increases accuracy and quality of listeners' work, yields fewer critical and costly mistakes, and saves time, money, and even lives.

AuSIM3D and the company's related products extend to all branches of military and security operations. The U.S. Navy initiated a next-generation destroyer project to significantly reduce the manning requirements for command and control, and AuSIM delivered over 30 systems to support this multi-model watch station project. Additionally, the Navy is using AuSIM systems to re-examine the use of aural sonar displays. Sonar encompasses visual displays of interpretations of data. Such displays require very acute attention focus, as the sonar data are collected from all directions. In a NASA/U.S. Army project, positional AuSIM audio displays have been added to flight simlulators to improve human performance and effectiveness.

AuSIM has broadened its original "mission-critical" business plan to make room for human interest applications. On a general level, AuSIM's products can be utilized in teleconferences, where spatially consistent voices can sound more natural, and in driver's education schools, so that a student can learn to react to realistic sound events in a simulator, putting fewer people at risk during the learning and thereby creating a prepared driver for the real situation.

For future applications, AuSIM has teamed with the Girvan Institute of Technology, with the intentions of developing and capitalizing on end-user products for more key markets. The institute selects the best and most promising small companies commercializing NASA technology to be incubated and capitalized.

AuSIM3D™ is a trademark of AuSIM, Inc.

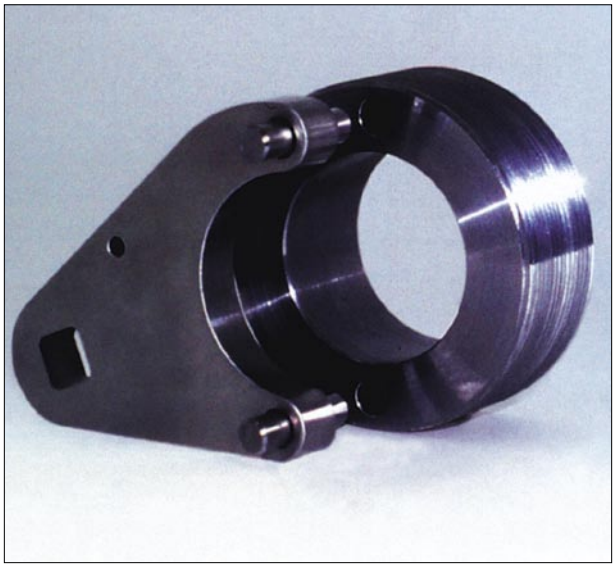
Test System for Studying Spatial Hearing through Obstructing Headgear: AuSIM, Inc.'s 32-channel, microphone-instrumented helmet provides soldiers with situational awareness of their environment, protecting them from potential ballistic, chemical, biological, optical, and percussive threats.

PROVIDING A TURN FOR THE BETTER

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

Engineers are tasked with designing new systems every day to meet changing or unexpected technical requirements. After the tragic explosion of the Space Shuttle Challenger on January 28, 1986, NASA engineers embarked on a complete overhaul of many of their long-standing quality systems and procedures. When the official cause of the accident was determined to be an O-ring failure in the right Solid Rocket Booster, NASA's Shuttle Program initiated a thorough redesign of the rocket boosters' clevis ends, which are the O-ring's mating surfaces.

One of the unique systems that NASA engineers developed as a result of this effort included a heating assembly that is coupled to the outside of the rocket boosters. When the assembly is affixed to the external surface of the boosters, the very nature of its design allows for the warming of the O-rings prior to launch. After the engineers completed the assembly's design, however, they found that it was nearly impossible to tighten the spanner nuts required for attaching the system, given the minimum amount of clearance they had in the limited and confined space. Under these circumstances, the standard wrenches typically used for tightening these types of nuts did not work, and there were no other existing devices to solve the problem.



The Fastorque tool allows for the full rotation of spanner nuts in confined spaces.

NASA engineers embraced the challenge, developing a torque wrench tool adapter that allowed for a full rotation of spanner nuts in confined spaces. The tool, which is similar to an open-ended crowfoot wrench and a fixed-face spanner wrench, contains two dowel pins that center and lock the wrench onto the nut.

PARTNERSHIP

Kennedy Space Center's Technology Commercialization Office provided AI Technologies, a unit of Advisors International (AI) LLC, with information about NASA's torque wrench tool adapter through a royalty-free, public domain technology transfer agreement. AI Technologies, based in New Berlin, Wisconsin, became aware of NASA's torque wrench tool adapter technology through the efforts of Kennedy Space Center and its Technology Transfer Program. Recognizing that the NASA technology could be applied to similar situations in common industrial settings, members of AI Technologies conducted an extensive market analysis to determine the device's viability for commercial sales. Six months later, results indicated that a commercial form of the technology would be well received by industry.

PRODUCT OUTCOME

Through AI Technologies' market analysis for the torque wrench tool adapter, the company quickly determined that the basic concept of the new technology would immediately impact businesses challenged by the limitations brought on by current wrench designs. After AI Technologies acquired the information about this public domain technology, the company assembled the final design concept and patented its product as "Fastorque."

While the tool was initially developed for a NASA-specific purpose, its applications span the aerospace, automotive, construction, energy, and petrochemical industries. Durable and portable, Fastorque is especially suited for hard-to-reach places, and saves time in disconnect/connect procedures for troubleshooting connectors. AI Technologies believes the tool is a good alternative to conventional spanner wrenches, which can be unwieldy and difficult to use, especially in places allowing little clearance for the wrench to rotate. While Fastorque allows for the full rotation of spanner nuts in places with minimum clearance, conventional spanner wrenches in tight spots can cause damage as the user tightens the nuts or withdraws the wrench.

With samples of Fastorque tested and approved, AI Technologies is distributing the product on a worldwide basis. AI LLC actively solicits sales through its own direct efforts. The company is also currently in the process of establishing an effective distribution network where interested customers may purchase the tool. Results from AI LLC's comprehensive marketing and sales efforts are showing that the product is being received positively by the market. The oil and gas, automotive, and aerospace industries are among the many industry segments that have expressed interest. The company expresses cautious optimism that future sales of Fastorque will continue to be enhanced by establishing a broad marketing approach for various industries that may have need of such a specialized tool.

FLUID FLOW TECHNOLOGY THAT MEASURES UP

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

From 1994 to 1996, NASA's Marshall Space Flight Center conducted a Center Director's Discretionary Fund research effort to apply artificial intelligence technologies to the health management of plant equipment and space propulsion systems. Through this effort, NASA established a business relationship with Quality Monitoring and Control (QMC), of Kingwood, Texas, to provide hardware modeling and artificial intelligence tools. Very detailed and accurate Space Shuttle Main Engine (SSME) analysis and algorithms were jointly created, which identified several missing, critical instrumentation needs for adequately evaluating the engine health status. One of the missing instruments was a liquid oxygen (LOX) flow measurement. This instrument was missing since the original SSME included a LOX turbine flow meter that failed during a ground test, resulting in considerable damage for NASA. New balanced flow meter technology addresses this need with robust, safe, and accurate flow metering hardware.

Marshall and QMC engineers performed extensive modeling and analysis of the SSME system, and determined that the existing instrumentation was not sufficient to fully evaluate the SSME health status primarily relating to turbine blade failures. With existing instruments, the best system models have approximately 2.5-percent error and actual data show that very significant hardware failures produce an efficiency change of less than 1 percent, which is within the error band, making many failures impossible to detect. The need for a direct LOX measurement with less than 1-percent error was clear, but the way to do it was not, since the SSME hardware and environmental requirements are extreme. To meet the SSME LOX flow need, the group required a meter that would operate in different fluid physical states; accommodate wide variations in temperature, pressure, vibration, and flow conditions; measure flow with less than 1-percent error; and provide a mechanically robust system with low probability of failure. In addition to these strict requirements, other desired features included operation in different fluid mediums (liquid hydrogen, liquid oxygen, kerosene, etc.); operation in any gravity environment; simplified, long-lasting meter calibration; minimal intrusion into the flow path; and the ability to measure, condition, or limit flow within the same design.

With all of these requirements in mind, the balanced flow meter technology was conceived, created, and tested through the Marshall Technology Investment Projects program. The combination of unique hardware design and unique algorithms met all of the objectives in laboratory experimentation. Testing to harsher environments, in different fluids, and in bi-phase situations is continuing.

PARTNERSHIP

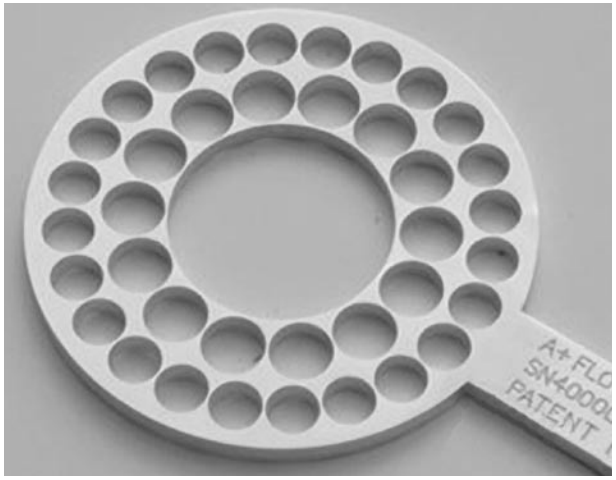
Based upon its work with NASA, QMC founded A+FlowTek, also of Kingwood, Texas, to commercialize the balanced flow meter technology. Together, A+FlowTek and NASA patented the Balanced Flow Meter, with the company receiving exclusive licensing rights.

PRODUCT OUTCOME

The Balanced Flow Meter determines the fluid flow rate in piping, channel, and conduit systems. It provides highly accurate flow metering, flow limiting, or flow conditioning in any fluid flow system. As a flow meter, the technology provides flow measurement with minimal intrusion into the flow path and requires no moving parts. Additionally, this technology is LOX-safe and the hardware is robust enough for consideration as an engine LOX flow meter. As a flow limiting device, the technology can simulate facility and engine fluid flow loads. The technology's sizing is more accurate than the currently used orifice plate technology, and it takes much less space and cost compared to Venturi flow technology. Finally, as a flow conditioning device, the balanced flow technology may improve engine performance by conditioning fluid flow profiles around elbows, combustion chambers, and pump inlets.

Fluid flow measurements such as these are used extensively in the processing industries for refineries and chemical, power, and pharmaceutical plants. Chevron and Sloss Industries are among the companies already using the Balanced Flow Meter technology in their industrial plants with good results.

The Balanced Flow Meter's applications to NASA's liquid propulsion systems and test facilities are numerous. Possible near-term NASA applications include using the technology as a flow limit device to simulate the engine loads during Stennis Space Center facility verifications. Once the concept is proven in the appropriate environments, there could be thousands of NASA applications for this promising technology.



7.5-inch Kerosene Rocket Engine Flow Plate with an 81-percent open area.

READING THROUGH PAINT

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

Two-dimensional data matrix symbols, which contain encoded letters and numbers, are permanently etched on items for identification. They can store up to 100 times more information than traditional bar codes. While the symbols provide several advantages over bar codes, once they are covered by paint they can no longer be read by optical scanners. Since most products are painted eventually, this presents a problem for industries relying on the symbols for identification and tracking.

In 1987, NASA's Marshall Space Flight Center began studying direct parts marking with matrix symbols in order to track millions of Space Shuttle parts. Advances in the technology proved that by incorporating magnetic properties into the paints, inks, and pastes used to apply the matrix symbols, the codes could be read by a magnetic scanner even after being covered with paint or other coatings. NASA received a patent for such a scanner in 1998, but the system it used for development was not portable and was too costly. A prototype was needed as a lead-in to a production model.

In the summer of 2000, NASA began seeking companies to build a hand-held scanner that would detect the "Read Through Paint" data matrix identification marks containing magnetic materials through coatings. Through the Research Triangle Institute's efforts to connect NASA to small, high-technology businesses, the Agency was introduced to PRI Research & Development Corporation (PRI), of Torrance, California. PRI possessed a fully mature and successfully operating inspection system, known as the Magneto-Optic Imager (MOI), which enabled aviation technicians to inspect commercial and military aircraft for cracks and corrosion beneath paint and other surface coatings. Although the MOI could not be used in its current configuration for the application intended by NASA, PRI provided expertise and a system at the highest technology readiness level from which to start. NASA Marshall's 13 years of direct part marking experience had enabled it to determine the reading requirements for identification symbols marked directly on parts through coatings. As a result, Marshall could provide PRI with a well-defined application, an understanding of what needed to be developed, and first-hand expertise.

PARTNERSHIP

After meeting with Marshall, PRI accepted the challenge to build a hand-held MOI specifically for detecting data matrix symbols through paint. NASA and PRI signed a Space Act Agreement in September 2000, stating they would work together on the MOI, sharing the cost as well as any intellectual property that resulted. NASA purchased the parts and components for the prototypes, while PRI provided the design, engineering, and assembly services. Sharing the costs greatly reduced the risk to PRI as a small business, and enabled NASA to participate in the development process of a product that would best suit its application.

PRI's Dr. William Shih, Gerald Fitzpatrick, and Craig Knisely worked with Marshall engineers to adapt PRI's MOI technology to its new application. They removed unneeded functionality of PRI's existing product to focus the device on its scanning mission, driving down both the size and cost of the magnetic scanner. The team also incorporated components from the HE-30 optical scanning product manufactured by Robotic Vision Systems, Inc. (RVSI), of Nashua, New Hampshire.

The Magneto-Optic Imager reads and decodes magnetic matrix symbols that are obscured by paint or other coatings.

PRODUCT OUTCOME

As a result of the Space Act Agreement and the work completed by NASA and PRI, another patent application was filed for the improved version of the MOI. The hand-held MOI is now the approximate size and weight of a portable hair dryer. In addition to detecting codes covered by paint, primers, and laminates, the scanner reads marks obscured by discoloration or contamination. While PRI manufactures the hand-held scanner, RVSI was granted a license to market the new product. Introduced for sale as the "RVSI Magneto-Optic Imager," model number A1-80299-1, the MOI enhances the company's already impressive optical reader and vision system product line with the first scanner capable of reading data matrix symbols covered with paint.

RVSI successfully tested the first MOI prototype for the National Center for Manufacturing Sciences/ Department of Defense (DoD) Retrofit Part Marking Development Program to demonstrate that both optical and Read Through Paint markings can survive and remain readable in operations, maintenance, repair, and overhaul environments. Magnetic marks placed on aircraft operated by the U.S. Coast Guard survived after 8 months of flight, and the MOI successfully imaged the data matrix symbols through the several layers of paint on the aircraft. This Phase II cooperative effort between NASA, the Coast Guard, RVSI, the DoD, and others is setting the stage for a Phase III effort to push the limits on Read Through Paint methods.

A variety of commercial applications are being explored by those involved in automatic identification. The MOI has the potential to help businesses improve inventory management, enhance safety, improve security, and aid in recall efforts. With more products in the world painted than not, the market for the MOI is very promising, particularly in the airline, automotive, electronics, and health care industries. For example, the automotive industry needs a flat identification mark under the paint that does not detract from a high-gloss paint job. The electronics industry, pharmaceutical industry, and others are becoming aware that product identification is no longer limited to marks that can be seen. Eventually, customers may receive packages with a visible mark on the top label and a magnetic mark underneath, or no visible marks on the outside at all, depending on the need for security.

Robotic Vision Systems, Inc., successfully demonstrated the magnetic hand-held scanner's ability to help NASA track painted Space Shuttle parts.

The MOI demonstrates the spin-in aspect of the technology transfer process. Through PRI and NASA's partnership, a new capability was created to help NASA track painted parts. With the MOI being spun-off, a product was created for the commercial market, enabling the technology to solve similar problems for the DoD, the automotive industry, and other market sectors. In addition to solving a serious tracking problem, the collaboration has added a new product to PRI's production line and a new product to RVSI's sales portfolio.

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

KeyMaster Technologies, Inc., develops and markets specialized, hand-held X-ray fluorescence (XRF) instruments and unique tagging technology used to identify and authenticate materials or processes. NASA first met with this Kennewick, Washington-based company as the Agency began seeking companies to develop a hand-held instrument that would detect data matrix symbols on parts covered by paint and other coatings. Since the Federal Aviation Administration was also searching for methods to detect and eliminate the use of unapproved parts, it recommended that NASA and KeyMaster work together to develop a technology that would benefit both agencies.

KeyMaster agreed to meet with NASA, sharing the opinion that its XRF instrument could be adapted to fit these needs. Up until that point, the company's instrument served extensively as an alloy analyzer in the metals industry.

PARTNERSHIP

In January 2002, KeyMaster representatives visited NASA Marshall Space Flight Center's Technology Transfer department to demonstrate their standard XRF instrument. The NASA participants, including technical personnel from the Engineering Directorate and the Science Directorate, were particularly interested in the instrument's portability and capability to quickly analyze the composition of most materials in the environment. The group recognized the instrument could have an immediate benefit to NASA for analyzing materials and avoiding many hardware nonconformance issues.

After NASA and KeyMaster determined that merging their technologies could provide beneficial new capabilities for both NASA's Space Flight program and the commercial market, they signed a Space Act Agreement in March 2002 establishing them as full partners in a research and development environment. The agreement stated that NASA and KeyMaster would work together on the increased capability of the hand-held XRF instrument, sharing any intellectual property that resulted, as well as the cost. NASA would purchase the parts and components for the prototypes, while KeyMaster would provide the design, engineering, and assembly services.

The TRACeR tags and detects unique elemental codes for material analysis and identification.

In June 2002, the company demonstrated its XRF instrument to personnel from NASA's Reusable Solid Rocket Motor (RSRM) project office at Marshall. The instrument successfully identified and matched six samples of Marshall weld rods. The RSRM personnel then began producing bolts, fasteners, and other items that had been the subjects of recent materials problems. The XRF determined the composition of the items in only a few seconds and to a degree of accuracy within 1 percent of the Material Safety Data Sheets. Based on this meeting, the participants agreed that NASA could benefit from the XRF during the manufacturing of Space Shuttle hardware.

NASA tasked ATK Thiokol, a prime contractor to the RSRM project office, with purchasing a standard XRF instrument from KeyMaster and performing a detailed evaluation to determine the extent of capability and

applicability of the technology for aerospace work. The first analyses at Marshall found that advances were needed to extend the instrument's detection range to include aluminum alloys, since aluminum is used to build the Shuttle's External Tank, the structure of the orbiter, and parts of the RSRM. However, further tests determined that when the instrument was operated in a vacuum, it would easily analyze the aluminum alloys.

The Marshall Space Shuttle Propulsion Office became involved with the project in order to incorporate a vacuum system with the standard XRF instrument, extending the instrument's sensitivity to detect elements in the range of aluminum. NASA's External Tank project office, RSRM project office, and the Space Shuttle Main Engine project office each agreed to purchase a vacuum-assisted instrument if KeyMaster developed it. KeyMaster developed the device, naming it the TRACeR III-V, and delivered three of the products to Marshall in April 2003.

KeyMaster and NASA filed two patent applications, demonstrating that the TRACeR brings value back to NASA in addition to yielding a commercial spinoff. One patent is for intrinsic product authentication through chemical tag identifiers that are converted to bar code language, benefiting primarily the commercial market. The other patent involves the merging of the Marshall innovation (the vacuum assist) to enable the instrument to detect certain low-energy elements or even certain contaminants within NASA hardware. KeyMaster signed an exclusive license to commercialize the technology.

The TRACeR is approximately the size of a portable drill, weighing less than 5 pounds.

PRODUCT OUTCOME

The TRACeR is now approximately the size of a portable drill, weighing less than 5 pounds. The instrument's extended detection range has opened the door to new markets, and KeyMaster has made the product available commercially across the globe. The company sold two devices abroad before the product was even announced in any news releases, and numerous orders were placed following the unveiling of the instrument at the 2004 National Manufacturing Week in Chicago.

In addition to the analysis of metals, sophisticated alloys, and lighter elements such as magnesium and silicon, the TRACeR applies an innovative process of tagging and detecting unique elemental codes for material analysis and identification. The TRACeR has software that allows users to mix chemicals with products to create tag identifiers, which the instrument can then read and convert to bar code language for product identification. In one application, the new instrument can analyze for many of the constituents of pharmaceuticals and read tags that authenticate the product. The automotive industry is exploring the new instrument's capabilities for material composition analysis as well as its potential for product identification and authentication. The U.S. Department of Defense may be able to apply the device, as it is using lighter materials in product development and needs new ways to analyze their composition. Invisible, intrinsic identification that is detectable by only one method may be the authentication tool of the future. The first application of the product for NASA involved the Shuttle's Return to Flight activities.

NEW GLASS SERVES AS WINDOW TO CUTTING-EDGE LASERS

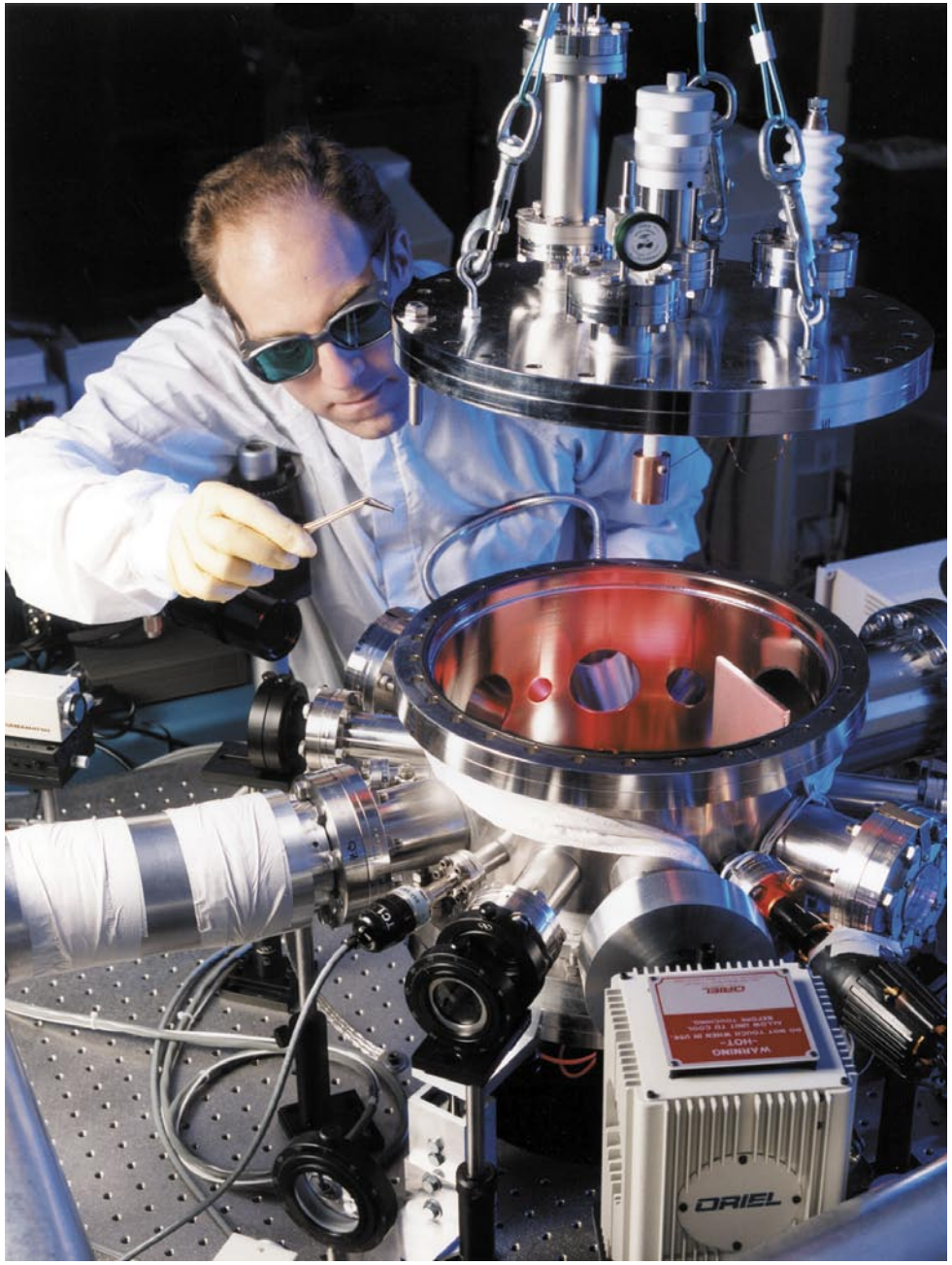
ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

Since 1997, Marshall Space Flight Center's Electrostatic Levitator (ESL) facility has been used to study the characteristics of new metals, ceramics, and glass compounds—in both their hot molten states and as they are cooled to form solid materials. The ESL provides a unique way to test such substances without having to make contact with a container or crucible that would contaminate the sample. Simply put, objects analyzed in the levitator's chamber float in mid-air with no visible means of support or containment, suspended only by static electricity. While a sample object is levitated, a laser beam heats it until it melts so that scientists can measure its physical properties without interference from a container.

Materials created as a result of the ESL tests include new optics, spacecraft components, and space-age alloys that have yielded longer-hitting, "liquid metal" golf clubs. One of the most recent creations to come from the levitator is a revolutionary family of glasses now being manufactured and sold by Containerless Research, Inc., of Evanston, Illinois.

PARTNERSHIP

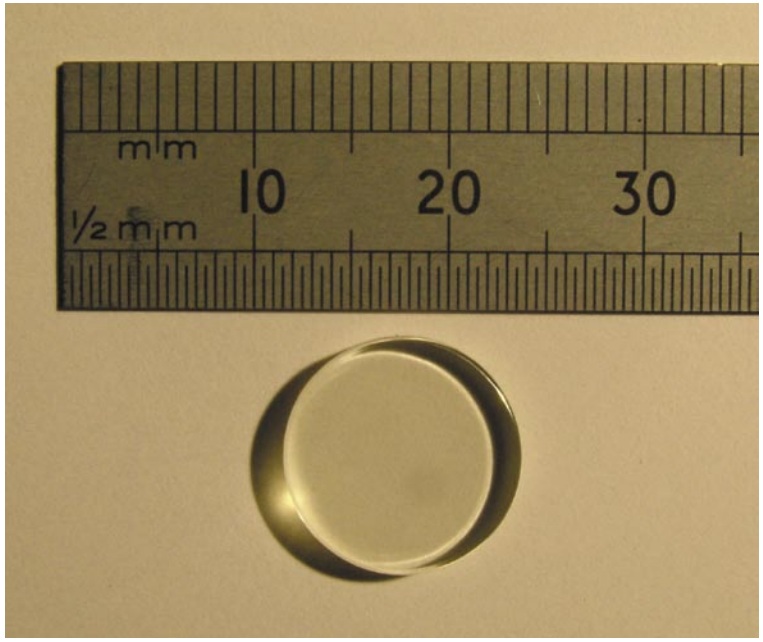
NASA's Research Announcement (NRA) program invites private corporations, research institutes, and universities to submit proposals for research projects on Earth and in space. Containerless Research received an NRA grant for a proposed International Space Station flight experiment to investigate liquid-liquid phase separation effects in deeply undercooled oxide liquids. The resulting research—also supported by the National Science Foundation and the U.S. Air Force Office of Scientific Research—involved the utilization of various types of containerless processing technology, including NASA's ESL, and ultimately led to Containerless Research's invention of **R**are **E**arth **Al**uminum oxide (REAl™) Glass materials.



A microgravity researcher works with the Electrostatic Levitator, which uses static electricity to suspend a sample object inside a vacuum chamber while a laser heats the object until it melts. This lets scientists record a wide range of physical properties without the sample contacting the container or any instruments, thus eliminating conditions that would alter the readings. Such "containerless" experiments have led to a new family of glasses.

PRODUCT OUTCOME

Made from rare Earth oxides, aluminum oxide, and trace amounts of silicon dioxide, REAl Glass is currently available for laser, infrared, and optical communications applications as a low-cost alternative to expensive optical glasses, gain media, and crystals. REAl Glass is generated from a "supercooled" liquid, meaning that a liquid is cooled quickly enough to prevent its atoms from organizing and forming a crystal structure (at room temperature and lower temperatures, the atoms are "trapped" in this jumbled, glassy state). The new patented innovation enables higher power densities, more efficient laser power conversion, broader spectral bandwidths, and increased infrared transmission when compared to the likes of other materials, such as conventional crystalline sapphire. Containerless Research is developing larger scale processing of the glass, and its goal is to offer products in a variety of forms, including rods and plates that are tailored to specific applications.



Containerless Research, Inc., can cast its REAl glass in a variety of shapes (disk shown here) needed for different applications, including surgical lasers and power lasers used to cut metal.

Containerless Research is establishing a niche-market for REAl Glass in the high-power laser field by giving lasers more power and much less heat dissipation. Whether it is an industrial power laser for cutting car bodies or a medical laser used for surgery, the "heart" of a laser is the "gain medium," which is where REAl Glass can be applied. This critical component increases or amplifies light, resulting in an intense, highly concentrated beam capable of precisely cutting metal parts or surgically removing or repairing human tissue. A more efficient gain medium allows for a more compact laser system that can operate at a lower power level while providing the same output power, thus giving laser manufacturers a broader range of choices in designing lasers.

"Most surgical lasers now use expensive single crystals, which limit the range of operating wavelength to very narrow bands," explains Dr. Richard Weber, director of Containerless Research's Glass Products Division. "REAl Glass provides the additional advantage of tunability, which can give more control over surgical procedures, an important factor in different types of surgery and for different skin types. Our glass can provide efficient power lasers and expand coverage to new wavelengths." The ability to tune the light wavelength could also have important implications for any lasers used in dental procedures.

REAl Glass also offers a medium for next-generation optical communications devices that need to be small, low-cost, and powerful enough to provide fiber for business and home broadband Internet connections. For example, the new glass innovation could cut back the size and weight of certain telecommunications components that are used in supplying fiber to the home, thus making room for smaller, inexpensive broadband amplifiers. Containerless Research has developed the capability to customize the glass composition for such communications applications.

Additionally, because REAl Glass possesses outstanding environmental capabilities and "moldability," a multitude of military and homeland security applications are on the horizon, including low-dispersion lenses and infrared windows, as well as technology that could possibly be used to help detect explosives and toxins and confuse heat-seeking missiles.

Marshall Space Flight Center's ESL facility is supported by NASA's Microgravity Materials Science Research Project Office, a division of NASA's Office of Biological and Physical Research (OBPR). OBPR conducts interdisciplinary, peer-reviewed, fundamental, and applied research to address the opportunities and challenges to NASA that are provided by the space environment and the human exploration of space.

REAl™ is a trademark of Containerless Research, Inc.

SMART CAMERA TECHNOLOGY INCREASES QUALITY

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

When it comes to real-time image processing, everyone is an expert. People begin processing images at birth and rapidly learn to control their responses through the real-time processing of the human visual system. The human eye captures an enormous amount of information in the form of light images. In order to keep the brain from becoming overloaded with all the data, portions of an image are processed at a higher resolution than others, such as a traffic light changing colors.

In the same manner, image processing products strive to extract the information stored in light in the most efficient way possible. Digital cameras available today capture millions of pixels worth of information from incident light. However, at frame rates more than a few per second, existing digital interfaces are overwhelmed. All the user can do is store several frames to memory until that memory is full and then subsequent information is lost. New technology pairs existing digital interface technology with an off-the-shelf complementary metal oxide semiconductor (CMOS) imager to provide more than 500 frames per second of specialty image processing. The result is a cost-effective detection system unlike any other.

SpecterView™ contains smart camera technology to benefit applications in quality assurance, product inspection, and automated manufacturing.

"Smart camera" technology has evolved as a way to process images inside a camera and reduce the amount of information passed through the data bus to the processor by several orders of magnitude. This increases the bandwidth of a control system while preserving resolution with specialized image-processing algorithms inside the camera. Robotic guidance, product inspection, quality assurance, and packaging are fields that benefit from smart camera systems.

NASA's Marshall Space Flight Center uses smart cameras for its Advanced Video Guidance Sensor (AVGS) on the Demonstration of Autonomous Rendezvous Technology (DART) mission. NASA's goal is to launch an unmanned spacecraft that autonomously docks with an on-orbit satellite without human intervention. The AVGS is an optical transceiver mounted on the spacecraft that fires near-infrared lasers in a predetermined sequence. A target on the satellite returns some of this light to the AVGS which then performs a pattern-recognition routine to determine its position and attitude relative to the satellite. Marshall's Engineering Directorate (ED)-19 developed the image-processing algorithms for the original Video Guidance Sensor flown on two previous Shuttle missions. Orbital Sciences Corporation, in Beltsville, Maryland, teamed with Advanced Optical Systems (AOS), in Huntsville, Alabama, and Marshall's ED-19 and ED-14 groups to increase the range and the update rate for the AVGS unit.

PARTNERSHIP

Southern Vision Systems, Inc. (SVSi), also of Huntsville, Alabama, developed its commercial SpecterView™ sensor based upon the work done in support of NASA's DART mission. SVSi President Andy Whitehead was the AOS program manager for Marshall's AVGS and recognized the potential applications of the technology. SVSi started prototype development on the SpecterView sensor in April 2003 at AOS and began volume manufacturing in its own facility by April 2004. AOS received one of the first beta

SpecterView™ performs as a rapid prototyping and diagnostic tool for scientists and engineers developing optical systems.

units and immediately used it to diagnose the flight version of the AVGS when problems arose during testing.

PRODUCT OUTCOME

The SpecterView is built around a CMOS imager that captures images of 1,280 by 1,024 pixels at 500 frames per second. An adjacent, large-area field programmable gate array controls the imager, downloads frames, and processes the image to reduce the throughput to manageable streams. After frame processing, digital data are sent to the host computer through a universal serial bus interface without the need for a frame-grabber. The largest commercial advantage of the sensor is its ability to emulate a suite of analog detectors with one two-dimensional digital imager. Similar to the way in which digital electronics displaced analog electronics for many applications, digital photo-detectors are replacing analog photo-detectors as digital speeds increase. The user-friendly nature of digital signals eases data manipulation and display.

Designed to be the equivalent to an optical engineer as the oscilloscope is to an electrical engineer, the SpecterView sensor looks at light in many different ways and graphically displays and logs the light signals captured. Its primary application is as a rapid prototyping and diagnostic tool for scientists and engineers developing optical systems. This application provided immediate benefits to NASA.

Following fabrication of the first flight unit of Marshall's AVGS, performance testing showed that one or more lasers inside the box were either firing out of sequence or at reduced output power. Since range information for the DART mission is very dependent on having a stable transceiver, the cause of the misfire needed to be quickly identified. As a flight box, the cover to the AVGS could only be removed for diagnostics under controlled environments. However, AOS used an imaging lens to image the output fiber bundle onto the SpecterView and record each individual laser's firing sequence. The high resolution of the imager array and large sampling bandwidth (up to 500 kilohertz) quickly identified which laser was firing at reduced output power. This enabled rapid repair once the decision was made to go inside the box.

The smart camera technology developed for AVGS and implemented in SpecterView has applications in quality assurance, product inspection, and even automated manufacturing of everyday products. The technology's implementation into these areas is driven by the manufacturer's desire to produce reliable quality products as efficiently as possible to satisfy customers' competing demands for quality inexpensive goods.

SpecterView™ is a trademark of Southern Vision Systems, Inc.

A COATING THAT COOLS AND CUTS COSTS

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

To enable low-cost space access for advanced exploration vehicles, researchers from NASA's Ames Research Center invented and patented a protective coating for ceramic materials (PCCM) in 1994. The technology, originally intended to coat the heat shields of the X-33 and X-34 next-generation vehicles for optimum protection during atmospheric reentry, greatly reduces surface temperature of a thermal control structure while it reradiates absorbed energy to a cooler surface or body, thus preventing degradation of the underlying ceramic material.

PARTNERSHIP

NASA Ames developed PCCM for use on ceramic fibers, but ongoing tests at the Center concluded that the coating could be effective on many other materials. As a result, Ames opted to align with a commercial partner to bring the protective coating technology to industry for thermal and fire protection. Wessex Incorporated, of Blacksburg, Virginia, obtained a partially exclusive license for PCCM in 1996, followed by an expanded exclusive license in 2001 for all fields other than space applications. Wessex initially applied the protective coating to building materials, specifically wood and steel for firewall applications. Through further testing and experimentation, however, the company would eventually come to learn the true potential of PCCM, leading to longer-lasting materials, greater energy conservation and fuel efficiency, increased productivity, and significantly reduced operating costs for numerous U.S. businesses.

PRODUCT OUTCOME

Known commercially as Emisshield,™ Wessex's PCCM product mirrors NASA's original PCCM coating in that it provides increased "hemispherical" emissivity—the ability to absorb energy and reradiate it to a cooler surface, body, or atmosphere. The Ames scientists who invented PCCM determined the emissivity of the coating to be between 0.8 and 0.9, making it a "grey body." This means that the ratio of energy absorbed is not exactly the same as the amount of energy reradiated (a substrate that absorbs all energy regardless of the direction or wavelength of the energy and is a perfect radiator of the same energy is considered a "black body," but to date, no such substrate exists, so a grey body is known to have the highest emissivity). Many substrates can have high emissivity values at ambient or lower temperatures, but as the temperature climbs, the emissivity of these non-grey body materials can decrease rapidly. Since PCCM was developed to withstand the extreme conditions of reentry, which involve going from -250 °F to almost 3,000 °F in a matter of seconds, the emissivity agents in the coating and in its commercial descendant maintain their grey body capabilities at temperatures exceeding 3,000 °F. In other words, PCCM and Emisshield will continue to absorb and reradiate at the same ratio, over a great range of temperatures.

Emisshield™ absorbs energy and reradiates it over a great range of temperatures, providing maximum protection for surfaces and underlying materials.

Like PCCM, Emisshield can be reused and repeatedly cycled between severe extremes of subzero temperatures and temperatures over 3,000 °F, without ever damaging the protective coating or the underlying material. With each use, the coating's molecular structure is rearranged to create a stronger bond between the coating and the underlying material, and an even greater level of thermal protection. In essence, the protective coating actually improves over time.

Wessex has embraced a high rate of success with Emisshield beyond its initial accomplishments in fireproofing building materials. In automotives, Modern Materials Incorporated, of Rochester, Indiana, is using Emisshield's AR-1 blend to coat racecars and automotive parts. The coating was recently applied to the driver's compartment of a racecar to lower floor pan temperatures that regularly range from 740 °F to 760 °F. By absorbing most of the heat and redirecting it away from the floor of the driver's compartment, Emisshield AR-1 cooled down the floor pan temperature to 370 °F—almost 50 percent cooler than an untreated floor pan.

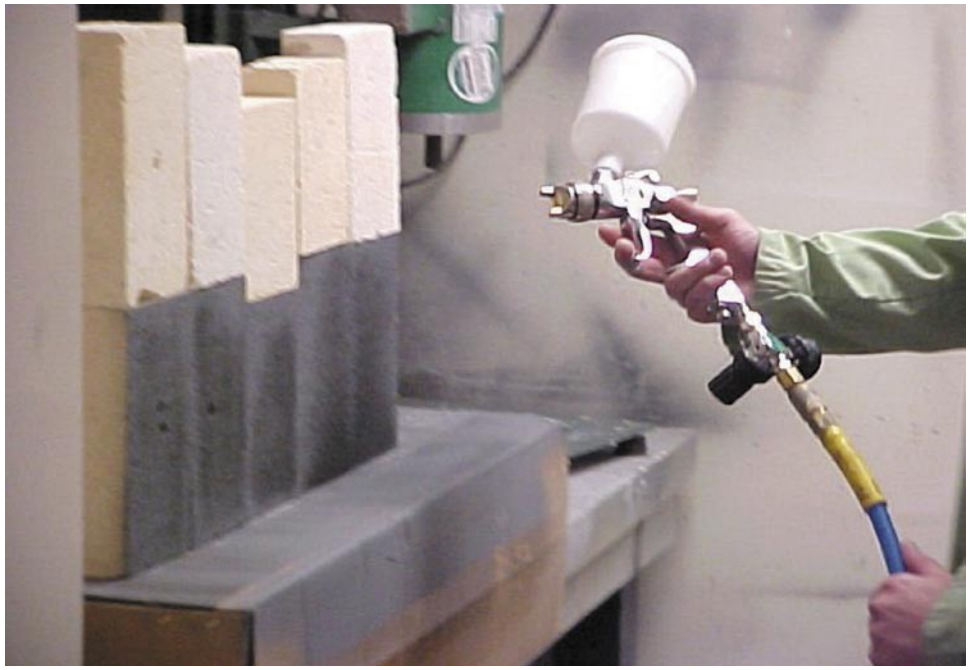
Separately, Emisshield was applied to the header pipes and collectors of a 1,400-horsepower, 800-cubic inch V-8 pro-stock dragster. Before the coating, the engine was tested by a dynometer for background performance. After the initial performance readings, the engine's header pipes and collectors were removed, grit-blasted, and coated with Emisshield on the outside only. The coating was allowed to dry for 1 hour before testing resumed on the engine in the same manner as before the coating was applied. Results from the follow-up test showed that Emisshield was able to increase horsepower by 15, decrease the pounds of fuel used by 26 pounds per hour to yield the higher horsepower, and reduce the outer surface temperature of the header pipes and collectors by 550 °F. These results will not only impact drag racers but other types

of race engines, along with the engines that are put into everyday street cars.

While the demand for Emisshield in various fields remains steady, Wessex is concentrating on three key areas: petrochemical production, metal heat treating, and general refractory applications such as boilers and heat exchangers. The company has discovered that the coating, when applied to refractories or the tubes in boilers, can help increase the efficiency of a process by requiring less fuel to yield the same amount of product.

To demonstrate this boost in efficiency, Wessex teamed with Virginia Carolina Refractory, of Denver, North Carolina, to apply Emisshield to the afterburner of a batch kiln that cures catalytic converter elements. The purpose of the afterburner is to heat the exhaust gasses during the kiln cycle to completely burn the organic binders that are discharged from the catalytic converter elements. In the kiln's total cycle of 48 hours, 25 percent of the total fuel usage is consumed by the 80-foot-long, 6-foot-tall afterburner to ramp up and maintain a temperature of 1,400 °F. Virginia Carolina Refractory wanted to see a decrease in fuel use and a shorter ramp-up time to reach 1,400 °F.

It took 15 gallons of the Emisshield ST-2 product to coat the entire afterburner, using a spray gun. In 3 months, the natural gas burners that are controlled by thermocouples hanging in the afterburner were able to be kept open at a rate between 25 percent and 29 percent, after previously being kept open at a rate setting of 35 percent. By reradiating energy back into the afterburner with Emisshield, the fuel needed to keep the afterburner at 1,400 °F could be reduced, ultimately shortening the ramp-up time. This translated into energy savings of approximately 23 percent in the afterburner chamber for an entire year, or a savings of $360,000 per year for owners of this batch kiln.



Samples are sprayed with Emisshield ST-1 in Wessex Incorporated's laboratory.

Emisshield also proved to be the coating of choice in tempering a heat treating furnace. In testing the impact of this application, a company from Tulsa, Oklahoma, coated the interior of a 1,200-pound loaded furnace with Emisshield and left an identical loaded furnace uncoated. Temperature readings taken from both furnaces revealed that the Emisshield-coated furnace took 1 hour less than the uncoated furnace to reach the prime operating temperature of 1,350 °F. This 30-percent decrease in total time-to-temperature represents an increase in production for operators. The coated furnace also cooled down faster than the uncoated model, reaching 600 °F in only 13 minutes, compared to 20 minutes.

To improve sales and distribution of Emisshield products, Wessex has united with Pittsburgh, Pennsylvania-based Harbison-Walker Refractories LTD, and Houston, Texas-based Thorpe Corporation to promote the coating in North America for a variety of industrial applications.

In June 2003, Emisshield was honored by NASA as a "Turning Goals into Reality" commercial technology award recipient. This award was presented in recognition of accomplishments deemed the most outstanding contributions toward each of NASA's Enterprise goals and objectives.

Wessex and Ames continue to work together on a regular basis and have recently discussed the potential use of Emisshield for some of NASA's thermal applications. Ames has received samples of the Wessex coatings for evaluation of their compatibility with research projects currently underway.

Emisshield™ is a trademark of Wessex Incorporated.

HELPING AIRCRAFT ENGINES LIGHTEN UP

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

High-temperature polyimide/carbon fiber matrix composites are developed by the Polymers Branch at NASA's Glenn Research Center. These materials can withstand high temperatures and have good processing properties, which make them particularly useful for jet and rocket engines and for components such as fan blades, bushings, and duct segments. Applying polyimide composites as components for aerospace structures can lead to substantial vehicle weight reductions.

A typical polyimide composite is made up of layers of carbon or glass fibers glued together by a high-temperature polymer to make the material strong, stiff, and lightweight. Organic molecules containing carbon, nitrogen, oxygen, and hydrogen within the polyimide keep the material's density low, resulting in the light weight. The strength of a component or part made from a polyimide comes mainly from the reinforcing high-strength fibers. The strength of the carbon fibers coupled with the stiffness of polyimides allows engineers to make a very rigid structure without it being massive. Another benefit of a polyimide's suitability for aerospace applications is its reduced need for machining. When polyimide parts are removed from a mold, they are nearly in their final shape. Usually, very little machining is needed before a part is ready for use.

PARTNERSHIP

Glenn awarded Maverick Corporation, of Cincinnati, Ohio, a Phase II **Small Business Innovation Research (SBIR)** contract to develop a family of nontoxic, high-temperature polyimide resins. The company successfully developed polyimides that exhibit high glass transition temperatures and excellent thermal oxidative stability for aircraft applications.

Maverick was then granted $500,000 from the Ohio Technology Action Fund to commercialize the polyimides for high-temperature Resin Transfer Molding, a low-cost manufacturing process commonly used in the aerospace and automotive industries. Glenn also contributed $50,000 to this effort.

In addition to its successful SBIR partnership with Glenn, Maverick also licensed a bundle package of four polymer technologies developed by the Center's Polymers Branch. Maverick worked with Glenn's Technology Transfer and Partnerships Office and the Great Lakes Industrial Technology Center (GLITeC) to sign the license. Through the license agreement, researchers in the Polymers Branch extended assistance to Maverick to further develop the technologies. Also as part of the partnership, GLITeC, NASA's Midwest Technology Transfer Center, worked to help Maverick identify markets and customers.

PRODUCT OUTCOME

Maverick's BIM product line, a family of affordable, low-toxicity polyimide resins, is the commercial result of the company's SBIR relationship with Glenn. The technology, which has caught the attention of the aerospace industry, offers high-temperature performance and processing versatility. The resins, which contain no mutagenic or carcinogenic components, can be processed by compression molding, autoclave, solvent-assisted resin transfer molding, and conventional resin transfer molding.

The product line benefits aircraft engine and airframe applications. Since the resins can reduce the cost and weight of aerospace structures, they will help NASA with the development of future space vehicles. The U.S. military may also use the technology in both aircraft and ground transportation applications.

Maverick expects that new products derived from its NASA license will lead to sales of over $50,000 per year within 3 years, with increases from there. One of the first products commercialized from this license is DMBZ, a Glenn-developed/patented polyimide designed for applications requiring short-term exposure to temperatures up to 800 °F.

This 4-foot aircraft engine cooling duct was produced using the solvent-assisted Resin Transfer Molding process.

HYBRID TANK TECHNOLOGY

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

Researchers have accomplished great advances in pressure vessel technology by applying high-performance composite materials as an over-wrap to metal-lined pressure vessels. These composite over-wrapped pressure vessels (COPVs) are used in many areas, from air tanks for firefighters and compressed natural gas tanks for automobiles, to pressurant tanks for aerospace launch vehicles and propellant tanks for satellites and deep-space exploration vehicles.

NASA and commercial industry are continually striving to find new ways to make high-performance pressure vessels safer and more reliable. While COPVs are much lighter than all-metal pressure vessels, the composite material, typically graphite fibers with an epoxy matrix resin, is vulnerable to impact damage. Carbon fiber is most frequently used for the high-performance COPV applications because of its high strength-to-weight characteristics. Other fibers have been used, but with limitations. For example, fiberglass is inexpensive but much heavier than carbon. Aramid fibers are impact resistant but have less strength than carbon and their performance tends to deteriorate.

PARTNERSHIP

NASA's Marshall Space Flight Center began doing initial work on the fabrication of hybrid tank structures through independent research and development (IR&D) activities with additional support from technology transfer funding called the Technology Investment Projects. However, this IR&D activity did not include the necessary depth to understand how a hybrid structure could be produced for pressure vessel applications.

To further the research, Marshall awarded Phase I and Phase II **Small Business Innovation Research (SBIR)** contracts to HyPerComp Engineering, Inc., a Brigham City, Utah-based company with expertise in the design and development of pressure vessels for commercial applications. HyPerComp Engineering's James Patterson and Marshall's Tom DeLay worked together on the development of a hybrid pressure vessel using a "design of experiments" approach on the type of fibers, resins, and lay-up sequences of the vessels. Over the course of their work, many test vessels were burst tested with and without impact damage. The results led to a refined tank design that NASA found to be beyond state of the art.

The new hybrid pressure vessels are aluminum lined, filament wound, and composite over-wrapped, with high-impact and fire-resistant properties. The unique hybrid technology has the potential to save weight while producing a more robust and safer pressure vessel that is applicable to both NASA and commercial missions. The vessels have passed many of the standard U.S. Department of Transportation tests and are currently being tested under more stringent means for military applications.

PRODUCT OUTCOME

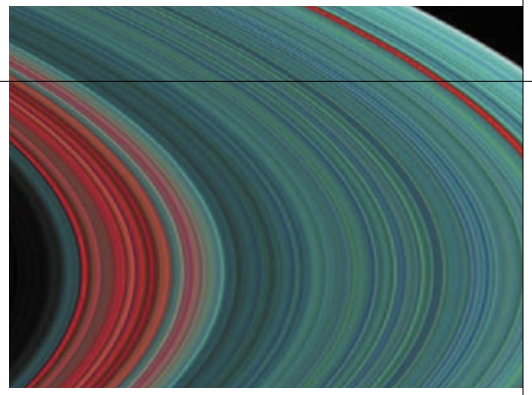
NASA licensed the technology to HyPerComp Engineering, allowing the company to manufacture different sizes of the hybrid pressure vessels. HyPerComp Engineering has established a manufacturing sister company, Onyx Technologies, which will bring the technology to the commercial marketplace.

The applications for the new pressure vessels include improved breathing apparatuses for homeland security and firefighting, as well as lighter and safer storage systems for automobiles and buses that run on hydrogen fuel as an alternative energy source. The pressure vessels may be used for chemical processing and pharmaceutical manufacturing, as well as for offshore drilling, oil production, and petroleum refineries. The technology benefits fuel tanks for over-the-road tankers, as the vessels carry more fuel for the same weight as existing tanks. The Gunfire-Survivable Pressure Vessel was designed for robust environments. Its customers include the U.S. military, battlefield environment and fire safety personnel, and the automotive industry.

Another area of significant interest to NASA is regarding cryogenic tank development. Again, Marshall has awarded both a Phase I and Phase II SBIR contract to HyPerComp Engineering for in depth development of cryogenic tanks. The cryogenic tank is being developed for next generation launch systems for the U.S. Department of Defense and NASA. For the Space Agency, the technology can provide fuel tanks for reusable launch vehicles, upper-stage launch vehicles, and other spacecraft.

This image shows one of HyPerComp Engineering, Inc.'s test cylinders. Applications for the company's hybrid pressure vessels include fire safety and the automotive industry.

RESEARCH AND DEVELOPMENT AT NASA



PREFACE

"Audentes Fortunas Juvat" – Fortune Favors the Bold

From the beginning, exploration and discovery have driven human curiosity and enriched the cultures that embraced them. Exploration provides the foundation of our knowledge, technology, resources, and inspiration. As President Bush stated when he unveiled the Vision for Space Exploration, "This cause of exploration and discovery is not an option we choose; it is a desire written in the human heart."

We are about to set forth on a journey that will mark the beginning of a sustained human presence in the solar system. Just take a moment to think about the possibilities this yields for our future. The exploratory voyages of the next few decades have the potential, in this lifetime, to answer age-old questions about how life begins, whether life exists elsewhere, and how the inevitable discoveries along the way will help better our lives here on Earth.

The Vision for Space Exploration seeks answers to fundamental questions about our existence, responds to recent discoveries, and puts in place revolutionary technologies and capabilities to inspire our Nation, the world, and the next generation…as only NASA can.

The extensive scope of technologies yielded from NASA research and exploration makes the notion that "NASA Explores, Humanity Benefits" even more relevant. From cancer detection and treatments used in hospitals throughout the world, to the treatment of Attention Deficit Hyperactivity Disorder, to the development of cordless power tools, technologies from NASA exploration have a major impact on our lives here on Earth. And to think, NASA has accomplished this with less than 1 percent of the Federal budget.

As we take our first steps towards sustaining a human presence in the solar system, we can look forward to far-off visions of the past becoming realities of the future. Whole industries that are currently unknown will unveil themselves, offering opportunities to our offspring that shall make their future, and their children's future, brighter.

Over the next century, the Vision for Space Exploration will set in motion activities to improve our understanding of those age-old questions, and inspire new generations to pursue math and science. We will see those new industries and technologies evolve, and discoveries will benefit all mankind. The technologies developed for exploration will underpin and advance the U.S. economy and help to ensure national security. I look forward to sharing this future with all of you.

RADM Craig E. Steidle (Ret.)
Associate Administrator,
Exploration Systems Mission Directorate

National Aeronautics and
Space Administration

The Vision for Space Exploration marks the next segment of NASA's continuing journey to find answers to compelling questions about the origins of the solar system, the existence of life beyond Earth, and the ability of humankind to live on other worlds.

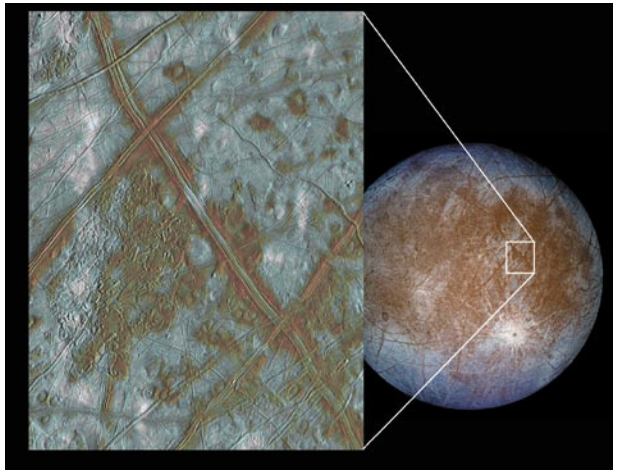
The success of the Vision relies upon the ongoing research and development activities conducted at each of NASA's 10 field centers. In an effort to promote synergy across NASA as it works to meet its long-term goals, the Agency restructured its Strategic Enterprises into four Mission Directorates that align with the Vision. Consisting of Exploration Systems, Space Operations, Science, and Aeronautics Research, these directorates provide NASA Headquarters and the field centers with a streamlined approach to continue exploration both in space and on Earth.

EXPLORATION SYSTEMS

The Exploration Systems Mission Directorate creates capabilities and supporting technologies that will permit sustainable and affordable human and robotic exploration. It includes the biological and physical research necessary to ensure the health and safety of crews during long-duration space flight. Led by Associate Administrator Rear Admiral Craig Steidle, USN (Ret.), the directorate actively supports the Vision for Space Exploration, ensuring that it is both achievable and affordable. The directorate will guide NASA's development of new systems for safe human missions to the Moon, Mars, and beyond.

JUPITER ICY MOONS ORBITER

The mission design requirement document for a proposed mission to Jupiter and its three icy moons was the first product formulated by NASA's new Exploration Systems Mission Directorate. The Jupiter Icy Moons Orbiter (JIMO) is a spacecraft with an ambitious proposed mission that would orbit the three planet-size moons of Jupiter (Callisto, Ganymede, and Europa), which may harbor vast oceans beneath their icy surfaces. The mission would be powered by nuclear fission and launched sometime in the next decade.



The image shows a region of Europa's crust made up of blocks which are thought to have broken apart and "rafted" into new positions. These features provide geologic evidence that Europa may have had a subsurface ocean at some time in its past. Combined with the geologic data, the presence of a magnetic field leads scientists to believe an ocean is most likely present on Europa today.

Managed by NASA's Jet Propulsion Laboratory (JPL), the JIMO mission is part of NASA's Project Prometheus, a program studying a series of initiatives to develop power systems and technologies for space exploration. The JIMO endeavor would be the first NASA exploration mission utilizing nuclear electric propulsion, which would enable the spacecraft to orbit each of these icy worlds to perform extensive investigations of their makeup, history, and potential for sustaining life.

According to Steidle, "The Jupiter Icy Moons Orbiter requirements represent our new way of doing business, tracing exploration strategies to the technology maturation programs that will enable this exciting mission and the other missions that make up Project Constellation." Just as the Apollo Program encompassed NASA's efforts to reach the Moon in the 1960s, Project Constellation embodies the Agency's new initiatives to fulfill the Vision for Space Exploration.

LIFEGUARD SYSTEM

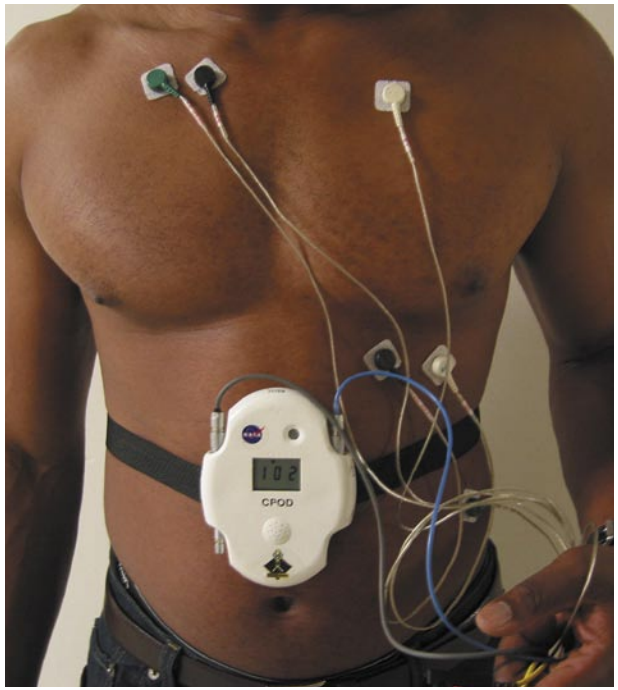
While NASA field centers such as JPL strive to develop more effective ways to safely power, propel, and maneuver spacecraft to explore worlds currently beyond our reach, other centers are preparing the technologies that will enable human beings to visit these worlds. An astrobionics team at NASA's Ames Research Center has focused on physiological monitors for the past decade, conducting research that supports the goals of the Exploration Systems Mission Directorate and the Vision for Space Exploration. The scientists recently developed the LifeGuard system, a lightweight, portable device enabling physicians to monitor the health and safety of explorers in remote locations on Earth. The system may eventually be used in space to monitor astronauts during space travel.

The wireless LifeGuard system watched over the vital signs of several expedition members who sampled soils and water from the world's highest alpine lake, nearly 20,000 feet up the Licancabur volcano, on the border between Chile and Bolivia late in 2003. The LifeGuard units sent real-time vital signs from the members at the volcano to scientists at Ames by satellite. This proved the monitor's potential to work in an extreme environment. The test also demonstrated the enhanced ability for doctors to practice telemedicine over long distances on Earth or potentially in space.

The LifeGuard system allows real-time monitoring of vital parameters such as heart rate, blood pressure, electrocardiogram (EKG), breathing rate, and temperature. It can also measure human movements in three dimensions. The LifeGuard's button sensors stick to the skin to measure a person's EKG and breathing rate, and the device uses an arm cuff to measure blood pressure. The data logger

connects to a sensor clipped or wrapped on an index finger to measure oxygen in the blood and pulse rate.

"The data logger part of the system that collects data from body sensors is about the size of your palm and weighs about 166 grams (6 ounces)," explains Carsten Mundt, an engineer who is developing LifeGuard at Ames. According to Mundt, "The sensors we use are quite easy to apply and comfortable to wear." In addition to potentially monitoring the health of astronauts on long-term spaceflights, the LifeGuard system may provide several applications on Earth. LifeGuard could be used by physicians on Earth to transmit a patient's vital signs during transfer to the hospital, and it could also be worn to monitor patients at home to diagnose sleep disorders, heart disease, or unsteady gait in the elderly. Firefighters and hazardous material workers could also wear the device to monitor their health during dangerous activities.



The LifeGuard system, which may eventually be used in space to monitor astronauts during space travel, recently monitored the vital signs of expedition members sampling soils and water from the world's highest alpine lake.

MOBILE AGENT SOFTWARE

In the spring of 2004, NASA scientists began testing "mobile agent" software that eventually may help astronauts on Mars talk with mission control on Earth. The mobile agent software project, based at Ames Research Center, called upon researchers to play the role of astronauts during tests in Utah's Southeast Desert. The "explorer astronauts" carried backpacks containing "smart" laptop computers that were loaded with the mobile agent software. The software, which scientists say may improve communications between human planetary explorers, robots, and mission support on Earth, comes in several types, including "personal agent" software—software to which people can speak—and "com" software, which links software and hardware devices.

The main objective of the effort was to test the mobile agent system while the explorer astronauts and a robotic assistant conducted real exploration in the desert. During the tests, each person's laptop computer was equipped with personal agent software that could literally speak with them. NASA's Glenn Research Center provided the satellite communications link from the Utah site to the NASA Research & Education Network located at Glenn. During the field work, the explorers used the mobile agent system to conduct real science, looking for geological evidence of past water in the desert as well as fossils from the Jurassic period.

During the tests, the explorers talked with the computer mobile agent software about science observations being made. They needed to relay the name of the location and identify which bag was being used to collect samples, while narrating the contents of the bag and the geologic context. The helper robot that took part in the tests, called the Extravehicular Activity (EVA) Robotic Assistant, followed along with the human explorers.

Developed at NASA's Johnson Space Center, the EVA Robotic Assistant responds to voice commands. The explorer astronaut speaks through a microphone to the personal agent software, which relays commands to the robot's personal agent software. This software activates computer programs that direct the robot to follow the explorer astronauts, take photographs, or carry samples.

During future planetary exploration, data will be relayed by personal agent software to others on the science team, both on the planet's surface and back on Earth. Information will be stored in a database in a Mars or planetary human habitat. The personal agent software will send these data via e-mail to the Earth-bound science team. The software will also automatically transmit images taken by the astronauts to their planetary habitat and to Earth. The computer that astronauts will carry will include a global positioning system device, enabling the software agent to stamp the collected data with time and location.

The astronauts will also be able to tell the software agent what activity they are going to do next by choosing activities from a menu of potential planned subjects. The chosen activity sets up expectations for the personal agent software describing where the explorer should be and how long the activity should continue. If the astronaut deviates from the plan or the planned location, or stays too long, the personal agent software will verbally warn the astronaut. At the same time, the computer agent also will send e-mail to the support team on Earth and to another computer agent in the habitat, which will announce on the habitat's loudspeaker that there is a possible problem.

During a mission, the astronauts will wear biosensors, possibly such as the ones designed for the LifeGuard system, which will detect and transmit human vital signs to his or her personal agent software. If vital signs are not normal, the agent software will send e-mail to Earth and broadcast a warning on the loudspeaker.

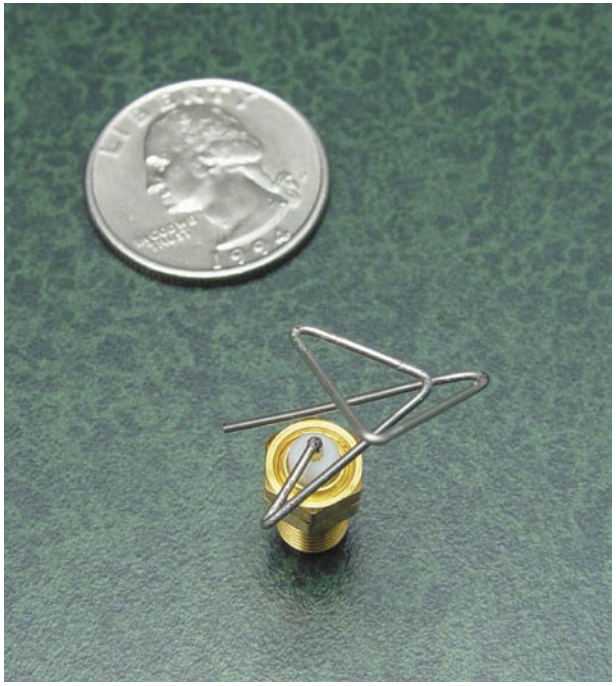
NASA scientists tested the mobile agent system while the explorer astronauts conducted real exploration in the desert.

ARTIFICIAL INTELLIGENCE SOFTWARE

Other current research and development activities supporting the Exploration Systems Mission Directorate are exploring the ways that artificial intelligence (AI) can help engineers design advanced components for long-term spaceflight. Funded by the directorate, four computer scientists at Ames Research Center wrote the AI evolutionary program, which can create designs faster than a human being. The software, which operates on 120 personal computers, can plan devices that are smaller, lighter, stronger, and consume less power—characteristics that meet spaceflight requirements.

The AI software's first task involved designing a satellite antenna scheduled to orbit Earth in 2005. The antenna, able to fit into a 1-inch space, can receive commands and send data to Earth from the Space Technology 5 satellites. The three satellites—each no bigger than an average television set—will help scientists study magnetic fields in Earth's magnetosphere.

According to project lead Jason Lohn, a scientist at Ames, "The AI software examined millions of potential antenna designs before settling on a final one." The software started with random antenna designs and refined them through the evolutionary process. It adapted existing designs quickly to meet changing mission requirements. Scientists also can use the evolutionary AI software to invent and create new structures, computer chips, and even machines. Lohn explains, "We are now using the software to design tiny microscopic machines, including gyroscopes, for spaceflight navigation."



This miniature antenna was developed using a NASA artificial intelligence software program that creates designs faster than a human being.

SPACE OPERATIONS

NASA's new Space Operations Mission Directorate is supported by Johnson Space Center, Kennedy Space Center, Stennis Space Center, and Marshall Space Flight Center. The directorate, led by Associate Administrator William F. Readdy, directs space flight operations, space launches, and space communications, as well as the operation of integrated systems in low-Earth orbit and beyond.

Johnson manages the development, testing, production, and delivery of all NASA human spacecraft, as well as all human spacecraft-related functions such as life support systems, space suits, and spacewalking equipment. Johnson also serves as the lead NASA center for the design and implementation of the International Space Station. Scheduled for completion around 2010, this working laboratory will serve as a stepping-stone to other planets by teaching the essentials of long-term living in space.

Kennedy's slogan, "Launching the NASA Vision," has never been more true or applicable as the Agency works diligently to return to flight safely and implement the Vision for Space Exploration. The Center will play a major role in these endeavors, since its dual mission includes space launch operations and spaceport and range technology development. The Spaceport Technology Center initiative carries out Kennedy's role within NASA to meet the goals of increased safety, reduced cost of space access, and rapid expansion of commercial markets by infusing spaceport technologies into all facets of current and future Space Transportation Systems.

Researchers record data as the hazardous gas detection system is used to analyze the toxic gases produced by active vents, called fumaroles, in the Turrialba volcano in Costa Rica.

VOLCANIC EMISSION MASS SPECTROMETER

A Kennedy research and development team recently used a new hazardous gas detection system to study volcanic emissions in Costa Rica. The new prototype system, named the "Aircraft-based Volcanic Emission Mass Spectrometer (AVEMS)," also will have a direct application to the Space Shuttle Program. The AVEMS is a step toward an advanced system that will be able to detect toxic gas leaks and emissions in the Space Shuttle aft, or rear, engine compartment and the crew compartment, providing an added level of protection for the astronauts and the vehicle.

The Kennedy team used AVEMS to analyze gases vented from the Turrialba volcano in Costa Rica. The tests were conducted from the air and in the volcano's crater. Johnson provided the WB-57F aircraft and support for the nine research flights in the hazardous gas study, while Ames provided infrared and visible photography as well as multispectral imaging on the mission.

The study was the first to sample and quantitatively analyze fresh volcanic gases in their natural state. Active vents in volcanoes, called fumaroles, produce toxic gases such as sulfur dioxide, hydrogen sulfide, and carbon dioxide, which, if too concentrated, can be fatal. "Hikers on the volcanoes sometimes get cold then are attracted to the warm vents. When a large vent is producing massive amounts of carbon dioxide, the carbon dioxide displaces oxygen,

which could be fatal to the hikers nearby," explains NASA project lead, Dr. Tim Griffin.

The new system shows promise for commercial applications in a variety of environments and industries such as semiconductor, petrochemical, automotive, refrigeration, and cathode ray tube. The technology could be used for breath and blood analysis as well as for monitoring air quality in the workplace. "Mass spectrometer technology could be used to ensure public safety and equipment protection in so many areas," says Griffin. "Previous mass spectrometer systems have been so expensive and bulky that their use was limited to laboratories." The new system is small and mobile and is able to easily and accurately produce in-depth data.

WIRE INSULATION REPAIR

Another Kennedy research and development project is investigating innovative methods to repair damaged wire insulation that can lead to self-healing systems. The wire insulation used in the Space Shuttle is either Kapton® (a polyimide) or Teflon® (a polyfluorocarbon). Similar to other critical applications in the aircraft and nuclear industry, wire inspection and repair is important in keeping these systems safe. Existing insulation repair methods use similar repair materials, and either wrap the damaged area with mystic tape and secure the ends with tie-wraps or melt a fluorocarbon polymer over the damaged area with a heat gun. These methods result in poor adhesion to the damaged insulation and can cause breaks at each end of the repair.

NASA's new repair methods for Kapton synthesize a polyimide on the surface of the damaged insulation, producing an excellent seal with very high adhesive forces. In addition to using this technology on the Space Shuttle, NASA has been awarded funding from the Federal Aviation Administration's aging aircraft group and is seeking partners to co-develop and commercialize self-healing insulation repair.

A Space Shuttle Main Engine undergoes a test firing on the A-1 Test Stand at Stennis Space Center.

SPACE SHUTTLE MAIN ENGINE ADVANCES

Stennis Space Center is NASA's primary center for testing and proving flight-worthy rocket propulsion systems for the Space Shuttle and future generations of space vehicles. Having conducted engine testing for 4 decades, Stennis is NASA's program manager for rocket propulsion testing with total responsibility for conducting and managing all NASA propulsion test programs.

The Space Shuttle's Main Engines (SSMEs) reached a significant milestone on January 21, 2004, by surpassing 1 million seconds of successful test and launch firings during a flight acceptance test. The engine test, conducted at Stennis, ran for 8.5 minutes, the length of time it takes the Space Shuttle to achieve orbit. "This 1 millionth-second test is a testimony to the NASA and contractor team that developed, tested, and continues to improve the SSME to safely take humans to low-Earth orbit," said NASA's Miguel Rodriguez, director of the Propulsion Test Directorate at Stennis.

Developed in the 1970s, the SSMEs are the world's most sophisticated reusable rocket engines. Each powerful engine is 14 feet long, weighs about 7,000 pounds, is 7.5 feet in diameter at the end of its nozzle, and generates nearly 400,000 pounds of thrust. The rigorous testing used to verify that an engine is ready to fly is critical to any flight program. According to Michael Rudolphi, Space Shuttle propulsion manager, "The Main Engine that flies today has gone through major upgrades and is safer, stronger, and more reliable than the one that flew on STS-1 in 1981. Reaching this milestone is a historic moment for the Space Shuttle Program."

In another effort to return the Space Shuttle safely to flight, engineers with Stennis' Propulsion Test Directorate recently modified two test stands for Space Shuttle flow liner testing. Flow liners, located in the Space Shuttle's main propulsion system fuel feed lines, protect flexible joints from the liquid hydrogen fuel as it feeds toward the SSME turbopumps. Small cracks have been found in the flow liners inside the hydrogen fuel lines aboard the NASA orbiters Atlantis, Discovery, and Endeavour. The cracks were first found in June 2002, resulting in concern that a piece of flow liner material may work free and enter the SSME turbopumps, causing potential for a premature engine shutdown in flight. After extensive testing and analysis, the existing cracks on the orbiters' flow liners were repaired by welding.

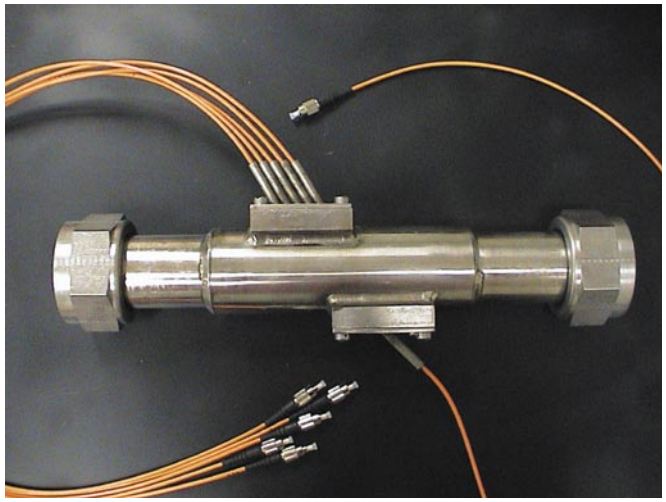
Stennis has reactivated the A-1 Test Stand to accommodate additional SSME upgrade testing and the E-1 Cell 2 Test Position articles are being activated to accommodate future flow liner testing that will be used to gather data while simulating the actual flight environment. The fuel duct on the A-2 Test Stand is also being modified to support fuel flow characterization efforts. The A-2 stand

currently supports SSME testing and certification for flight. The A-1 stand was used for testing the SSME until last summer, when refurbishment of the A-2 stand was completed and all SSME test activities were transferred there.

"We are proud of the effort that was put forth by our A-1 Activation Team," asserts Ronnie Rigney, deputy project manager of the SSME Project Office at Stennis. "Successful completion of the A-1 Activation test demonstrated that we are ready to support the Space Shuttle Main Engine Test Program in its Return to Flight work."

FIBER-OPTIC MASS FLOW SENSOR

Marshall Space Flight Center recently developed a technology that both supports the Vision for Space Exploration and offers opportunities for commercial partnerships with private industry. Companies can license Marshall's new fiber-optic mass flow sensor system, whic was originally developed to accurately determine the flow rates and tank levels of multi-phase cryogenic fuels used on various NASA vehicles, including the Space Shuttle, and in ground-based propulsion testing.

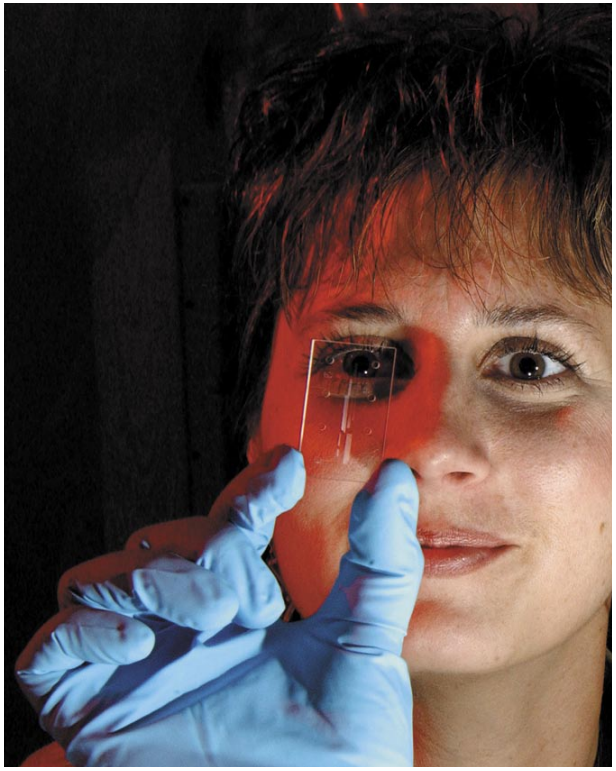


The fiber-optic mass flow sensor system was originally developed to accurately determine the flow rates and tank levels of multi-phase cryogenic fuels used on various NASA vehicles such as the Space Shuttle.

Capable of measuring multi-phase flows in a pipe, the technology is minimally invasive, cost effective, retrofittable, and compact. Marshall's new technology combines high accuracy, intrinsically safe operation, and low-cost flow sensing for virtually any optically transparent medium, providing a superior product for measuring multi-phase flows. Possible applications include oil and gas industry multi-phase flows; industrial, automotive, and aerospace multi-phase flows; powder spray coatings; food processing; and chemical processing, handling, and storage.

LAB-ON-A-CHIP TECHNOLOGY

Another current Marshall research and development effort involves the study of "lab-on-a-chip" technology. The technology allows chemical and biological processes—previously conducted on large pieces of laboratory equipment—to be performed on a small glass plate with fluid channels, known to scientists as microfluidic capillaries. Dr. Helen Cole, project manager for the Lab-on-a-Chip Applications Development program, explains, "We are studying how lab-on-a-chip technology can be used for new tools to detect bacteria and life forms on



Dr. Lisa Monaco, the project scientist for the Lab-on-a-Chip Applications Development program, examines a lab on a chip. The small dots are actually ports where fluids and chemicals can be mixed or samples can be collected for testing.

Earth and other planets, and for protecting astronauts by monitoring crew health and detecting microbes and contaminants in spacecraft."

The Marshall team is collaborating with scientists at other NASA centers and universities to design chips for many applications, such as studying how fluidic systems work in spacecraft and identifying microbes in self-contained life support systems. Since the chips are small, a large number of them can be carried on a Mars rover to search for life or carried on long-duration human exploration missions for monitoring microbes inside lunar or Martian habitats.

SCIENCE

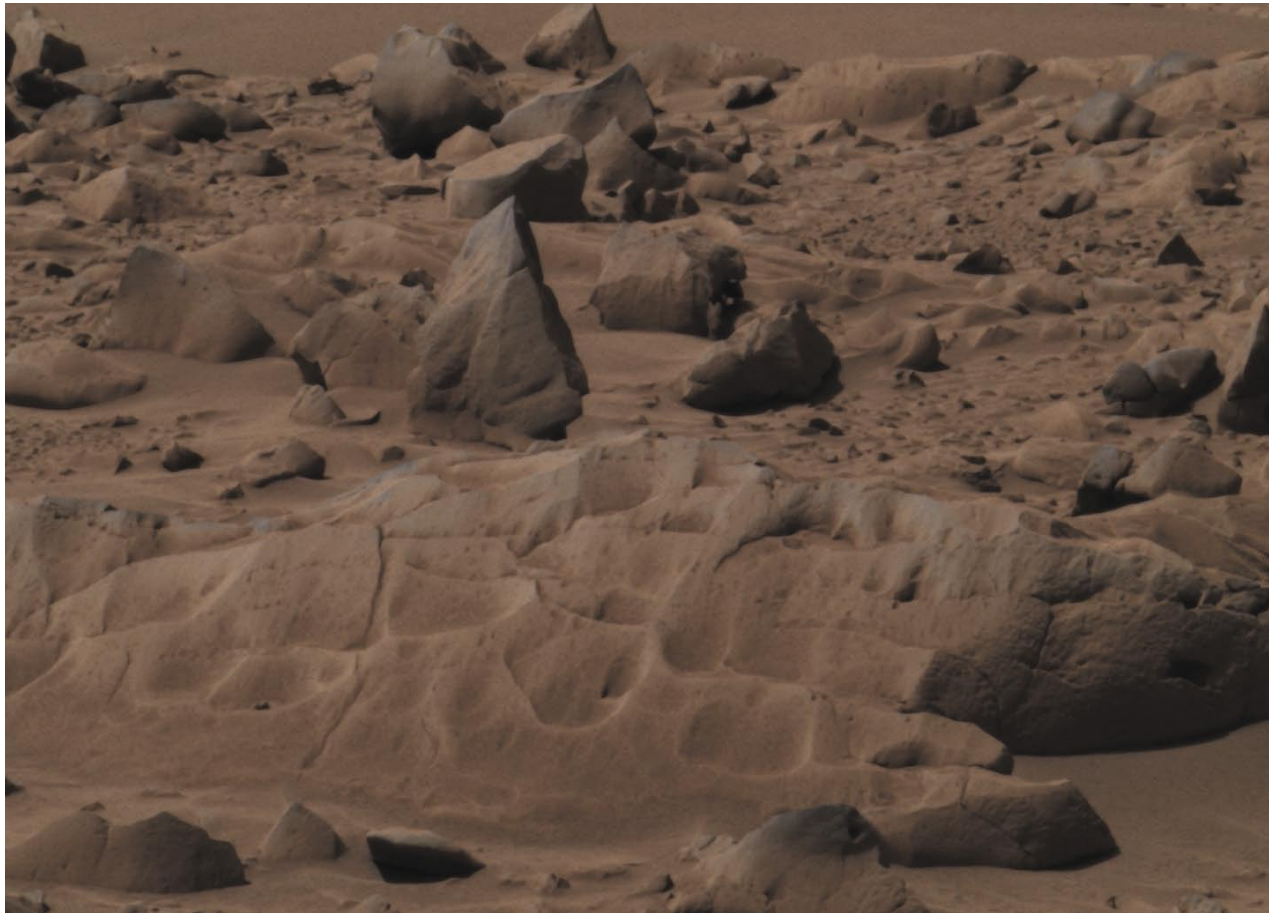
NASA's Science Mission Directorate, headed by Alphonso V. Diaz, carries out the scientific exploration of the Earth, Moon, Mars, and beyond; charts the best route of discovery; and reaps the benefits of Earth and space exploration for society. By combining Earth and space studies, NASA is best able to establish an understanding of the Earth and the surrounding solar system, to assure the discoveries made here will enhance our work there, and vice versa.

MARS EXPLORATION ROVER MISSION

Headlining NASA's research efforts in the areas of science and discovery, the Mars Exploration Rover mission has been turning up valuable data regarding the Red Planet's past and present environment, thanks to a loyal mission team managed by JPL and two determined robotic explorers, Spirit and Opportunity. The big science question for the mission team is how past water activity on Mars has influenced its environment over time. While liquid water cannot exist for long on the surface of Mars today, the record of past water activity on Mars can be found in the rocks, minerals, and geologic landforms, particularly in those that can only form in the presence of water. That is why the rovers are specially equipped with tools to study a diverse collection of rocks and soils that may hold clues to past water activity on Mars.

Spirit and Opportunity are offering unique contributions in pursuit of the overall Mars science strategy to "follow the water." Understanding the history of water on Mars is important to meeting the four science goals of NASA's long-term Mars Exploration program: Determine whether life ever arose on Mars, characterize the climate of Mars, characterize the geology of Mars, and prepare for human exploration.

Spirit traveled 487 million kilometers (302.6 million miles) and nearly 7 full months to reach Mars after its launch from Cape Canaveral Air Force Station on June 10, 2003. On January 3, 2004, Spirit landed on Mars and successfully sent a radio signal to notify the mission team of its historic arrival. NASA chose Gusev Crater as Spirit's landing site, based on evidence from Mars orbiters that this crater may have held a lake long ago. A long, deep valley, apparently carved by ancient flows of water, leads into Gusev. The crater itself is a basin the size of Connecticut, created by an asteroid or comet impact early in the planet's history.



Clues from a wind-scalloped volcanic rock on Mars investigated by NASA's Spirit rover suggest repeated possible exposures to water inside Gusev Crater.

While the rover worked to free itself from its lander platform over the next 12 days, it did not waste any time in taking panoramic pictures of its new "neighborhood" to send back to Earth. The initial images—the highest-resolution pictures ever sent from Mars and more than 3 times as detailed as images from Mars Pathfinder in 1997—excited the mission's scientists about the prospects of exploring the region.

On January 15, Spirit rolled all six of its wheels onto Martian soil to begin what was originally scheduled as a 90-day adventure to explore Mars. Research was underway the next day, as Spirit reached out with its versatile robotic arm and examined a patch of fine-grained soil with a microscope at the end of the arm. One unexpected finding was the detection of a mineral called olivine, which does not survive weathering well. According to the mission scientists, the lack of weathering suggested by the presence of olivine might be evidence that the soil particles are finely ground volcanic material. Another possible explanation is that the soil layer where the measurements were taken is extremely thin, and the olivine is actually in a rock under the soil. The most prevalent elements detected in the soil patch were silicon and iron. Significant levels of chlorine and sulfur were also found, characteristic of soils at previous Martian landing sites but unlike soil composition on Earth. The scientists believe that the soil may not have even originated anywhere near Spirit's landing site, because Mars has dust storms that redistribute fine particles around the planet. The next target for use of the rover's full set of instruments was a rock the mission team named "Adirondack," which was more likely to have originated nearby.

Prior to the chance to study Adirondack, Spirit temporarily stopped communicating on January 22. The problem was later diagnosed as a memory-management issue. Engineers regained partial control of the spacecraft within days and reformatted the rover's flash memory to prevent recurrence of the problem. Meanwhile, NASA's second Mars Exploration Rover, Opportunity, successfully sent signals to Earth during its January 25 landing in a region of Mars called Meridiani Planum, halfway around the planet from the Gusev Crater site. A healthy Spirit got back to work 4 days after the arrival of its twin, and resumed its pursuit to examine Adirondack. Spirit grinded the rock with an abrasion tool to reveal its interior. Mission scientists were able to confirm from the sublayer's properties that Adirondack was volcanic basalt, a predominant material found on the planet's surface. In spite of this, further examination of Martian rocks would turn up more promising results.

In early March, Opportunity found strong evidence that the region of Meridiani Planum was once wet. A rock outcrop dubbed "Guadalupe" yielded clues that made the case for a watery history, such as the presence of sulfates and crystal-filled niches. "Liquid water once flowed through these rocks. It changed their texture and it changed their chemistry," says Dr. Steve Squyres of Cornell University, Ithaca, New York, and principal investigator for the science instruments on the two rovers. "We've been able to read the tell-tale clues the water left behind, giving us confidence in that conclusion." On Earth, rocks with as much salt as this outcrop of Mars rocks either have formed in water or, after formation, have been highly altered by long exposures to water.

Back at the Gusev Crater, Spirit found hints of a water history in a rock—albeit a very different type of rock than those in which Opportunity found clues to a wet past. A dark volcanic rock dubbed "Humphrey," about 2 feet tall, shows bright material in interior crevices and cracks that looks like minerals crystallized out of water, according to the team scientists. The amount of water suggested by the possible crystals in Humphrey is far less than what is indicated by the minerals and structures that Opportunity revealed in the Guadalupe rock outcrop, indicating that Mars is a diverse planet.

Further clues uncovered by Opportunity caused the mission team to deduce that some rocks on Mars probably formed as deposits at the bottom of a body of gently flowing saltwater. "We think Opportunity is parked on what was once the shoreline of a salty sea on Mars," Squyres notes. The evidence continued to mount up in early April when Spirit grinded down a wind-scalloped volcanic round and found a fracture in which water may have flowed through at one time.

Given the success of the rovers, NASA decided to extend the mission, handing Spirit and Opportunity up to 5 months of overtime assignments.

AURA EARTH-OBSERVING MISSION

In searching for conditions that might support life on other planets, one of the first things to look for is water—as in the case of the Mars rovers—but the thin sliver of gases and air that make an atmosphere around a planet is just as necessary for life to exist. On July 15, NASA launched Aura, a next-generation, Earth-observing satellite managed by Goddard Space Flight Center that will supply the best information yet about the health of Earth's atmosphere, according to the Space Agency. Aura will provide an essential component for understanding changes in our climate, our air quality, and the ozone layer that protects life from harmful solar radiation. In doing so, it will help answer some fundamental questions regarding climate change.

One question that researchers have asked is: "Is the stratospheric ozone layer recovering?" International agreements have banned ozone-destroying chemicals like chlorofluorocarbons (CFCs), but scientists are unclear about the effectiveness of these treaties. Aura will accurately detect global levels of CFCs, and their byproducts, chlorine and bromine, which destroy the ozone layer.

Another question to which researchers need more information is: "What are the processes controlling air quality?" Aura will help greatly to unravel some of these mysteries by tracking the sources and processes controlling global and regional air quality. When ozone exists in the lower atmosphere, the troposphere, it acts as an air pollutant. Gasoline and diesel engines give off gases in the summer that create ozone and smog. Aura will help scientists follow the sources of ozone and its precursors.

Additionally, Aura will offer insights into the question: "How is the Earth's climate changing?" As the composition of Earth's atmosphere changes, so does its ability to absorb, reflect, and retain solar energy. Greenhouse gases, including water vapor, trap heat in the atmosphere. Airborne aerosols from human and natural sources absorb or reflect solar energy based on color, shape, size, and substance.

The impact of water vapor and aerosols on Earth's climate remains largely unquantified, but now Aura will have the unique ability to monitor these agents.

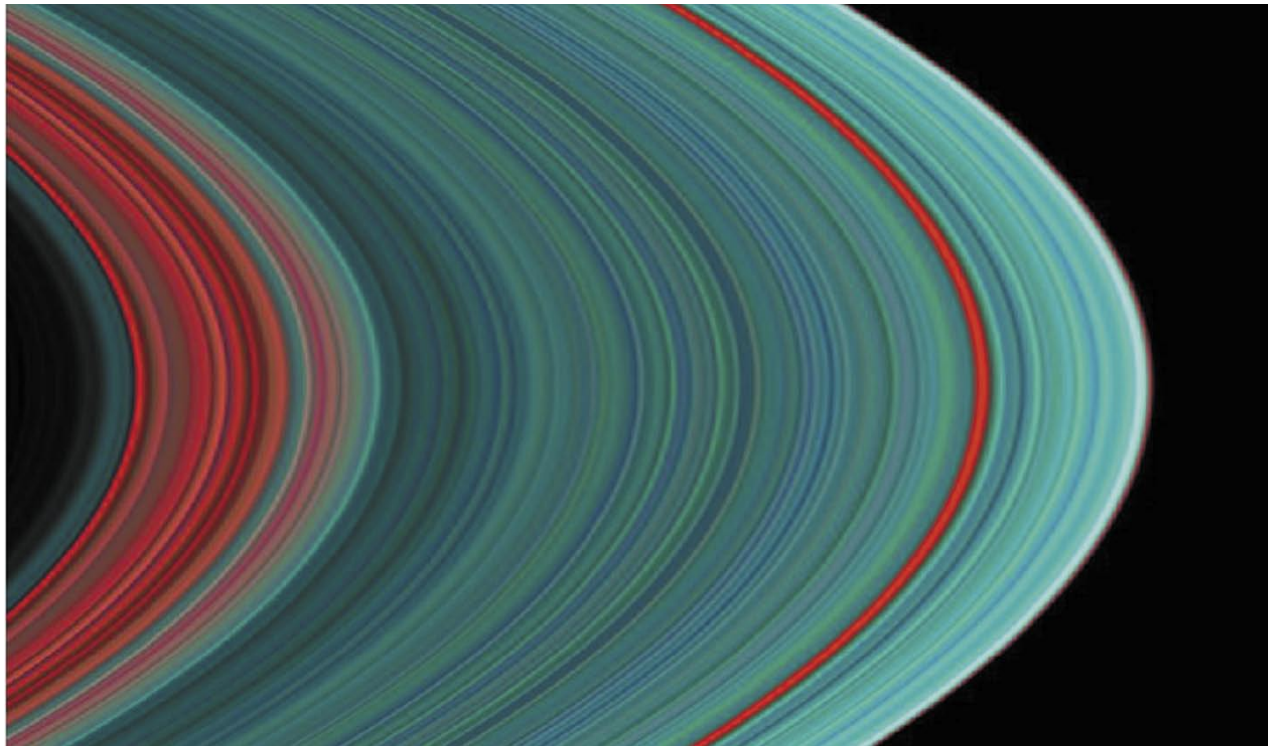
Aura's space-based view of the atmosphere and its chemistry will complete the first series of NASA's Earth Observing System satellites. The other satellites are Terra, which monitors land, and Aqua, which observes Earth's water cycle.

CASSINI-HUYGENS MISSION

An extensive tour of Saturn, its majestic rings, and its 31 known moons is currently underway, following a nearly 7-year journey to the planet.

Launched October 15, 1997, from Cape Canaveral Air Force Station, Cassini is the most instrumented and scientifically capable planetary spacecraft ever flown. It aims to fulfill the Cassini-Huygens mission, a cooperative project of NASA, the European Space Agency, and the Italian Space Agency. The 4-year mission, managed by JPL, will draw upon the spacecraft's 18 highly sophisticated science instruments to study the Saturnian system in detail.

Cassini's first stop on its historical tour of Saturn was a June 11 fly-by visit of Phoebe, Saturn's largest outer moon. Data collected from the fly-by indicate that Phoebe may be a frozen artifact of a bygone era, some 4 billion years ago, like a woolly mammoth trapped in Arctic ice. Mission scientists concluded that Phoebe is likely a primordial mixture of ice, rock, and carbon-containing compounds, and further believe bodies similar to this moon were plentiful in the outer reaches of the solar system long ago.

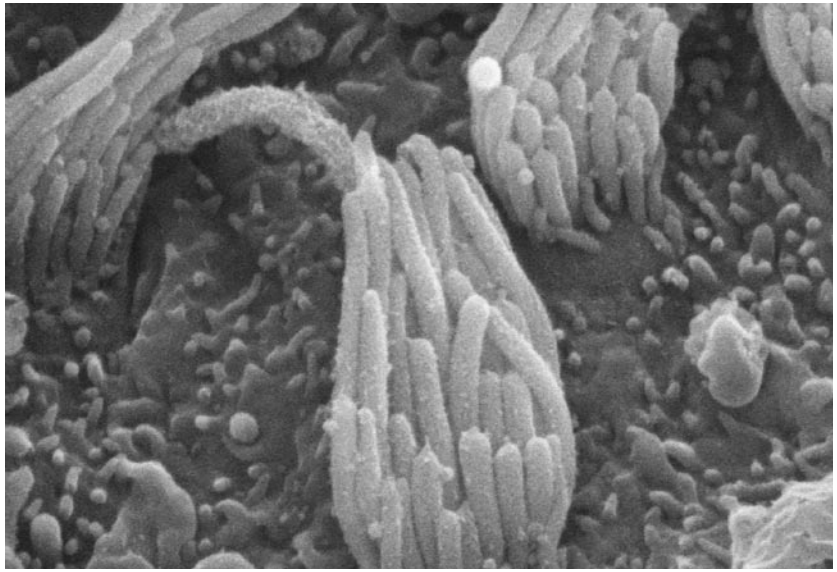


This image, taken with Cassini's Ultraviolet Imaging Spectrograph instrument, indicates that there is more ice toward the outer part of Saturn's rings than the inner part.

The international Cassini-Huygens mission successfully entered orbit around Saturn on June 30 of this year, after completing a critical 96-minute main engine burn that was calculated to slow the spacecraft by 626 meters per second, or 1,400 miles per hour. According to Robert T. Mitchell, program manager for the mission, orbit insertion is "sort of like applying your brakes while driving your car downhill. Although you've got your foot on the brakes, you still pick up speed as a steep gravity pulls you in." During the orbit insertion, Cassini flew closer to Saturn than it will at any other time during the planned mission.

Just 2 days after Cassini entered Saturn's orbit, preliminary science results from breathtaking images and scientific measurements showed a complex and fascinating planetary system. One early result concerns Saturn's Cassini Division, the large gap between the "A" and "B" rings. While Saturn's rings are almost exclusively composed of water ice, new findings show the Cassini Division contains relatively more "dirt" than ice. Further, the particles between the rings seem remarkably similar to dark material that scientists saw on Phoebe. These dark particles refuel the theory that the rings might be the remnants of a moon. Also, Cassini's ultraviolet imaging instrument detected the sudden and surprising increase in the amount of atomic oxygen at the edge of the rings. The finding leads scientists to hypothesize that something may have collided with the main rings, producing the excess oxygen.

Still to come, the Cassini spacecraft and its piggybacking Huygens probe (built by the European Space Agency) will target Saturn's largest moon, Titan. "In the 350 years since the discovery of Titan we have come to see it as a world with surprising similarities to our own, yet located almost 1.5 billion kilometers (900 million miles) from the Sun," said Dr. Jonathan Lunine, Huygens interdisciplinary scientist and professor of planetary science and physics



High-resolution image of the hair bundle (stereocilia and kinocilium) of a horizontal semicircular canal hair cell in a young chicken, taken with a scanning electron microscope (16,250 times magnitude). The electron micrograph was obtained during a remote collaborative scientific activity between NASA Ames' Visualization, Imaging, and Simulation Technology Center and the National Institute of Deafness and Other Communication Disorders in Bethesda, Maryland.

at the University of Arizona, Tucson. "With a thick, nitrogen-rich atmosphere and possible hydrocarbon seas, Titan may harbor organic compounds important in the chain of chemistry that led to life on Earth."

On December 24—6 months after reaching Saturn—Cassini will release the wok-shaped Huygens probe towards Titan. The event will be by far the most distant descent of a robotic probe on another object in the solar system. On January 14, 2005, Huygens will enter Titan's atmosphere, deploy its parachute, and begin its scientific observations of Titan.

REMOTE SCANNING ELECTRON MICROSCOPY

In another far-reaching extension of NASA's scientific know-how, researchers for the first time can study laboratory specimens from thousands of miles away by remotely operating NASA's new "super magnifying glass."

The Remote Scanning Electron Microscopy (RSEM) technology was developed at Ames Research Center, and has been successfully tested to allow scientists to help NASA solve problems encountered by astronauts during long-duration spaceflights.

"This technology will enable multiple researchers at locations across the country to observe and control the scanning electron microscope, thus allowing for remote, real-time simultaneous analysis of tissue by several investigators," notes Dr. Richard Boyle, director of the Biological Visualization, Imaging, and Simulation Technology Center at Ames.

In contrast to conventional microscopes that use light waves, the RSEM uses electrons to magnify details of tissue from 10 to 100,000 times. This "super-dissecting microscope" illuminates the sample with a great depth of field and produces three-dimensional, high-resolution images. All scientists need to use the RSEM is a suitable Web browser and network access to connect to the instrument. A remote-control system on the microscope enables real-time interface with the tissue researchers are studying.

The technology is being utilized in a collaborative project with the National Institute of Deafness and Other Communication Disorders in an attempt to unravel key developmental processes of structures of the inner ear involved in hearing. "The inner ear cells change when you are in space and this impacts astronauts' health," claims NASA astronaut and physician Dr. Yvonne Cagle. "If we understand how these hair cells reposition themselves, we can better understand what happens over a long period of time in space."

AERONAUTICS RESEARCH

The Aeronautics Research Mission Directorate, led by Associate Administrator Dr. J. Victor Lebacqz, is committed to developing tools and technologies that can help to transform how the air transportation system operates, how new aircraft are designed and manufactured, and how our Nation's air transportation system can reach unparalleled levels of safety and security. Such tools and technologies will drive the next wave of innovation, enabling missions to be performed in completely new ways and creating new missions that were never before possible. The three NASA field centers that make up the directorate are: Dryden Flight Research Center, Glenn Research Center, and Langley Research Center.

As NASA's primary installation for flight research, Dryden Flight Research Center sits on the northwest edge of Rogers Dry Lake, at Edwards Air Force Base in Southern California's high desert. Since its creation in 1946, Dryden has advanced the design and capabilities of many civilian and military aircraft. To demonstrate improved reliability, capability, and enhanced safety, new technologies and new vehicles for both aviation and space flight require validation through flight testing. Dryden's workforce expertise in aeronautics and in the development of flight research tools and techniques, coupled with the suite of specialized laboratories and facilities needed for flight validation, are key to the development and maturation of new vehicles. Dryden operates a variety of

specialized aircraft that are used to verify a technology's performance, validate its safety and reliability, and discover any previously unknown problems.

Glenn Research Center, located in Cleveland, Ohio, and founded in 1941, provides research leadership in power and propulsion technologies for aircraft and spacecraft applications, aerospace communications, microgravity fluid physics and combustion, and bioscience and bioengineering. Glenn researchers are working to develop, verify, and transfer air-breathing propulsion technology for subsonic, supersonic, hypersonic, general aviation, and high-performance aircraft and rotorcraft, along with conducting fundamental research in propulsion-related specialties and new technologies, such as high-temperature nanomaterials, nanodevices, and computational intelligence. In the area of aerospace communications, Glenn develops communication and network architectures, systems modeling, and enabling technologies for global communications network connectivity and integrated communications, navigation, surveillance, and weather information.

Langley Research Center, located in Hampton, Virginia, and established in 1917, is renowned for scientific and technological expertise in aerospace research, systems integration, and atmospheric science. Langley leads NASA initiatives in aviation safety and security, quiet-aircraft technology, small-aircraft transportation systems, and aerospace vehicles systems technology. The Center's unique infrastructure of wind tunnels, laboratories, and equipment arrays have enabled researchers to develop, validate, and deliver to the commercial sector technologies to improve the effectiveness, capability, efficiency, and safety of the Nation's air transportation system. Langley supports space programs with atmospheric research and technology testing and development. The Center serves a principal role in understanding our planet through uniquely developed atmospheric missions, measurement instruments, and climate prediction data.

The X-43A hypersonic research aircraft and its modified Pegasus booster rocket accelerate after launch from NASA's B-52B launch aircraft over the Pacific Ocean.

X-43A HYPERSONIC RESEARCH AIRCRAFT

In a combined research effort involving Dryden, Langley, and several industry partners, NASA recently demonstrated the value of its X-43A hypersonic research aircraft, as it became the first air-breathing, unpiloted, scramjet-powered plane to fly freely by itself. The March 27 flight, originating from Dryden, began with the Agency's B-52B launch aircraft carrying the X-43A out to the test range over the Pacific Ocean off the California coast. The X-43A was boosted up to its test altitude of about 95,000 feet, where it separated from its modified Pegasus booster and flew freely under its own power.

Two very significant aviation milestones occurred during this test flight: First, controlled accelerating flight at Mach 7 under scramjet power, and second, the successful stage separation at high dynamic pressure of two non-axisymmetric vehicles. To top it all off, the flight resulted in the setting of a new aeronautical speed record. The X-43A reached a speed of over Mach 7, or about 5,000 miles per hour faster than any known aircraft powered by an air-breathing engine has ever flown.

Hyper-X, NASA's multi-year experimental hypersonic ground and flight test program for the X-43A, is demonstrating air-breathing engine technologies that promise to increase payload capacity—or reduce vehicle size for the same payload—for future hypersonic aircraft and/or reusable space launch vehicles. As envisioned, payload capacity will be increased by discarding the heavy oxygen and associated tanks that rockets must carry by using a propulsion system that uses the oxygen in the atmosphere as the vehicle flies at many times the speed of sound. Hydrogen fuels the X-43A's scramjet engine, which scoops oxygen from the atmosphere for combustion.

In-flight icing research activities will soon be aided by a new addition to Glenn Research Center. A former U.S. Navy S-3 Viking aircraft was recently transferred to NASA and will undergo modifications to provide a state-of-the-art flying laboratory in 2006.

S-3 VIKING ICING RESEARCH AIRCRAFT

Meanwhile, at Glenn, researchers under NASA's Aviation Safety and Security program are preparing to retire a 22-year-old icing research "workhorse" in order to accommodate a successor that will provide increased power, speed, and range. The S-3 Viking, a former U.S. Navy aircraft, will replace Glenn's current icing research aircraft, a DeHavilland Twin Otter, with initial research flights scheduled to be performed in 2006. The S-3 Viking arrived at Glenn in March and is being modified by the Center's technicians to incorporate diagnostic tools and allow for in-flight icing weather forecasts.

The DeHavilland Twin Otter icing research aircraft has helped Glenn in studying icing cloud characterization, natural icing physics studies, full-scale iced aircraft aerodynamics, and ice protection development. It has also helped solve the problems of tail plane stall and super-cooled large droplet dangers. However, to support NASA's new aviation safety objectives, strategic icing research plans have identified that icing flight research will require increased capability in range, speed, payload, and onboard power beyond the Twin Otter's capabilities.

The S-3 Viking's range and speed will enable research flights from Cleveland to Wyoming and back in a single day. These increased capabilities are essential in the areas of improved aviation weather forecast development, icing simulation tool development, icing cloud characterization, identification and simulation of aerodynamic effects of icing, and continued development of education and training materials for modern regional and general aviation/business aircraft operators.

The NASA Aviation Safety and Security program is a partnership with the Federal Aviation Administration, aircraft manufacturers, airlines, and the U.S. Department of Homeland Security that is working to reduce the fatal aircraft accident rate and protect air travelers and the public from security threats.

As NASA begins its new quest to achieve the Vision for Space Exploration, the research and development efforts across the Agency will continue to bring cutting-edge technologies to the American public. These innovations will help build the future, while protecting and improving the world today.

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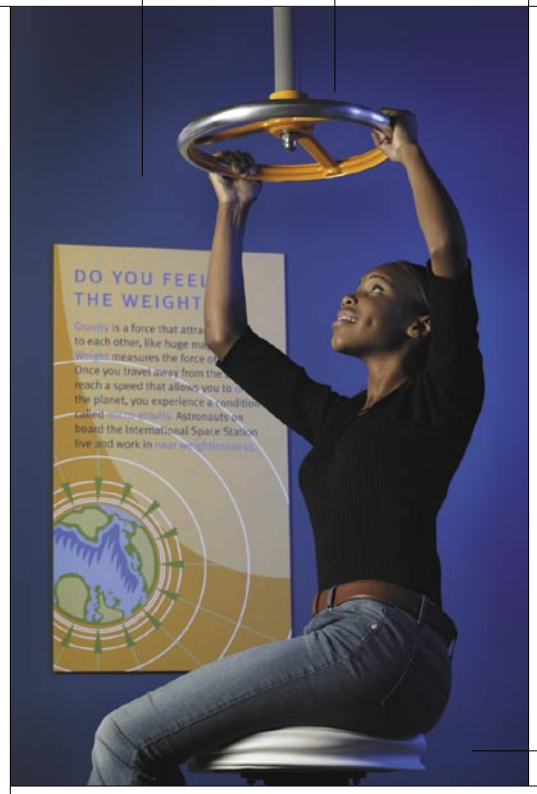
EDUCATION NEWS AT NASA



NASA's challenging missions provide unique opportunities for engaging and educating America's youth, the next generation of explorers. Led by Chief Education Officer Dr. Adena Williams Loston, the Agency coordinates education programs for students, faculty, and institutions in order to help inspire and motivate the scientists and engineers of the future.

On the first anniversary of the NASA Explorer Schools program, NASA announced the selection of 50 new schools across the Nation that will share in studying the exciting world of math and science through the program. Each year, the program partners 50 school teams with NASA for a 3-year period to participate in real-life experiences that inspire students' imaginations. The goal is to spark their interest in pursuing careers in math, science, technology, and engineering.

The program, which was launched in June 2003, sends science and mathematics teachers "back to school" at NASA centers during the summer to acquire new resources and technology tools. Sponsored in collaboration with the National Science Teachers Association, the program uses NASA's unique content, experts, and resources to make learning science, mathematics, and technology more appealing to students. During the commitment period, NASA education specialists and scientists provide investigation opportunities and professional development for the teams of teachers. After the summer training ends, the teachers take the new material and translate it into subjects that will motivate their students.

In April 2004, several Explorer Schools participated in NASA's Reduced Gravity Student Flight Opportunities program. Teams of teachers and administrators from Nebraska, Minnesota, and Iowa flew aboard NASA's KC-135A aircraft. Known as the "weightless wonder," the KC-135A is a flying science laboratory that alternates steep climbs and dives, giving riders the best opportunity to experience weightlessness on Earth.

Teachers from several Explorer Schools conducted microgravity experiments aboard the KC-135A aircraft, a flying science laboratory that gives riders the best opportunity to experience weightlessness on Earth.

Students and teachers from the NASA Explorer Schools worked in collaboration with NASA scientist-mentors to develop microgravity experiments. Two teachers from each school conducted the experiments during flights aboard the KC-135A aircraft. The flights took place from Ellington Field in Houston, Texas, near NASA's Johnson Space Center.

In 2004, three teachers were selected to embark on a new education mission through NASA's Educator Astronaut program. Mission Specialist-Educators Joe Acaba, Ricky Arnold, and Dottie Metcalf-Lindenburger were introduced in May as members of the 2004 Astronaut Candidate Class. These educators are now full-fledged astronaut candidates who will help ensure a new generation is ready for the challenges of exploration.

When NASA opened the door to professional educators to apply for the astronaut corps in January 2003, teachers from elementary, middle, and high schools filed their applications with hopes of making the team. Acaba, Arnold, and Metcalf-Lindenburger will represent those educators as they train for and perform their duties as astronauts. With the knowledge gained from this program, the three educator astronauts will inspire students to consider careers in math, science, technology, and engineering.

In another effort designed to address the national need for a new generation skilled in these disciplines, NASA recently created the Corporate Recruitment Initiative (CRI) to attract and maintain a work force capturing the full potential of U.S. diversity. In September 2003, the Agency began hosting a series of events called NASA Awareness Days on college and university campuses. NASA has a 5-year plan for the CRI and an integrated, Agency-wide approach to human capital management that is coordinated by the Offices of Education, Human Resources, and Equal Opportunity programs. The goal of the initiative is to attract a diverse workforce with the technical competencies needed to accomplish NASA's challenging missions.

NASA expects the CRI will strengthen the Agency's college recruitment program by increasing students' awareness of and interest in NASA education and employment opportunities. The CRI will partner with professional

and educational organizations for minority, women, and individuals with disabilities in order to enhance interest and participation in NASA career opportunities. By the late fall of 2004, teams of NASA representatives, including NASA Administrator Sean O'Keefe, Deputy Administrator Frederick D. Gregory, and Associate Deputy Administrator for Institutions and Asset Management James Jennings, will have met with students from approximately 40 institutions.

In November 2003, NASA introduced an unprecedented traveling educational space exhibition designed to inspire young people and raise public awareness about space exploration. "SPACE: A Journey to Our Future" was created in collaboration between NASA and the National Science Teachers Association. The sights and sounds of space exploration envelop visitors through live performances, interactive displays, state-of-the-art projection, and audio technology. The exhibition will travel to museums and science centers in several U.S. cities over the next 5 years.

Back in the classroom, NASA expanded NASAexplores, a Web-based education program that features express lessons and online resources for teachers and students. The Web site includes articles about research conducted in microgravity, the low-gravity environment on spacecraft such as the International Space Station and the Space Shuttle. Biology and physics space research material, provided by NASA's Office of Biological and Physical Research, add to articles and lessons about aeronautics, exploration systems, and space flight. The site has attracted users in more than 100 countries with more than 1.5 million hits monthly over the past 2 years.

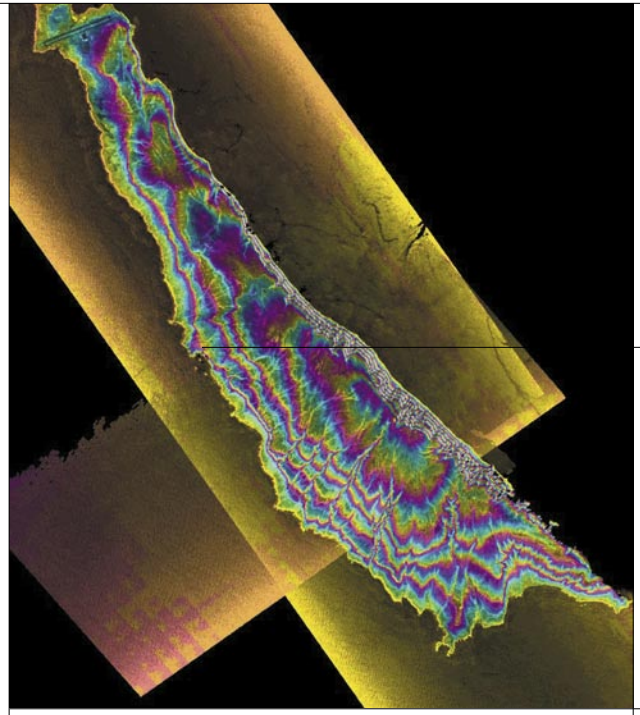
New space research topics planned for the site include gravity and space environmental impacts on life; research opportunities that expand understanding of the laws of gravity and enrich life on Earth; issues around human survival in space; technologies to enable the next generation of explorers to explore space; and strategies for inspiring the next generation to take up the challenges of exploration.

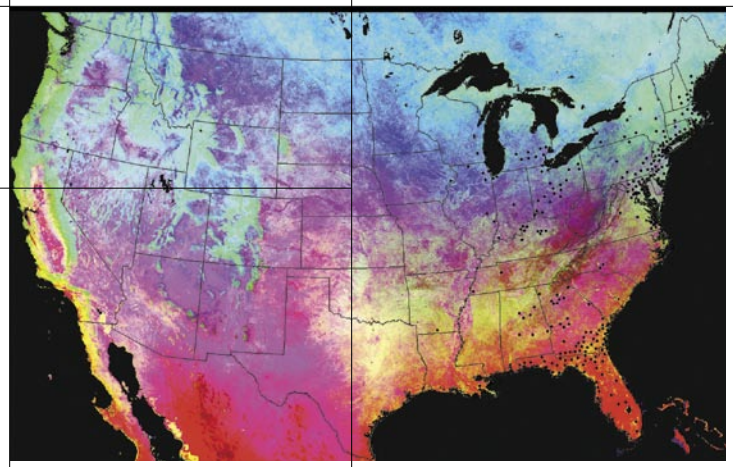
"The new NASAexplores content will give K through 12 teachers and students access to materials that focus on all aspects of microgravity, from its physiological effects on the human body to its physical effects on materials and biological samples exposed to the space environment," says Jim Pruitt, manager of education programs at Marshall Space Flight Center. Pruitt is responsible for the creation and management of NASAexplores.

Each NASAexplores lesson is presented in four versions: elementary, middle, high school, and teachers' editions. Each grade-level article features two lesson plans for students, teacher sheets, and a glossary. Weekly e-mail notices, with abstracts of articles and brief descriptions of the latest lesson plans and activities, are sent to subscribers. The site is updated each Thursday with new material, including news and details about national education conferences and other events of interest to the education community.

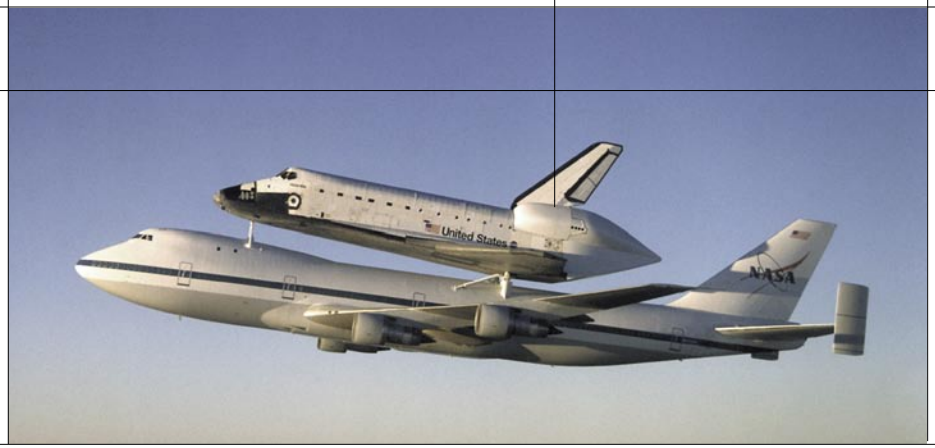
"Educators have one of the world's most important jobs, educating the next generation," says Pruitt. "NASA's mission statement dedicates the Agency to inspiring the next generation of explorers, and we believe that partnering with teachers is vital to this goal."

The exhibition, "SPACE: A Journey to Our Future," is traveling throughout the United States as an educational tool to inspire young people and raise public awareness about space exploration.





PARTNERSHIP SUCCESSES



As NASA plots new courses to fulfill its bold, new mission to explore the Moon, Mars, and beyond, the Agency continues to hold steadfast in its commitment to explore and improve our very own home planet. In doing so, NASA fervidly goes to great lengths to draw correlations between the "know-how" of its many scientists, engineers, and other technology facilitators, and the "know-how" of Federal agency counterparts, academic institutions, and private organizations. By sharing knowledge and resources, these entities come together to find the common ground necessary to preserve the past, present, and future of Earth—in the best interests of all of its inhabitants.

The success that results from these partnerships is not always measured in the form of tangible spinoff products. Often, the outcomes yield benefits that are not physical in nature, and therefore cannot be seen or touched. Instead, these unique benefits are experienced, in a way that impacts all that exists on Earth. The following examples are just a few of the ways we experience NASA's impact as it reaches out to improve the quality of life on Earth.

COMMERCIAL AVIATION SAFETY

An aircraft normally used to transport the Space Shuttle has been pressed into service to test technology that could make airliners safer.

Researchers from Glenn Research Center arranged for a fuel-inerting system to be installed aboard a NASA Boeing 747. The system, designed to reduce the chance of an explosion inside an airplane tank, made its first flight tests in June as part of ongoing research being conducted by the Federal Aviation Administration (FAA) in partnership with NASA.

NASA's Boeing 747 Shuttle Carrier Aircraft, seen here delivering Space Shuttle Atlantis to Kennedy Space Center, was used to study a fuel-inerting system that is designed to reduce the chance of explosion inside an airplane tank.

The FAA had already tested the system using ground-based facilities, but the next critical step in the technology development was the program of actual flight tests aboard a large aircraft, such as NASA's 747. Glenn's Dr. Clarence Chang proposed that the FAA use the B747-100 Shuttle Carrier Aircraft.

The 747 flight tests, completed in 2 weeks at Johnson Space Center, produced data the FAA will use to help implement its recently announced policy to reduce fuel tank flammability. The FAA and NASA have been working on technology to prevent fuel tank fires since July 1996, when TWA Flight 800, a Boeing 747-131, suffered a catastrophic fuel tank explosion and crashed. To design a system that can be more readily installed on airliners, the FAA developed a relatively simple and unique technology-test system made up of inerting technology already available. NASA is conducting research that is closely coupled with the FAA's efforts. Engineers at Glenn are studying next-generation advanced gas-separation technologies that can make inert gas generation cheaper and fuels harder to ignite in the tank. This work, and research into advanced fire-detection gas sensors, is part of NASA's Aviation Safety and Security program.

ARCHAEOLOGY

Federal legislation mandates that all archaeological sites on Federal lands be located and evaluated by Federal managers, particularly if the sites could be damaged by construction or military maneuvers. Legislation also specifically protects Native American burial sites on Federal lands. However, less than 10 percent of the more than 700 million acres under Federal control have been surveyed, according to a recent National Park Service report.

In a conventional survey, archaeologists usually cover an area on foot. Sometimes they have to dig holes to see beneath the surface. It is a slow and expensive procedure. Last year, the U.S. Department of Defense's Strategic Environmental Research and Development program

turned to researchers Dr. Ronald Blom, a Jet Propulsion Laboratory (JPL) geologist, and Dr. Douglas Comer, an archaeologist, to see if a JPL instrument with an advanced type of radar could help speed up the process and make it more economical.

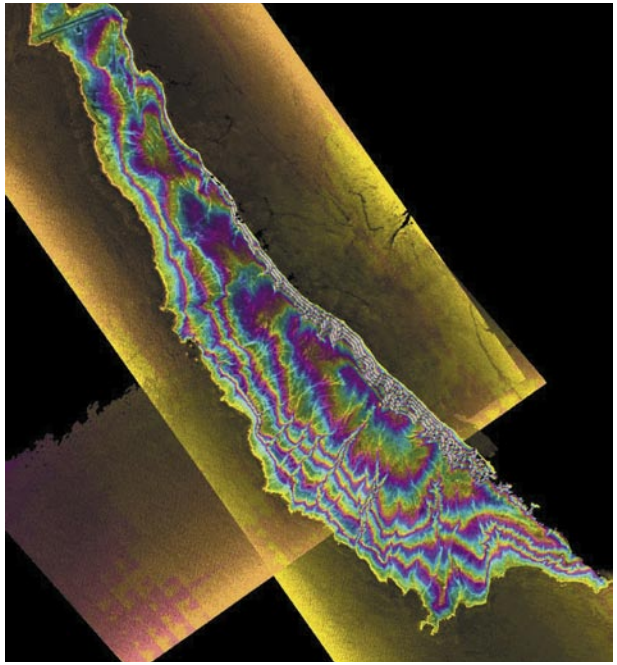
To test the idea, Blom, Comer, and their colleagues recently set out for San Clemente Island. Controlled by the U.S. Navy, San Clemente is the southernmost of the eight California Channel Islands, about 25 miles long and 31 miles offshore, northwest of San Diego. There are no ancient cities, temples, or monuments, but evidence remains of the Native Americans who camped and fished there for hundreds and thousands of years before the Spanish arrived in the 18th century.

Researchers began surveying the island the old-fashioned way, by closely analyzing some of the sites on foot. They then collected radar data from above the island with the unique JPL instrument known as Airsar, short for airborne synthetic aperture radar. Airsar is not new to archaeology, however. In the 1990s, it revealed a previously unknown section of the ancient city of Angkor in Cambodia.

"Radar is particularly good at describing the physical environment and sensing changes, especially man-made changes," notes Blom. The idea in the San Clemente project was to collect Airsar data over a large area, process the data to bring out indications of past human presence, and then combine the results with other information, such as detailed topographical measurements, to target the most likely spots to search for archaeological sites.

So far, the results have been promising. "Yes, we can find archaeological sites," says Blom. "They show up as bright radar spots. Now we need to refine the system and find ways to screen out false positives."

The researchers are incorporating the radar results into a geographic information system, where they can be combined with detailed topographical measurements and information on soils, proximity of fresh water, drainage,



Radar reveals details of San Clemente Island's environment, history, and topography.

and vegetation. "We're looking for patterns that link the archaeological sites with the island's geography," says Blom. "We know, for example, that most sites will be within 200 meters or so of a source of fresh water. So far, radar has not only shown us where many sites are, it has also told us so much about the environment that we know where the sites should be."

The final result, they hope, will be a model that can predict which bright spot on the radar image will indeed be a potential archaeological site—or in other words, they hope the radar will allow them to look at the haystack and predict where the needle will be.

"Of course, our ultimate goal," adds Blom, "is to identify and protect our cultural heritage so that we can both learn from those who came before and honor them."

WEATHER FORECASTING

NASA is providing new technology and satellite data to help forecasters at the National Oceanic and Atmospheric Administration (NOAA) create the best possible forecasts of severe weather situations.

NASA data gathered from satellites, a lightning ground-tracking network, and unmanned vehicles that fly into storms are some of the many tools used by NOAA, the Federal agency charged with issuing weather forecasts. These tools will help make the severe weather season safer for everyone. "It's an evolutionary process and partnership between NOAA and NASA," claims Bill Patzert, a JPL oceanographer. "NOAA is the ultimate operational meteorological agency in the world, and NASA is developing state-of-the-art operational and fundamental research to make it better than ever. Together we're looking to the future to provide better and better service to the American public."

NOAA's National Weather Service is responsible for monitoring and forecasting severe weather events. The service issues watches and warnings for tornadoes, flash floods, severe thunderstorms, and non-precipitation events (such as high-wind warnings), as well as daily weather forecasts. It reaches the public with these watches and warnings mainly through NOAA weather radio and the Internet.

At NASA, scientists pull data from Earth-observing satellites and models to characterize and understand the way atmosphere, oceans, and land interact. "Adding NASA satellite data and model output to NOAA forecasts could lead to more confident 7-day severe local storm forecasts, better prediction of thunderstorm occurrence by 3 hours, and an increase in tornado warning lead times by 18 minutes," says Dr. Marshall Shepherd, research meteorologist at Goddard Space Flight Center. NASA satellite data that enhances NOAA's weather model forecasts include surface wind data from QuikScat and rainfall data from the Tropical Rainfall Measuring Mission satellite. NASA's new Aura satellite will additionally provide

A lightning ground-tracking network from NASA is one of the many tools the National Oceanic and Atmospheric Administration is using to create the best possible forecasts of severe weather situations.

temperature and moisture information to give a clearer atmospheric picture, and improve forecast model prediction capabilities.

HEALTH AND MEDICINE

Using an infrared video camera developed by NASA scientists at JPL, surgeons are testing thermal imaging and image processing to see if they can create useful maps of brain tumors. The camera, which detects infrared, or heat, emissions, might help neurosurgeons better visualize tumors before they operate and find tiny clusters of cancerous cells that might remain after surgery. Physicians have used infrared technology for mapping the roots of skin cancer, but it has never been used for brain tumors until now.

Doctors at the Keck School of Medicine of the University of Southern California in Los Angeles are using the JPL-developed camera and infrared imaging in a clinical trial. Since tumor cells emit more heat than healthy ones, the doctors are trying to learn if they can sketch tumor margins by detecting temperature changes during surgery. Currently, neurosurgeons delve carefully into the brain and remove as much of the tumor as they can see under magnification. However, they may take healthy tissue along with the cancerous cells or leave residual cells that can grow back along the tumor's margins.

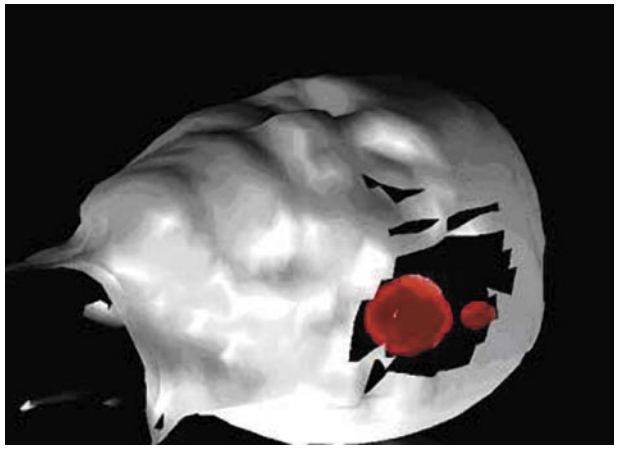
"Brain tumor tissue looks the same as healthy tissue on the edges," explains Babak Kateb of the Keck School of Medicine, a research fellow and lead scientist of the project. "Tumor cells use different biochemical pathways from normal cells, and when researchers use the infrared camera, they can pick up hotspots or areas of tissue warmer than normal tissue," he adds.

After doctors receive infrared images of the brain, imaging-processing software marks the boundaries between tumor regions and surrounding healthy tissue. "An advantage of thermal imaging is that it's noninvasive," says Dr. Peter Gruen, a neurological surgeon at the Keck School of Medicine. "It measures heat energy emerging from patients without exposing them to X-rays or intravenous solutions, and is performed without incisions or contact to the brain tissue."

The continued study of infrared technology is also bringing value back to NASA, as JPL refines software similar to what the medical group is using for analyzing rocks on Mars and other planets.

EARTH SCIENCE

Last year, more than a million people died of malaria, mostly in sub-Saharan Africa. Outbreaks of Dengue Fever, West Nile Virus, Rift Valley Fever, and even Plague still



This three-dimensional, computer-generated image shows two red spots that represent brain tumors.

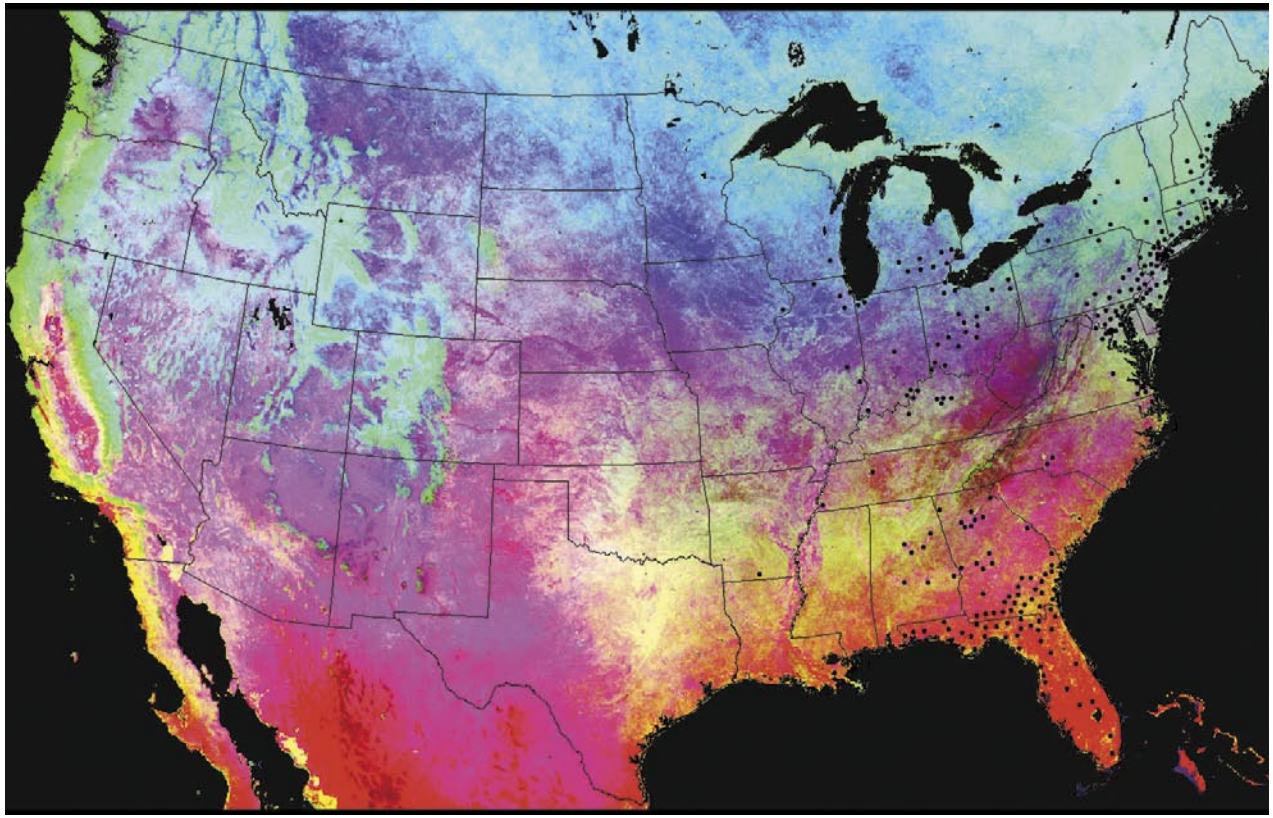
strike villages, towns, and whole regions. When outbreaks occur, they usually are tied to environmental conditions such as temperatures and rainfall that attract disease-carrying pests like mosquitoes and ticks.

Ronald Welch of NASA's Global Hydrology and Climate Center in Huntsville, Alabama, is working to develop an early warning system for disease outbreaks that combines data from environmental satellites with field work. Scientists seek out and visit places with disease outbreaks, then scrutinize satellite images to learn how disease-friendly conditions look from space. The satellites can then watch for those conditions over an entire region, country, or continent.

Field data such as soil type, lingering water puddles, humidity levels, pest behavior, and locations of human and animal dwellings are plugged into a computerized mapping system known as a geographical information systems database. Then, region-wide variables such as rainfall, temperature, vegetation types, and soil moisture are derived from medium-resolution satellite data, such as from the Landsat 7 or NASA Terra satellites. All of the information is fed into a computer simulation that runs on top of a digital map of the landscape. Mathematical algorithms produce an estimate of outbreak risk.

Welch expects the system will be able to give warnings of high disease risk for a given area up to a month in advance. Once they receive the warning, health officials will be able to focus their vaccination programs, mosquito spraying, and other disease-fighting efforts in the areas that need them the most. With proper preparation, it may be possible to prevent an imminent outbreak altogether.

With the same determination to make known what is currently unknown about our surrounding universe, NASA continues to uncover the secrets of the Earth with each new partnership it forms. In "doing business" with NASA, the partnering organizations are doing their part in making the world a better place to live.



NASA is working to develop an early warning system for disease outbreaks that combines data from environmental satellites with field work. This composite of land surface temperatures recorded between 1997 and 2000 was used to help monitor and predict the spread of West Nile Virus in the United States.

TECHNOLOGY TRANSFER NETWORK AND AFFILIATIONS

The NASA Innovative Partnerships 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 Technology Transfer 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, the 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, the NTTC has grown into a full-service technology commercialization center. In addition to providing access to Federal technology information, the 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.

The 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. The 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 the 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 research center within the School of Engineering at the University of Southern California in Los Angeles. Using the Remote Information Service to generate information from hundreds of Federal databases, FWRTTC staff work closely with businesses and entrepreneurs to identify opportunities, expertise, and other necessary resources. The FWRTTC enhances the relationships between NASA and the private sector by offering many unique services, such as the NASA Online 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 Hampton, 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 nonprofit organization, based in Westborough, Massachusetts. Covering New England, New York, and New Jersey, the CTC currently has eight satellite offices that form strong relationships with Northeast industry. Operated by the CTC, the NASA Business Outreach Office stimulates business among regional contractors, NASA field centers, and NASA prime contractors.

Southeast (AL, FL, GA, KY, LA, MS, NC, SC, TN): The **Southeast Regional Technology Transfer Center**

(SERTTC) <http://www.edi.gatech.edu/nasa> at the Georgia Institute of Technology facilitates and coordinates private industry interests in the transfer and commercialization of technologies resulting from NASA's space and Earth science research. Assistance is also provided in Small Business Innovation Research and Small Business Technology Transfer applications, as well as the establishment of connections to specialized research needs within NASA research and development centers nationwide.

NASA-INCUBATOR-PROGRAMS

Eight 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.

BizTech <http://www.biztech.org>, of Huntsville, Alabama, is a small business incubator, offering participating companies access to services at Marshall Space Flight Center laboratories for feasibility testing, prototype fabrication, and advice on technology usage and transfer. BizTech is sponsored by the Huntsville-Madison County Chamber of Commerce.

The **Emerging Technology Centers (ETC)** <http://www.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 the FNBIC is to increase the number of successful technology-based small businesses originating in, developing in, or relocating to Brevard County. The 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. The 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> is a partnership between NASA's Johnson Space Center and the University of Houston. The incubator is designed to help local small and mid-size 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.

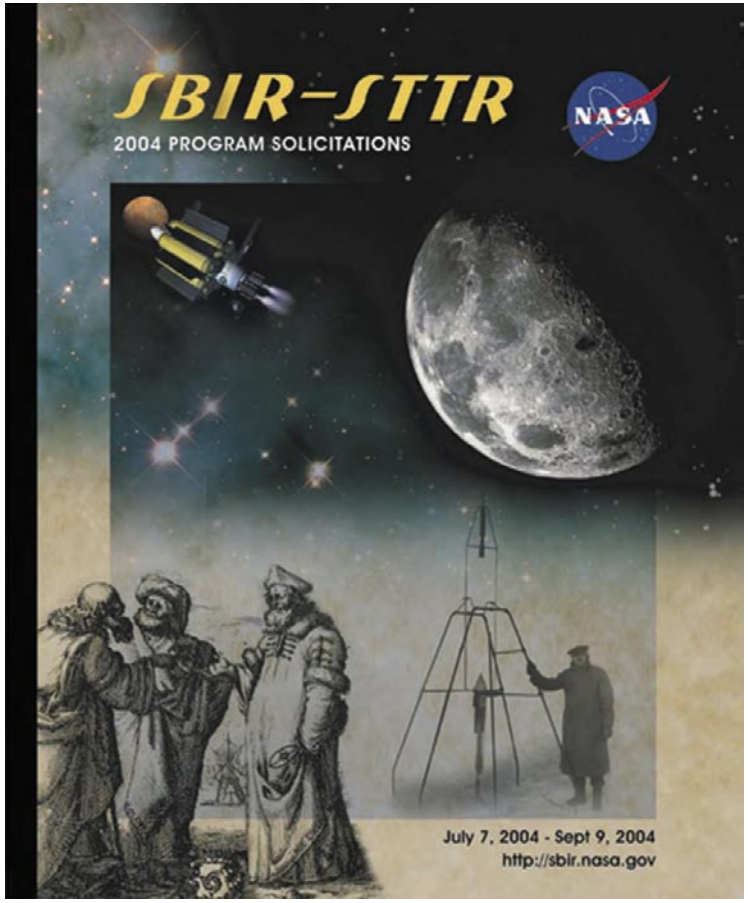
AFFILIATED-ORGANIZATIONS,-SERVICES, AND-PRODUCTS

To complement the specialized centers and programs sponsored by the NASA Innovative Partnerships 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 6 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.

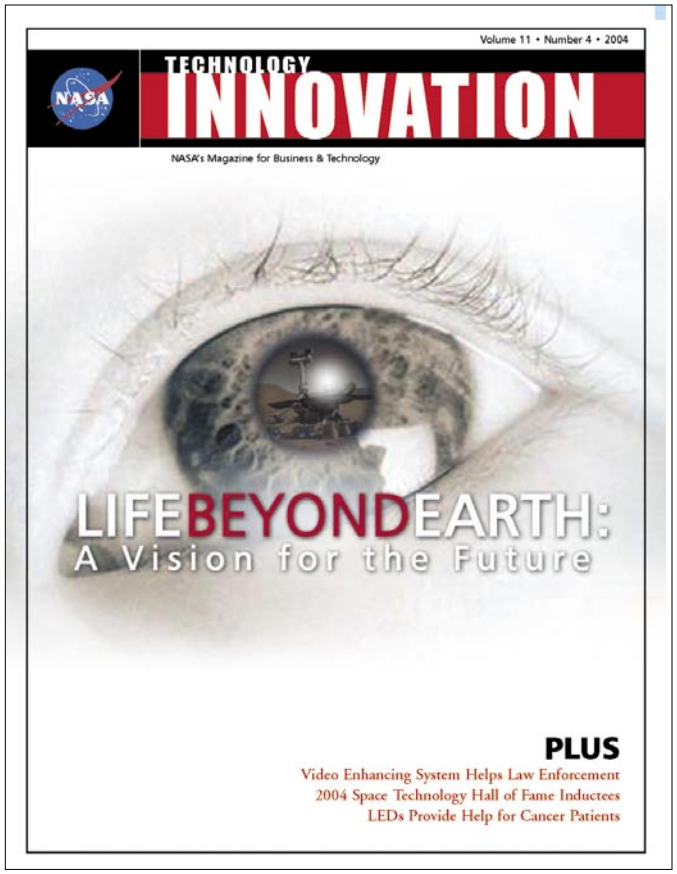
The **Federal Laboratory Consortium (FLC) for Technology Transfer** <http://www.federallabs.org> was organized in 1974 to promote and strengthen technology transfer nationwide. More than 600 major Federal laboratories and centers, including NASA, are currently members. The mission of the FLC is twofold:

- To promote and facilitate the rapid movement of Federal laboratory research results and technologies into the mainstream of the U.S. economy.
- To use a coordinated program that meets the technology transfer support needs of FLC member laboratories, agencies, and their potential partners in the transfer process.

The **National Robotics Engineering Consortium (NREC)** <http://www.rec.ri.cmu.edu> is a cooperative venture among NASA, the city of Pittsburgh, the State of Pennsylvania, and Carnegie Mellon's Robotics Institute. Its mission is to move NASA-funded robotics technology to industry. Industrial partners join the NREC with the goal of using technology to gain a greater market share, develop new niche markets, or create entirely new markets within their area of expertise.

Other organizations devoted to the transfer of NASA technology are the **Research Triangle Institute (RTI)** <http://www.rti.org>, and the **MSU TechLink Center** <http://techlink.msu.montana.edu>.

RTI, 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 Technology Transfer Offices.



The **MSU TechLink Center**, 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.

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 3.5 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.

Technology Innovation <http://www.ipp.hq.nasa.gov/innovation/index.html> is published quarterly by the NASA Exploration Systems Mission Directorate. Regular features include current news and opportunities in technology transfer and commercialization, and innovative research and development.

NASA *Spinoff* <http://www.sti.nasa.gov/tto/spinoff.html> is an annual print and online publication featuring successful commercial and industrial applications of NASA technology, current research and development efforts, and the latest developments from the NASA Innovative Partnerships Program.

FY 2004 TECHNOLOGY TRANSFER NETWORK

The FY 2004 NASA Technology Transfer Network (NTTN) 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://www.ipp.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>.

★ **NASA Headquarters** manages the Spinoff Program.

▲ **Field Center Technology Transfer 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 (RTI)** 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.

FY 2004 TECHNOLOGY TRANSFER NETWORK

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The award-winning Spinoff team: (front row) Bernadette Gilliam, *publications web coordinator*; Deborah Drumheller, *publications specialist*; Michelle Birdsall, *editor/writer*; (back row) Jamie Janvier, *editor/writer*; John Jones, *graphic designer*; Jutta Schmidt, *project manager*; David Eminizer, *webmaster*. *Administrator* Sean O'Keefe presented the team with the Public Service Group Achievement Award at the 2004 Agency Honor Awards ceremony.